PAACS

Principles of Reconstructive Surgery

Revised Edition

PAN-AFRICAN ACADEMY OF

CHRISTIAN SURGEONS

PAACS

Editors

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A PAACS Publication

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Foreword

The reality is that surgery and surgical conditions are one of the greatest unmet public health issues in the developing world. The Pan-African Academy of Christian Surgeons (a commission of the Christian Medical and Dental Association, www.cmda.org) is a unique strategic response to the great need for surgical manpower in Africa. A rural-based surgical educational initiative utilizing rural mission hospitals in multiple countries, PAACS seeks to train national physicians, schooling them in modern surgical thought as applied to resource-poor environments with the intent of having high rates of retention of the its trainees within Africa. PAACS is a nondenominational, multinational, volunteer service organization striving to serve the poor of Africa, to build capacity within the healthcare sector, and to help maintain the faith-based healthcare facilities that have traditionally provided a significant percentage of the healthcare there. Please read more about PAACS at www.paacs.net.

Professor Ajayi of Nigeria once wrote, "Surgery in a poor resource environment demands more, rather than less, skill from the surgeon, and the training programs must ensure that the specialist is adequately equipped to deal with conditions that may not be considered general surgery" (Olajide Olaolu Ajayi, "Surgery in Nigeria", Arch Surg Vol 134 [Feb 1999], p. 206). We who work in under-resourced areas are aware that general surgery is often much broader than we were trained—that general surgery is "the skin—and its contents."

But how do we train everyone in everything? The obvious answer is that we cannot—but we can pick the low-lying fruit, using the expertise of surgeons expert in their field and experienced in low-resource areas. General surgeons and others not trained in plastic and reconstructive surgery are able, with a little help by books like this one, of relieving a great deal of this burden. This long-awaited textbook "Principles of Reconstructive Surgery in Africa" is the second of what PAACS proposes to be a series of books that will help bring solutions down to the level of the non-expert who is on the front line. Professor Maurice King and his Primary Surgery texts must be recognized as forerunners in this concept and now Dr. Carter and his team have carried reconstructive and plastic surgery to the next level.

This book is first and foremost designed to be practical in the setting of limited resources. The authors, comfortable in the most advanced of operating theatres, recognize that not all of the latest technologies are appropriate, affordable or available, and that many of the older techniques give very acceptable results and work better in the world in which under-resourced surgeon finds himself. The editors and their hand-picked team of authors are experienced in the world of missionary medicine, especially in Africa. I am honored to know them and appreciate this seminal work. This book is the labor of love and represents long hours of work. It is being offered to qualified physicians and surgeons without cost. The motive behind this work is not fame or fortune; they seek to relieve suffering, striving to follow in the steps of the Great Physician, Jesus Christ.

I know that all of us who work in the developing world see daily the chronic wounds, contractured burns, congenital and acquired deformities and tumors both great and small that mock us and belittle our abilities. I know that there will be thousands and tens of thousands of patients helped through this book—and a lot of surgeons, formally trained or otherwise, who will be blessed by the availability of this amazing textbook.

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Preface to Revised Edition

After the first edition was completed, I realized the need for assistance and the need to enhance the book with the addition of Dr. Peter Nthumba from Kenya as co-editor. Dr. Nthumba had a major role in the first edition and has been responsible for the addition of extra chapters for this revision, including urethral strictures, chest wall reconstruction, and lymphedema. Several readers suggested additional chapters to cover conditions commonly seen in Africa by general surgeons. In addition, I realized the necessity to add authors from the Far East to give this book a wider spectrum of readability. An acute burn chapter was added and authored by Dr. Derick Mendonca from Bangalore, India. There are many chapters on burns in the world literature but few cover burns in the developing world. Dr. Jim Radcliffe from Papua New Guinea authored a chapter on evaluation of the trauma patient. Dr. Leland Albright revised the chapter on neural tube defects and Michael Cheatham the chapter on abdominal wall reconstruction.

Most general surgeons are faced with many urologic challenges and they are quite capable of handling prostatic conditions. They also see difficult urethral strictures, vesico-vaginal fistulae, and hypospadias, without having nearby consultants to refer these patients to. Therefore, chapters were added on these conditions by Dr. Nthumba, Dr. Andy Norman, and Drs. Dan Poenaru, Frehun Ayele, and Ronald Sutherland. Dr. Peter Bird, from Kijabe, Kenya, suggested a chapter on the use of the latissimus dorsi muscle in breast and chest reconstruction. The editors also asked thoracic surgeon, Dr. Russ White, to author a chapter on chest wall reconstruction. Though the PAACS Orthopedic text covers distal forearm fractures, Dr. Bob Greene added additional thoughts for the general surgeon who commonly sees these fractures but does not have a C-arm to properly reduce and fix these injuries.

The editors are grateful for the assistance of Justin Lonas, a graphic designer and copyeditor who has given many hours to the completion of this revised edition. This book now looks and reads like a book thanks to Justin's excellent design work.

Louis Carter and Peter Nthumba
March 2016.

Introduction to Revised Edition

For many years, several of the authors have discussed the need for a book on plastic and hand surgery for mission hospitals in Africa. The senior editor has spent most of his medical life in Africa, the first 10 years in Nigeria, and during the last 20 he has traveled to 26 mission hospitals world-wide to teach basic plastic and hand surgery. While originally in Nigeria as a general surgeon, he saw many cleft cases, open fractures of the lower extremity with exposed bone, cancrum oris (noma), etc. He initially sent most of these cases off to University College Hospital (UCH) in Ibadan, Nigeria, for care. Unfortunately, the specialists at UCH, such as Professor Oluwasanmi in plastic surgery, did not have time to treat all the patients referred to them. So over time the patients returned, unoperated on, to the editor. After the first seven years in Nigeria, the editor entered a plastic surgery residency so he could better handle these patients. After three additional years in Nigeria, he saw the need to obtain further training in hand surgery in order to better care for his disabled and deformed patients in Nigeria.

The stigma associated with visible deformities, especially those that are untreated, has been largely unappreciated in the Western world where these deformities and anomalies are treated early in life. We remember in the Bible that Christ's disciples questioned whether or not the parents of one born blind could have sinned or even if the man himself had sinned. In Nigeria in the early 1970s, the senior editor realized there was a difference in the perception of the visible versus the invisible deformity or disability. Internal illnesses were not often suspect of a curse, sin or judgment. On the other hand, families and even patients voiced their concern that they were cursed or judged if they had external deformities or disabilities.

The senior editor's older sister was born with many congenital deformities. Only with God's intervention and pastoral counseling did his parents accept the fact that God allowed these for His purpose. This shame or guilt is world-wide, and it is only by God's mercy that some will accept the fact that God allows these congenital anomalies for a purpose.

The intent of this book is to give general surgeons in remote areas some basic principles by which to treat congenital and acquired deformities and disabilities. No attempt has been made to describe the technical steps of common operations, as they are well described in the basic texts. Our goal has been to cover conditions that are seen in the Emerging World, but that are not seen in the West and therefore not covered in Western textbooks. Also there are conditions seen around the world but treated differently in the Sub-Saharan Africa due to lack of equipment or therapists. Therefore, chapters have been added to give alternate methods of management for these conditions.

The editor would like to thank the other authors and editors for their freely given time and effort. He would especially like to thank his long-time friend, Dr. Peter Nthumba, for his expertise and advice.

The authors look forward to your comments and suggestions. Though initially this book was intended for Africa, most of the chapters will be applicable around the world. We trust this publication will help you take better care of your patients and that your patients will experience the love and compassion of Jesus Christ in your hospital. May God bless you as you seek to glorify Him in your work and practice.

Louis L. Carter, Jr., M.D.
Peter M. Nthumba, M. Med. (Surg.)

Dedications

LLC: Dedicated to my wife, Anne.
PMN: Dedicated to Louis L. Carter, Jr.

Contents

Chapter 1
Abnormal Wound Healing
Hypertrophic Scars and Keloids

Bill Rhodes and Louis L. Carter, Jr.

The science of wound healing is covered in basic surgical textbooks, and it is important that all surgeons have a clear understanding of the principles of wound healing. Surgeons in Africa are confronted with not only acute wounds but a variety of chronic wounds with many different etiologies. This chapter will help one better understand the causes and treatment of abnormal wound healing, discussing the processes that lead to hypertrophic scarring and keloid formation, as well as the- basic steps to prevent and to treat these conditions. Other chapters will deal with chronic wounds and ulcers, vacuum assisted wound closure, and skin grafts.

Etiology

There are many causes of abnormal healing. Some of the more common causes in Africa and Asia are:

1 **Anemia**—though the hemoglobin must be below 5 grams before it directly affects acute wound healing, it frequently coexists with chronic malaria, worm infestation, general malnutrition, immuncompromised conditions, and poverty.

2 **Diabetes** is common, and uncontrolled diabetes leads to impaired fibroblasts, collagen deposition, and epithelialization.

3 **Untreated AIDS** is a major cause of delayed wound healing. The first sign of an immunocompromised condition may be a chronic wound (Fig. 1, 2).

4 **Atherosclerosis** is present more than one would expect.

5 **Venous Insufficiency** affects wound healing in the lower extremity. Lack of elevation with venous stasis is a common cause of slowly healing traumatic wounds.

6 **Aging**.

7 **Malnutrition** with deficiency of:
   A. Amino acids and a low serum albumin.
   B. Vitamin C and A deficiency.
   C. Trace elements.

8 **Infection.**

9 **Sickle Cell Anemia**.

10 **Drugs**—tobacco, betel nut, etc.

11 **Environment**—excessively wet or dry climates

Fig. 1

Fig. 2

Delayed healing of wounds secondary to AIDS.

may contribute to poor wound healing.

12 **Repeated trauma** commonly causes recurrent and chronic lower limb wounds and ulcers.

With any slowly or non-healing wound, a reasonable workup to exclude the above factors and conditions should be carried out. The most likely causes of delayed wound healing are diabetes, other immunocompromised states, and repeated trauma. The chapter on chronic wounds discusses management of the subacute or chronic wound.

Excessive Scar Formation

There are two types of excessive cutaneous scar formation: hypertrophic scarring and keloid formation. Though both result in an overgrowth of a scar with excessive collagen formation, it is important to differentiate between the two.

Hypertrophic Scars

Hypertrophic scars are self-limited, raised, hypertrophic scar tissue that remains within the border of the wound. They often occur within weeks after the original wound. Hypertrophic scars occur in persons of any age and at any wound site, either surgically created or by a traumatic injury. They tend to regress in size over time and are more responsive to treatment than keloids. Skin tension is often responsible for the formation of hypertrophic scars. They have a propensity to form on the chest, the upper back, or the deltoid regions, where there is excessive horizontal tension. Other factors contributing to hypertrophic scar formation are a prolonged inflammatory response, infection, foreign body (e.g. suture material), and wound orientation different from the direction of skin tension lines. Patients often complain not only of their appearance and but also itching.

Small hypertrophic scars respond well to a steroid injection with triamcinolone acetonide (Kenalog®). A dose of 10-40 mg (it comes in vials of 10 or 40mg/ml) is injected into the scar using a 25-27 gauge needle. Unlike keloids, hypertrophic scars may be excised and closed in a tension-free manner parallel to relaxed skin tension lines with little chance of recurrence. The excision is in a fusiform or elliptical fashion with a 4:1 length to width ratio. When a hypertrophic scar is not oriented along relaxed skin tension lines, it can be reoriented in a tension-free direction using a one or more simple z-plasties. Compression therapy with Spandex or other elastic material can be used in garments to apply pressure (See chapter 44). These garments can be worn after acute wounds have healed for the prevention of hypertrophic scars. Silastic gel sheeting may be used if available. When special garments are not available, bandages such as an ACE® or crepe may be used to apply pressure. When primary closure is not possible without tension, then a split thickness or full thickness graft should be used. Once a wound has healed pressure may be applied to prevent recurrence.

Burns over joints are often associated with hypertrophic scarring and contractures. These scars can also be excised with skin grafting or with a local flap transfer. It is best to wait 12 months for the scar to mature especially if the scarred skin will likely be in a local flap. Rarely, after complete surgical excision of a hypertrophic scar, there will be a recurrence. If one is close to a large city, low dose irradiation may be helpful in the control of recurrent hypertrophic scars. Cocoa butter is often available, and its application has been found to help control itching (See chapter 12 on burn reconstruction).

Keloids

Clinically, keloids are identified by the continued excessive growth of the scar beyond the border of the actual wound. Keloids are less common than hypertrophic scars but have a genetic component that primarily affects African and Asian populations. This abnormal proliferation of scar tissue with immature collagen synthesis is up to 20X normal in keloids as compared to 14X normal in hypertrophic scars. As in hypertrophic scars, the etiology may be from a surgical incision, burns, or a simple and sometimes forgotten traumatic injury to the skin. Compared to hypertrophic scars, keloids do not naturally regress in size, but may continue to enlarge over time. They are also predominantly in high-tension areas of the skin such as the shoulder, anterior chest, and neck. Keloid formation begins within a year after injury. Risk factors are similar to hypertrophic scarring, healing by secondary intention or if an infection is present. Keloids are often found with pierced ears and are caused by a low-grade infection. Patients complain of the keloid's unsightly appearance as well as itching and a burning sensation in or around the keloid.

The treatment of keloids can be frustrating. The most important consideration is prevention in those areas that are at a high risk for keloids. Great care should be taken in closing wounds in a tension free manner, paying attention to the direction of the scar and appropriate layered closure in keloid-prone areas. Monofilament suture may cause less reaction, and the author frequently uses PDS or Monocryl® or clear Ethilon® suture for deep dermal sutures. Sterile technique should be followed to minimize the risk of subsequent infection. No readily available modality can completely prevent keloid formation. Hypertrophic and keloid-prone acute wounds should be carefully closed, especially with long lasting deep dermal sutures.

Since the recurrence is high, the author will not attempt removal of keloids over the anterior chest or shoulder. These are common and disfiguring, but best left alone as recurrence is frequent and often the secondary keloid is larger.

Fig. 3

Fig. 4

Large keloids that have grown outside the borders of the original wounds, both likely caused by infection.

In large cities, low dose irradiation is often available and can be administered within a few days of keloid excision. There are different treatment regimens, with irradiation is given once or daily over 3-4 days postoperatively. The results are outstanding in the smaller keloids as those around the ear. Irradiation should is not used in children. The injection of a steroid into the keloid is the best first-line treatment for small keloids. The corticosteroid of choice is triamcinolone acetonide (Kenalog®). The goal is to inject the body of the keloid scar with 10-40 mg triamcinolone. The triamcinolone is mixed half and half with a local anesthetic, providing anesthesia for the injection and increased volume for the injection. The author will penetrate superficially into the keloid with a needle, and then make multiple radial sticks throughout the keloid prior to injection of the steroid (see fig. 5). The needle is then withdrawn to just inside the keloid and the steroid injected. The solution is dispersed in multiple directions and fills the keloid. Often, a larger gauge needle is needed with larger and firmer keloids. Some feel the internal pressure within the keloid by the injected fluid is as significant as the triamcinolone in the resolution of the keloid. It may be impossible to inject hard keloids, and these require surgical removal. Care should be taken not to inject the steroid into the surrounding subcutaneous tissue as this may result in atrophy and loss of pigmentation. The results of steroid injections in small keloids can vary from partial flattening to nearly complete resolution. Large keloids are not effectively treated with triamcinolone.

As with hypertrophic scars, compression therapy has been an effective adjunct to treating keloids after steroid injection and after keloid excision. Patients should be encouraged to massage keloids regularly after steroid injections. Recurrent ear keloids can be prevented by using special large earrings that apply pressure after surgery or after steroid injection. These are commercially made, but it may be possible to create locally a device to apply pressure. (A Google search for "pressure earrings" can point to possible sources for these earrings). Garments made of Spandex, fabricated to provide consistent pressure may be helpful in the treatment of keloids occurring on the trunk, extremity or even face and neck. If one has Spandex or a similar elastic material, a seamstress may be able to custom-make a garment to apply constant pressure. These should be worn a minimum of 12 hours at night and sometimes all day. Silastic gel can also be applied to the area if it is available (See chapter 44).

If it is decided to proceed with excision of a keloid, the patient should be informed preoperatively of the high rate of recurrence. Excision with primary closure of keloids has recurrence rates of 50% and the recurrent keloid is of equal or larger size. Incisions should be made in relaxed skin tension lines whenever possible. If a tension free closure is not possible, a flap or skin graft may be best. A steroid injection is often administered at the time of the keloid excision into the superficial dermal edges of the wound. This can be repeated for several months at two or three-week intervals postoperatively. Additionally, methotrexate can be given as a single oral dose, 15-20 mg in an adult, one week before keloid excision and then continuing weekly for 3-4 months after surgery. Methotrexate can be helpful in limiting keloid recurrence. In younger patients, a dosage of 0.3 mg/kg orally is used weekly for at least six weeks after surgery. If possible, compression therapy is always used after keloid excision. If available, low-dose radiation is the best method to prevent recurrence. Recently, 5-flourauracil and bleomycin have been tried, with results still pending.

Fig. 6

Intra-keloidal excision: When keloids are large and other treatment methods are not available, an intra-keloidal excision may be carried out leaving a 3-4 mm rim. A skin graft may be sutured into place using this rim of tissue.

Some have excised the bulk of the keloid and left a 2-4 mm rim of keloid. The closure is then with sutures within this rim and not in normal tissues that might excite further keloid formation (see Fig.6). This method is best for smooth keloids that are not visible as it leaves an obvious scar. This method is difficult to do with multilobulated keloids. If a patient has a very large visible keloid, this method may still be used as the resulting scar is still a great improvement.

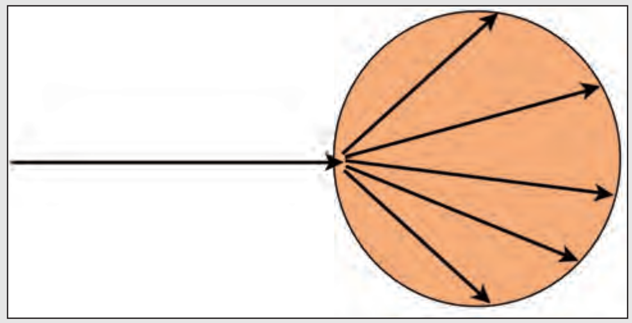


Fig. 5

A needle is first placed just inside the keloid, and then multiple tracks are made throughout the keloid with the needle. Then the needle is withdrawn to where the needle entered the keloid and triamcinolone with lidocaine is injected. The solution diffuses throughout the keloid.

When keloids are secondary to infection, the infection is first treated and cleared for several months before excision. Many other medical therapies have been used with inconsistent results. Patients with keloids will travel many kilometers and will pay large sums of money for any help they can get. Unfortunately, complete cure is rare and especially in more remote areas with limited treatment modalities.

Summary of methods of keloid excision:

- Excision with triamcinolone in wound edges.
- Intra-keloidal excision, leaving behind a 2-4 mm rim for sutures.
- Triamcinolone for small keloids.
- Irradiation.
- Low-dose methotrexate with excision.
- Compression therapy in conjunction with other methods.

Fig. 7

Fig. 8

Fig. 9

This patient had bilateral severe folliculitis keloidalis. He was draining from multiple deep sinuses. Multiple secondary tangential excisions with the Weck blade were required to completely excise all of the deep infected follicles. Fig. 8 shows the wound after the first excision.

Differentiation between Folliculitis Keloidalis and Sycosis Barbae

Folliculitis keloidalis and Sycosis Barbae are keloidal conditions seen in men, usually of African descent, although they may affect any individual. Folliculitis keloidalis involves the nape, while sycosis barbae involves the bearded areas of the face; these usually start off as folliculitis, following the irritation of a haircut or shaving of the beard, respectively. Repeated episodes of infection lead to keloid formation, deep-seated infection, and multiple discharging sinuses. These are difficult to treat, as the deep infections do not respond well to antibiotics. Since these keloids are chronically infected and constantly draining, they should be removed.

Complete excision with delayed skin grafting is recommended. Initial excision is carried out under general anesthesia with Xylocaine/ Lidocaine with adrenalin infiltration in the skin to decrease the bleeding, and also help with visualization. This is diluted when dealing with large keloids, as in the case seen in Figs. 7-9. Electrocautery is also used in the initial debridement. Repeat debridements are carried out every other day.

In subsequent debridements, the Weck or Humby blade is used for tangential excision. Since vital structures are nearby, especially the marginal mandibular branch of the facial nerve, the author feels that tangential excision down to viable, non-infected tissue is the safest method of debridement. As soon as the bed is clean without evidence of residual infection, it is skin grafted. Complete and adequate debridement may require 7-10 days.

Since infection is usually the cause of the keloid, recurrent keloid formation may be prevented by careful shaving and early antibiotic treatment of any infection. In the author' experience, recurrence is not likely if one follows these guidelines. Additional measures to prevent recurrence are listed below, but prevention of future infection is the most important.

Fig. 10

Fig. 11

After a period of oral antibiotic intake and local antibiotic cream application, complete excision of the keloids, skin grafting and postoperative single-low dose radiation therapy. The patient then used silicone sheets for a year, and has not had any recurrences. He uses depilatory powder for his beard.

If cultures can be obtained, appropriate antibiotics should be used. Otherwise, broad spectrum antibiotics are used for these chronic deep infections. Skin grafting is carried out only when there is no evidence of residual infection.

One may also elect to initiate antibiotic treatment pre-operatively, both oral (Doxycyline) and topical where available, for 3 to 4 weeks. Once the discharge from the sinuses stops, surgery is performed, with careful wide excision down to fat. Electrocautery is useful in minimizing bleeding, but one must be careful not to damage vital structures within the area of surgery. Skin grafting and, where available, postoperative single dose radiation treatment, will aid in reducing recurrence. The patient may need to change from mechanical shaving to using chemical depilatory agents—creams or powders that will be available in city pharmacies and stores.

Additional measures to prevent a recurrence can be used. A compression garment maybe gently placed over the graft. This could include a dressing with a neck collar or an elastic bandage wrap. Triamcinolone may be injected around the edges of the graft every month for several months if it is available. Triamcinolone 40 mg. is diluted with lidocaine 1:1 or 1:2 to infiltrate large areas. The lidocaine, in addition to its dilutional effect, is useful for analgesia after the injection, as this can be a painful procedure.

If one has access to silicone sheets, these maybe placed on the healed wound under a neck collar. The silicone should be used continuously for several months, and then at night time for a year to reduce chances of recurrence.

Conclusion

Understanding the basic phases in the normal wound healing process is necessary for managing wounds at various stages of healing. Recognizing that abnormal healing may lead to excessive scar formation—which ultimately may hinder function—should lead the surgeon to use preventive measures prior to or after surgery, or soon after injury or burns. It is important to distinguish the two kinds of scars and to proceed carefully in their treatment so that a bad scar is not made worse. As in any other wound care, dedicated physician care, as well as patient compliance, is required for the best results.

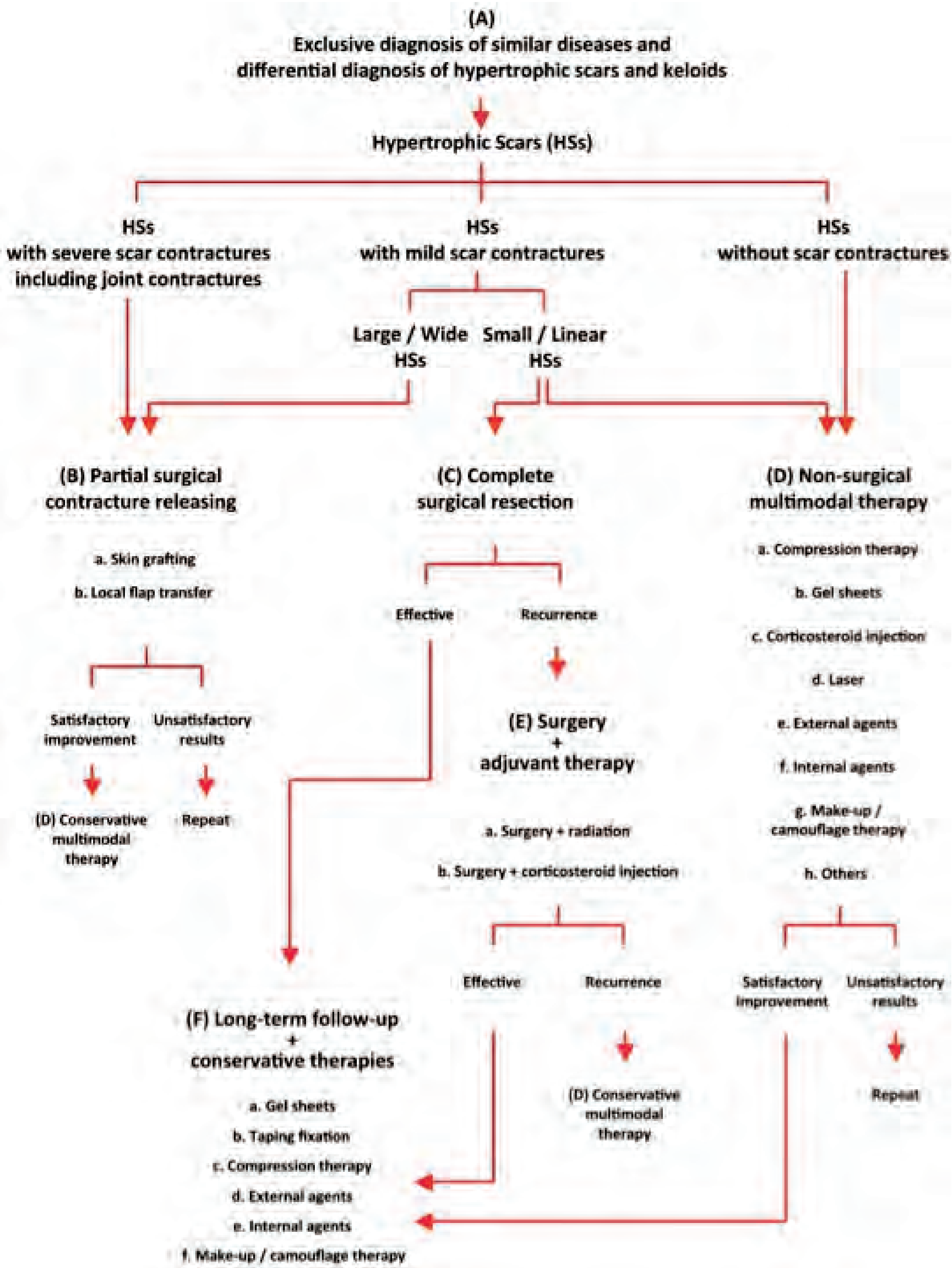
Other chapters will deal with chronic wounds, ulcers, vacuum assisted wound closure, and skin grafts.

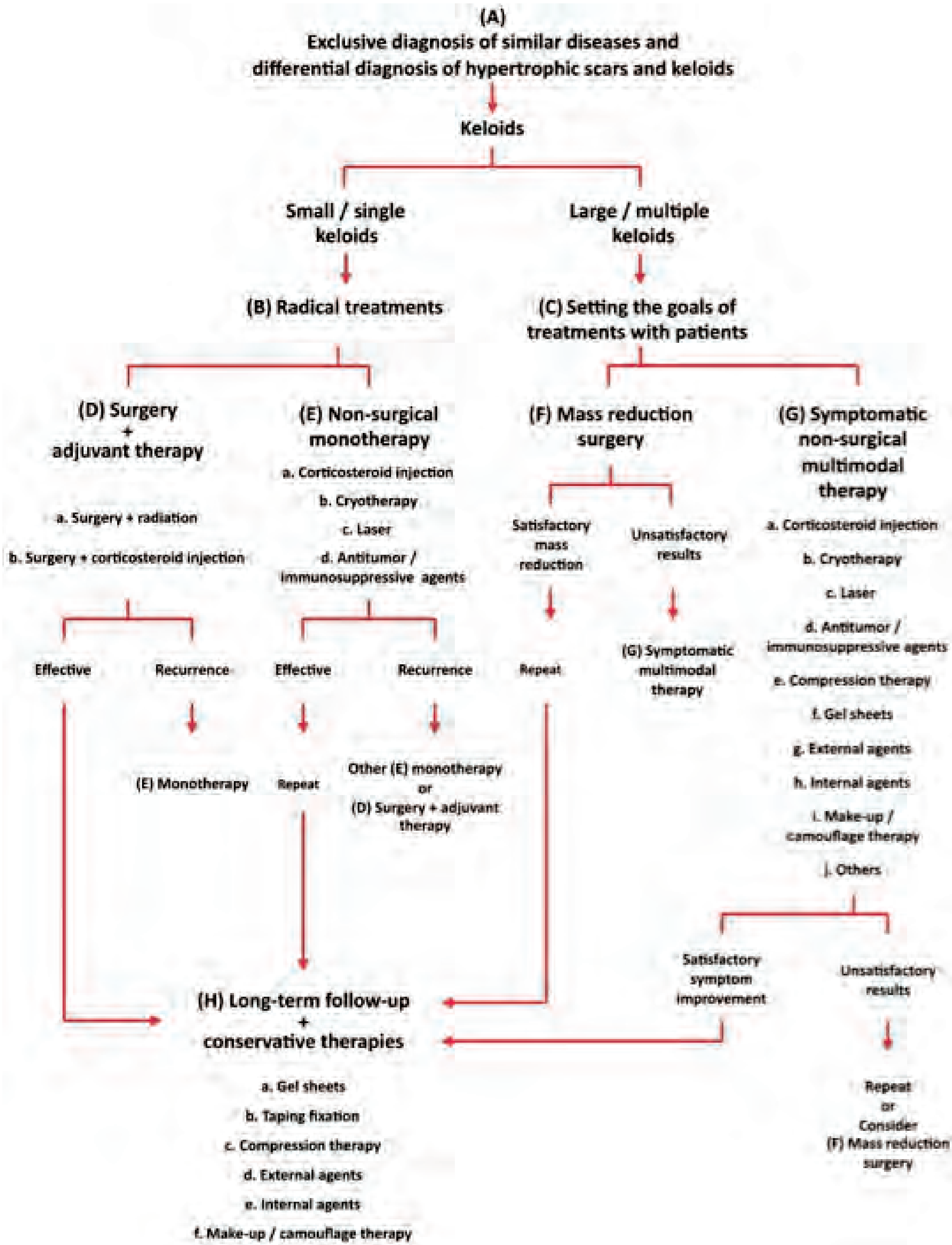
Further Reading

The most current algorithms for the treatment and prevention of hypertrophic scars and keloids are shown on the following pages. No one will have all the modalities mentioned, but this gives one a guide for possible treatment.

Ogawa, Rei M.D., Ph.D, Plastic & Reconstructive Surgery, February 2010, Volume 125, Issue 2, pp. 557-568.

(Algorithms used by permission from Lippincott, Williams, and Wilkins.)


(A)
Exclusive diagnosis of similar diseases and differential diagnosis of hypertrophic scars and keloids
Hypertrophic Scars (HSs)
HSs with severe scar contractures including joint contractures
HSs with mild scar contractures
HSs without scar contractures
Large / Wide HSs
Small / Linear HSs
(B) Partial surgical contracture releasing
a. Skin grafting
b. Local flap transfer
Satisfactory improvement
Unsatisfactory results
(D) Conservative multimodal therapy
Repeat
(C) Complete surgical resection
Effective
Recurrence
(E) Surgery + adjuvant therapy
a. Surgery + radiation
b. Surgery + corticosteroid injection
Effective
Recurrence
(D) Conservative multimodal therapy
(D) Non-surgical multimodal therapy
a. Compression therapy
b. Gel sheets
c. Corticosteroid injection
d. Laser
e. External agents
f. Internal agents
g. Make-up / camouflage therapy
h. Others
Satisfactory improvement
Unsatisfactory results
Repeat
(F) Long-term follow-up + conservative therapies
a. Gel sheets
b. Taping fixation
c. Compression therapy
d. External agents
e. Internal agents
f. Make-up / camouflage therapy


(A)
Exclusive diagnosis of similar diseases and differential diagnosis of hypertrophic scars and keloids
Keloids
Small / single keloids
Large / multiple keloids
(B) Radical treatments
(C) Setting the goals of treatments with patients
(D) Surgery + adjuvant therapy
a. Surgery + radiation
b. Surgery + corticosteroid injection
(E) Non-surgical monotherapy
a. Corticosteroid injection
b. Cryotherapy
c. Laser
d. Antitumor / immunosuppressive agents
(F) Mass reduction surgery
Satisfactory mass reduction
Unsatisfactory results
(G) Symptomatic non-surgical multimodal therapy
a. Corticosteroid injection
b. Cryotherapy
c. Laser
d. Antitumor / immunosuppressive agents
e. Compression therapy
f. Gel sheets
g. External agents
h. Internal agents
i. Make-up / camouflage therapy
j. Others
Effective
Recurrence
Effective
Recurrence
Repeat
(G) Symptomatic multimodal therapy
(E) Monotherapy
Repeat
Other (E) monotherapy or (D) Surgery + adjuvant therapy
Satisfactory symptom improvement
Unsatisfactory results
(H) Long-term follow-up + conservative therapies
a. Gel sheets
b. Taping fixation
c. Compression therapy
d. External agents
e. Internal agents
f. Make-up / camouflage therapy
Repeat or Consider (F) Mass reduction surgery

Chapter 2
Acute and Chronic Wound Care

Louis L. Carter, Jr.

Chronic wounds are the cause of great patient morbidity and expense to both patients and hospitals in Africa. With more surgeons and the availability of Vacuum Assisted Closure (VAC)—commercial or home-made (see Chapter 4), this situation is gradually improving.

Most chronic wounds are due to either inadequate treatment and delayed closure of acute wounds or long-standing ulcers (tropical ulcers) in the lower leg where the blood supply is diminished and where repeated trauma is common.

There are many risk factors beyond inadequate initial surgical care. Patients often live far from a health center, and may have to walk long distances to get to the closest health center or hospital. They may not have sufficient money to go by taxi or bus. The local health center may not have adequate equipment or supplies for the care of these wounds. Most importantly, the nurses and physicians may lack the experience and expertise needed to care for chronic wounds and ulcers. Dependency and lack of underlying muscle complicate those chronic wounds on the distal third of the leg.

Other common contributing causes of chronic wounds include diabetes, HIV/AIDS, old age, infection, venous stasis, long-standing and inadequately treated burn wounds, and repeated trauma.

Chapter 4 discusses wound closure with the VAC and skin grafts. This chapter will discuss the preparation of wounds for direct closure or with skin grafts or flaps.

It is important to discuss the proper care of acute wounds to prevent the progression to a chronic wound. **Closure is classified as:**

> **Primary**—closed at time of injury, direct or by skin graft or flap.
>
> **Delayed Primary**—closed within the first seven days, usually within 2-3 days. This wound will heal as well as one closed primarily.
>
> **Secondary Closure**—when a chronic wound is sharply and completely debrided and closed directly or by skin graft or flap as in primary closure.
>
> **Secondary Intention Healing**—wound is allowed to granulate and gradually epithelialize and close. **This is not acceptable**, except in rare situations, as this will certainly lead to a chronic wound.

A variation of primary closure is the "clean closed wound concept" whereby the acute wound is closed initially after irrigation and debridement. Vital structures as tendons, nerves and fractures can be repaired several hours or days later when someone capable of repairing these structures is available. If necessary, the patient may be referred and a delay up to two weeks would not be harmful to the patient.

Timing of Closure

This depends on the time of injury, mechanism of injury, location, contamination, etc.

Primary closure should be the goal after initial debridement and irrigation.

If an acute wound is too contaminated for primary closure on the day of injury, then further debridement and irrigation should be carried out on Day 2, Day 4, and Day 6 with a plan to close as soon the wound as it is clean. This is **delayed primary closure** and should be carried out as soon as the wound is clean and any time before Day 7. If the closure is delayed past seven days, it will become a chronic wound.

If, after debridement, the wound is clean but the wound is too large to close, a skin graft can be applied acutely. There is no reason to wait for granulation tissue to skin graft a wound or even to advance a flap. A meshed skin graft is ideal on the trunk or lower extremity in this situation as it allows drainage and molds into wound crevices.

If less than one cm. of bone or tendon is exposed, a graft can be placed over these structures in an acute situation with an excellent chance for bridging epithelialization and closure.

If there are large areas of exposed tendon or bone, a flap should is used acutely or a VAC can be applied. As with a skin graft, there is no need to wait until the wound is granulating to close with a flap.

Debridement and Irrigation

Debridement and irrigation are performed on every acute wound. For simple wounds of the face and upper extremity, this may simply be irrigation with normal saline as one prepares the wound for closure. If normal saline is not available, even sterile water can be used. Debridement involves the removal of devascularized tissue and foreign bodies. The amount of devascularized tissue depends on the nature of the injury (whether a sharp or a crushing injury), where the injury occurred (e.g. at home or on a farm), and the location on the body (face, arm, leg, etc.). High-velocity road traffic accidents with large wounds and open fractures will need considerable debridement.

If available, **pulse lavage** is an excellent method for irrigation as well as debridement in large contaminated wounds. Saline or Ringers Lactate is used in the pulse lavage. The condition of the wound after the initial debridement determines the need for further debridement. Often in large lower extremity wounds, one cannot be certain if all devitalized tissue has been removed and a repeat debridement is performed in 1 to 2 days. The **muscle that bleeds may not be viable; on the other hand, if it contracts it is usually viable**. Bleeding from the edges of bone indicates viability. Unless there is severe arterial bleeding that must be controlled, one should not use a tourniquet at the first debridement. If a tourniquet is necessary because of significant bleeding, then one should release the tourniquet before one has finished the debridement to identify and debride any non-bleeding or non-viable tissue.

Ideally, **wounds should be kept moist** and the extremity elevated between debridements. Allowing tissues to dry out or desiccate between debridements and dressing changes is detrimental to the tissues. In some cases, silver sulfadiazine may be used as a local antibiotic and also to keep the wound moist. Instilling raw honey in the wound is an excellent method to keep the wound moist between debridements. Honey is bactericidal and kills most bacteria. There is no need for systemic antibiotics in simple, clean wounds that can be closed, but a cephalosporin is often given in contaminated wounds. In severely contaminated road or farm injuries, better gram-negative and anaerobic coverage is used. Elevation of an extremity is imperative with extremity injuries (See Chapter 4 on use of the VAC).

It is often difficult to determine the amount of damage and the need for debridement in **crushing injuries**. Even if the wound is clean, a second or even third look several days later may be necessary. The naked eye cannot determine the amount and depth of injury in crushing injuries, and late wound breakdown is often seen if the wound is closed too soon.

If closure is **delayed beyond 7 days**, the wound heals with secondary intention and becomes infected and colonized with greater than 10^5 (100,000) microorganisms per gram of tissue—a special quantitative test carried out on a biopsy of 1 gram of tissue. (The **definition of wound infection** or

Fig. 1

Fig. 2

Fig. 3

Chronic lower extremity wound surrounded by poorly vascularized tissue. Radially debrided twice and closed with a reverse sural artery flap.

colonization is a wound with greater than 10^5 microorganisms per gram of tissue. This determination can only be carried out in specialized laboratories.) Colonization occurs when a wound is left open for 7 and certainly for ten days. **Intermittent extensive debridements**, where the entire wound surface is excised down to normal tissue, delays the development of colonization in a wound. Unfortunately, in busy hospitals, debridements are often scheduled as the last case of the day and are performed by junior staff. When "more important" cases take longer in small hospitals with few operating rooms, these necessary debridements are often postponed until the next day and then often delayed again and again. These delays lead to a chronic, colonized wound.

After 7-10 days, a **wound will need a complete debridement** with complete excision of the wound and wound edges before secondary closure with a STSG or flap. A scalpel, Weck blade or Humby/Watson knife is used to debride tissues.

Waiting for granulation tissue to cover bone or tendon often results in an infected wound and a long hospital stay with many dressing changes. This will be of considerable cost to both the patient and the hospital for the necessary supplies (See chapter 4 on Wound Closure with VAC). More than likely, the patient will not be able to pay for his prolonged care.

Outpatient treatment of such wounds is unsatisfactory, with lack of proper wound care by the OPD or physical therapy (PT) staff. There will be missed days due to weekends, probable lack of patient compliance, and the dependency of the involved extremity while traveling to the hospital each day. Soaking of the wound in a whirlpool-type bath leads to cross-contamination of the wound. **The key to long-term wound care is keeping the wound moist, and this is best done by using Silvadene impregnated gauze or honey**. (In hospitals where the government pays for all the medical care, a long hospital stay fortunately does not deplete the patient's funds.)

Clean Closed Wound Concept

As mentioned above, if an acute wound requires tendon or nerve repair, but no one is available to do this when the patient presents to the hospital, a clean wound may be loosely closed after initial debridement with skin sutures 1-2 cm. apart. A delayed repair of the vital structures may be carried out the next day, or even several days to two weeks later. The wound is then re-opened for the repair of these structures, and it is still a clean wound. This is very helpful in hand surgery. These structures will heal just as quickly as if they had been repaired acutely. Muscles and tendons will retract over time and may be difficult to repair after two weeks, so one should aim at definitive repair and closure by seven days.

Chronic Wounds

Chronic wounds occur because of:

1 Delays in presentation.
2 Delays in adequate debridement.
3 Problems with healing due to age, diabetes, HIV/AIDS, inadequate blood supply, etc.
4 Other causes:
   Underlying osteomyelitis.
   Buruli Ulcer—Mycobacterium ulcerans.
   Marjolin's ulcer—squamous cell carcinoma.
5 Vascular conditions, especially with venous stasis.

Treatment Methods for Chronic Wounds

Careful evaluation of possible causes of chronic wounds must be carried out before attempted closure. Even chronic wounds that occur in the hospital will need evaluation.

There are three possible methods for the treatment of chronic wounds when first seen:

First, one can perform **daily wound dressings** with the hope that the wound will go on to secondary healing with epithelialization, or finally granulate and be ready for a skin graft. As mentioned, this method requires significant nursing care, and is costly for the patient. This method is commonly used but **not recommended**.

In such chronic wounds, healing will be improved if the wound can be kept moist at all times. Keeping a wound **moist** will accelerate wound healing. One possible method is to dress the wound with a bulky gauze dressing once daily, place the extremity on a Macintosh (rubberized fabric), and drip saline on the dressing every 1-2 hours or continuously through an IV tubing. This requires dedicated nursing care. Another method mentioned above is covering the wound with honey and then gauze or food wrap (Cling or Saran® wrap). Silver sulfadiazine (Silvadene®) may also be used, but it is expensive.



Fig. 4 **Fig. 5** **Fig. 6**

Aggressive care of necrotizing fasciitis: First debridement on admission is followed by every-other day debridements until the wound is clean. The last debridement is carried out with a Weck blade, Humby knife or even a dermatome to tangentially excise infected granulation tissue down to bleeding dermis or subcutaneous tissue (Fig. 5). The overlying skin in necrotizing fasciitis is usually excised as the blood supply to the skin is just superficial to the diseased fascia, which is always debrided.

Unfortunately, this method of allowing the wound to granulate with minimal intervention is a commonly accepted practice. Granulation tissue in a chronic wound is infected, and it is not an ideal recipient bed for a skin graft. It must be sharply excised—tangentially excised—down to good, bleeding, "normal" tissue before skin grafting. If debridement is performed by only scraping off the superficial granulations with a knife blade, the graft may take but will be prone to breakdown with minor trauma, especially if the graft overlies the anterior tibia or other bones. (**Note**: superficial granulation tissue will always bleed, but it is still infected.) On the other hand, if sharp tangential debridement of granulation tissue is carried down to bleeding and normal appearing dermis or subcutaneous tissue, the graft or flap should take and heal well.

The **second approach** is a more aggressive treatment and will lead to early wound closure. This method requires "**ownership**" of the wound by an experienced surgeon. An **aggressive and extensive debridement** is carried out when the patient is first seen. Then on Day 2, 4, etc. the wound is again radically debrided, and the wound closed as soon as it is clean with either direct closure, skin graft or flap. The goal should be to close the wound within 7 days after the first debridement. The days of debridement



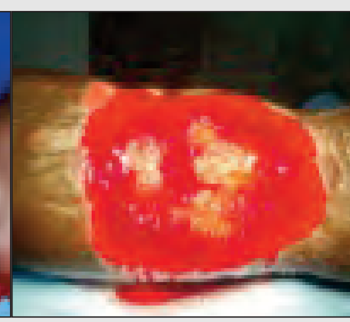



Fig. 7 **Fig. 8** **Fig. 9** **Fig. 10**

After the first debridement, the surgeon should then plan on serial debridements to get the chronic wound closed by seven days. Negative pressure therapy (VAC) was used on the wound above between debridements. The Weck blade (black arrow) is used (Fig. 8) for tangential debridement. Fig. 9 shows the wound at seven days when it was skin grafted. Fig. 10 is the healed wound at one week post skin graft. This healed wound is protected from trauma for six weeks.

Fig. 11

Fig. 12

Fig. 13

After excision of a chronic leg ulcer in a young man with repeated breakdowns, a VAC was applied for five days, and the wound grafted several days later.

are carefully scheduled after the initial debridement to ensure that closure will be done by Day 10 at the latest. (These days should be scheduled to coincide with the operating days for the primary surgeon.) This method decreases the hospital stay and saves everyone money. Between debridements, an attempt is made to keep the extremity elevated and the wound moist throughout the day, using the methods described above. Unless there is "ownership" of the wound by a senior surgeon, these wounds will often be neglected with inadequate debridement, and Day 7 or even 10 will pass without wound closure.

Summary of technique:

1 Initial wide debridement with the removal of devitalized tissue and foreign bodies is carried out. At that time, the surgeon can usually predict the type of wound closure, whether directly or by graft or a flap.

2 Debride every two days with an attempt to close the wound by seven days after initial debridement. This care will require dedication and **ownership** of the wound by an experienced team member—usually the senior surgeon. The wound should be closed whenever the wound is clean, and before day seven if possible. **Important: With extensive serial debridements of chronically infected wounds, a wound may occasionally still not be ready for closure at seven days. Still, the aim is to close the wound by at least ten days.**

3 **Keep the wounds moist** and the extremity **elevated** between debridements.

The above steps should be carried out on chronic wounds as well as contaminated acute ones.

Third is a newer approach using the **VAC—Vacuum Assisted Closure** or **Negative Pressure Therapy (NPT).** This is an excellent method for debridement, and stimulates gradual wound closure in chronic wounds. (It may also be used in acute wounds. See Fig. 11-13.) After the initial debridement, the negative pressure suction is applied and the dressing is changed every 2-3 days. The supplies and suction machine used for this method are manufactured commercially by KCI or Smith Nephew, but home-made varieties are possible anywhere in the world. This is described with fuller discussion in Chapter 4. VAC is especially helpful with wounds over bone or tendons.

One should not forget honey for chronically infected wounds. Most plastic surgeons would rely on debridements rather than honey, but honey is hyperosmotic and antibacterial, and it keeps the wound moist and odor free. Honey inhibits the growth of most bacteria including MRSA, Staphylococcus, Streptococcus, and Pseudomonas. Honey is also deodorizing, and one rarely finds the odor associated with chronic wounds when honey is used. The hyperosmolar honey draws in the exudate, and the wound is clean when the dressing removed. Honey produces an enzyme that produces very low concentrations of hydrogen peroxide, and at this concentration hydrogen peroxide is also antibacterial. Honey does not have to be sterile to use. One can use "raw" honey. When one does not have silver sulfadiazine, honey is a good substitute for wounds and large burns. It is also cheaper. Wounds with honey dressings can be redressed every 2-3 days, according to the amount of drainage, until the wound is ready for skin grafting. See Fig. 14 and 15.

Fig. 14

Fig. 15

Fig. 16

Honey dressings for a large, 6 week-old burn where Silver Sulfadiazine was not available. Within one week, wounds were ready for grafting and grafts took well.

Honey from Manuka trees is especially beneficial for wound care. These trees only grow in New Zealand and Southeast Australia and commercially manufactured honey-impregnated dressings are available there. Manuka honey is fungicidal. The author has used honey extensively in Africa and recommends this as a cheap, safe and readily available agent for wound and burn care. The honey is used raw, just as it comes from the bees and without sterilization. When one changes a dressing after the application of honey, there is clean, non-infected granulation tissue without residual exudate or odor. Usually, no residual honey can be seen. Wounds can be grafted without further debridement. (Manuka honey is now being exported from New Zealand specifically for wound care. In the U. S., it is marketed as Medihoney.)

Failure for wounds to heal with these methods will require a more thorough investigation. The following questions and tests would likely have been performed earlier:

- Determine if tobacco products are being used.
- Diabetes and HIV testing.
- Albumin should be checked if possible.
- Sickle Cell studies.
- Biopsy to rule out Marjolin's ulcer, Buruli ulcer and fungal infection, etc.

Tobacco use is not as common in Africa as in the West, but should be stopped if there is a chronic, non-healing wound. The same is true for **betel nuts** that contain arecoline, arecaidine, and guvacine, which have vasoconstricting properties. Betel nuts are used mainly in Southeast Asia and East Africa as a stimulant.

Sickle cell ulcers are chronic ulcers usually seen with

Fig. 17

Fig. 18

Buruli ulcers with characteristic undermining of the edges (Courtesy of Dr. John Tarpley).

homozygous sickle cell anemia and sickle cell thalassemia. They are seen on the lower extremities and just above the malleoli. They occur spontaneously or as a result of minor trauma or underlying osteomyelitis. Probable causes are an obstruction to vessels by the sickled cells, increased venous and capillary pressure, bacterial infection, and reduced oxygen-carrying capacity of the blood. Treatment is good local care, antibiotics, repeated debridements as described above, blood transfusions and skin grafting when the wound is ready. Also, the use of the VAC has been reported to be useful in preparing these ulcers for closure. When the ulcer is grafted, the area should be protected for several months to prevent repeated trauma and recurrent breakdown after the wound heals.

Buruli Ulcers are secondary to Mycobacterium ulcerans. They are seen on almost every continent, but especially in West and Central Africa. The classic finding is undermining around the edge of the ulcer. An acid-fast or Ziehl Neelsen stain may be positive. Biopsy with histopathology is the best diagnostic tool if available. Culture takes many weeks. The main treatment is medical, and based on the TB treatment regimen that includes rifampicin, streptomycin, and amikacin for a minimum of eight weeks. Treatment also includes wide debridement of edges back to good tissue with local wound care and later skin grafting or flap coverage. VAC therapy may be used.

Marjolin's ulcer is a rare but aggressive cutaneous malignancy that occurs in long-standing wounds and chronically inflamed skin, classically in chronic burn wounds but it may occur in any chronic wound as a decubitus ulcer or tropical ulcer. Most Marjolin's ulcers are on the lower extremity, but it can appear on the upper extremity as well as the scalp. Most commonly it is a well-differentiated squamous cell carcinoma, though basal cell carcinoma, adenocarcinoma, and malignant melanoma are seen. It occurs in two forms, the more common exophytic type and a shallow type. Usually, the wound is present 10-25 years before malignant degeneration; however, an acute variant has been seen within a year of injury. Many authors describe early metastasis at the time of diagnosis with poor prognosis. SCC normally has a metastasis rate less than 3% whereas SCC in chronic burn scars has a metastasis rate of 30%, 10 times normal. If associated with pressure sores, metastasis is even higher.

Treatment begins with prevention of chronic wounds by proper care of acute wounds with early wound closure. This will eliminate most cases of Marjolin's ulcer. When a chronic wound is first seen, it must be urgently treated to get it closed so it will not undergo malignant change (See Fig. 1-3). Repeated breakdown of a wound may be an early sign of carcinoma. Diagnosis is best made by histopathology, even though the ulcer may have a typical appearance. When it is on the scalp or lower leg, bony invasion may be found (see Fig. 15). Recommended treatment includes wide excision with 2 cm. margins. If there is bony involvement, radical surgery and even amputation may be required. If available, X-rays and a CT scan may help determine the depth of bony involvement. Without these modalities, exploration

Fig. 19

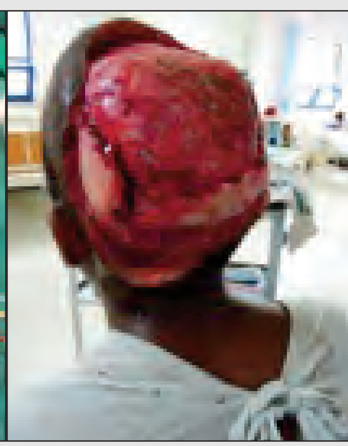


Fig. 20

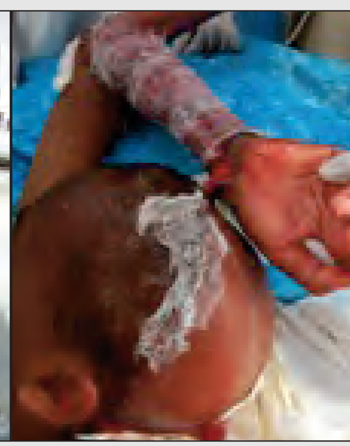


Fig. 21

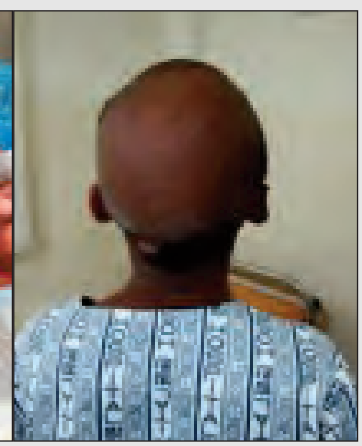


Fig. 22

Full-thickness skull removed in a 12-year-old boy with Marjolin's. Entire forearm skin was taken based on retrograde flow through the radial artery. Flap was divided at 20 days (courtesy Dr. Einar Eriksen).

Variables in Prognosis for Marjolin's Ulcer

		PROGNOSIS	
	Variable	**Better**	**Poorer**
Clinical	Latency to malignancy	Less than 5 years	More than 5 years
	Tumor location	Head, neck, upper extremeties	Lower limbs, trunk
	Tumor source	Post-burn, chronic osteomyelitis	Pressure sore carcinomas
	Tumor diameter	Smaller than 2 cm	2 cm or more
	Tumor type	Exophytic	Infiltrative
	Metastases	None	Present
	Tumor recurrence	None	Present
Histological	Degree of differentiation	Well differentiated	Moderately-well and poorly differentiated
	Peritumoral T lymphocyte infiltration	Heavy	Scarce or absent
	Depth of dermal invasion	Superficial to reticular dermis	Reticular dermis or deeper
	Vertical tumor thickness	Less than 4 mm thick	4 mm thick or more

Fig. 23

Fig. 24

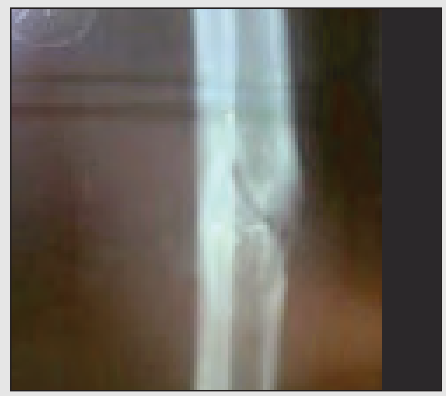


Fig. 25

Marjolin's ulcer in long-standing leg wound with pathologic fracture.
After diagnosis confirmed by histopathology, amputation was performed.

is often required to determine the depth.

For **scalp** wounds, **if the ulcer is down to, but not involving, the pericranium**, then the pericranium should be excised. If the pericranium is involved, then the outer table should be removed with skin grafting or flap coverage. If **both tables** are involved, then full-thickness skull should be removed with skin graft or flap on the dura. If the **dura** is involved, it is excised and grafted with a pericranial patch, as long as the brain is not involved and the pericranial graft can be covered with a flap of vascularized tissue (Fig. 21, 22). This is attempted in relatively young patients without metastasis.

If one excises the pericranium (periosteum), and the outer table remains, the skull can be covered acutely with a skin graft or better with a local flap. A skin graft will often take on acutely exposed bone, especially skull.

In the lower leg, if the tibia is possibly involved, x-rays and CT should be carried out if available. There are many variables in such cases including depth of bone involvement, age, comorbidities and general health, lymph node involvement, availability of a prostheses, and quality of family support, etc. At one extreme are the elderly with deep, aggressive ulcers, possible lymph node metastasis, and generalized weakness (Fig. 26). These should have an AK amputation, but they may not have a reliable and strong caretaker, and they will likely have difficulty using crutches or a prosthesis. In these cases, local care may be all that should be done, as an amputation will lead to a bed-ridden state and early death. These patients may be allowed to live with the

Fig. 26

Fig. 27

Fig. 28

Marjolin's ulcers.

Chronic deep leg ulcer in an older man who lived alone and who had little chance to obtain prosthesis. He was allowed to live with the tumor as it was slow growing (Fig 26). Superficial biopsy proven SCC in an arm burn (Fig. 27). In a young 15-year-old girl with a scalp burn wound, present for only ten years (Fig. 28).

tumor as they will have a better quality of life during their remaining months. At the other extreme is an early skin lesion without bone involvement that only requires wide excision with a graft or flap.

In all extremity cases, the muscle fascia should be excised. As with scalp lesions, if the ulcer is down to the periosteum, but no bony invasion is evident, the periosteum should be removed with a flap or VAC coverage followed by a skin graft. If the periosteum is involved and/or the bone minimally involved in a young person, then a portion or all of the bone can be removed. Antibiotic beads (small beads made from methyl methacrylate mixed with an antibiotic and sutured together as a necklace) are then placed in the defect. An external fixator is applied and a muscle flap is used to cover the defect followed by a skin graft. Reconstruction can be carried out later with a bone graft, bone transport—fibula moved over into tibial defect, or a free fibula microvascular reconstruction, but only after there is no evidence of recurrence for a year or more. Another older method of reconstruction is fusing the fibula to the tibia above and below the tibial defect through a posterior approach. This Phemister technique is an old method used when there was tibial loss secondary to trauma. Bone transport using the Ilizarov technique to transport the remaining tibia into the wound is a sophisticated method that is now available in many hospitals. Bone transport is radical surgery and is only done in younger patients without metastasis. One should never perform such extensive multistage surgery unless a cure is likely possible. Early amputation may provide a more secure future for the patient without concern for recurrence. These young people can easily learn to use crutches or prosthesis.

Lymph node dissection

There is no consensus for lymph node dissection with Marjolin's ulcer in the extremities. Though some have suggested prophylactic lymph node dissection, most would only do so if palpable suspicious nodes are present. Widespread nodal involvement would be a contraindication for node dissection, but local surgical removal of the mass is still done. If the lesion is large (>10 cm) and there are no obvious regional nodes, then a sentinel node biopsy could be done if one has experience with this technique. The limiting factor with this technique is adequate histopathology.

In relatively **young patients with large aggressive ulcers**, amputation with or without lymph node dissection is advised if they can obtain a prosthesis or will be able to use crutches. If there is a reasonable chance for cure, radical surgery with or without amputation is advised. If local care is an option, then an osteotomy of adjacent or involved tibia may be carried out with flap coverage and external fixation if necessary. When the wound is well healed, a bone graft may be inserted into the bony defect or an uninvolved segment of the fibula can be transposed over to the tibia. In the future, more hospitals will be able to perform a free microvascular transfer with a contralateral fibula.

If a node dissection has not been done, it can be done later if nodal involvement appears. Where radiation is available, it has been suggested for Marjolin's ulcer though the guidelines are not certain. Chemotherapy is used when there is lymph node metastasis.

As stated above, in long-standing extensive ulcers in the elderly when it will be difficult to obtain an adequate prosthesis and when the patient will have difficulty using a prosthesis or even crutches, it may be best to provide wound care and allow the patient to have "quality" life rather than have extensive surgery/amputation and be bedridden for life. This is especially true when the patient lives alone or does not have a family to care for him.

Finally, it is important to emphasize that every surgeon that cares for wounds should strive to reconstruct any non-healing wound or fragile scar that continues to breakdown repeatedly. This will likely prevent the future development of a Marjolin's ulcer. Any chronic wound that fails to heal or continues to break down should be biopsied before extensive reconstruction.

Chapter 3

Skin Grafts

Peter M. Nthumba and Tertius H. J. Venter

Introduction

Skin grafts are a valuable option for the closure of wounds that cannot be closed primarily. On the wound closure ladder, when primary closure and delayed primary closure will not be possible, skin grafts are the next option. If acute wounds are clean but cannot be closed, then skin grafting should be done immediately—at the time of admission/first operation. Waiting for granulation tissue to develop, as practiced by many, should not be done.

Outline of skin grafts:

1 Split Skin Graft.
  - Thin or thick.
  - Sheet or meshed.

2 Full Thickness Skin Graft.

3 Composite Graft; skin, fat, cartilage.

Split Thickness Skin Grafts (STSG)

Thin STSGs are 0.006 to 0.012 inches (0.015-0.30 mm), **intermediate** are 0.012 to 0.018 inches (0.30-0.46 mm), and **thick** are 0.018 to 0.024 inches (0.46-0.61 mm). A split thickness skin graft consists of the epidermis, and a variable thickness of underlying dermis, which is detached from its source of blood supply and transferred to another site. Split-thickness grafts can be sheet grafts or meshed. Meshing provides holes in the graft to allow drainage of fluid, serum, and blood. This allows for an improved take when absolute hemostasis cannot be performed. Meshing also allows for better molding of the graft into difficult recipient sites, and provides more graft. A full thickness skin graft (FTSG) includes all the dermis but it may be thick or thin according to the donor site.

Primary graft contraction is dependent on the amount of elastin in the graft, and therefore the thickness of the dermis. The thicker the dermal

Table 1

	Split Thickness Skin Graft (STSG)	Full Thickness Skin Graft (FTSCG)
Anatomy	Varying thickness of dermis.	Contains entire dermis.
Donor Sites	Multiple, depending on amount of skin required. Heals spontaneously.	Limited. Primary closure if small, otherwise split thickness grafting.
Graft "Take"	Less demanding on recipient site.	Requires favorable recipient site; a well-vascularized recipient site is needed.
Adnexal structures	Few. Depends on thickness.	Contains adnexal structures (sweat glands, sebaceous glands, hair follicles, and capillaries).
Contraction	Secondary contraction significant. Primary contraction depends on thickness of dermis	Primary contraction significant. Minimal secondary contraction.
Sweating	Depends on the number of sweat glands	Depends on re-innervation.
Sensory Return	Some sensation after three months.	Greatest—presence of neurilemmal sheaths.

Outline of differences between split and full thickness skin grafts.

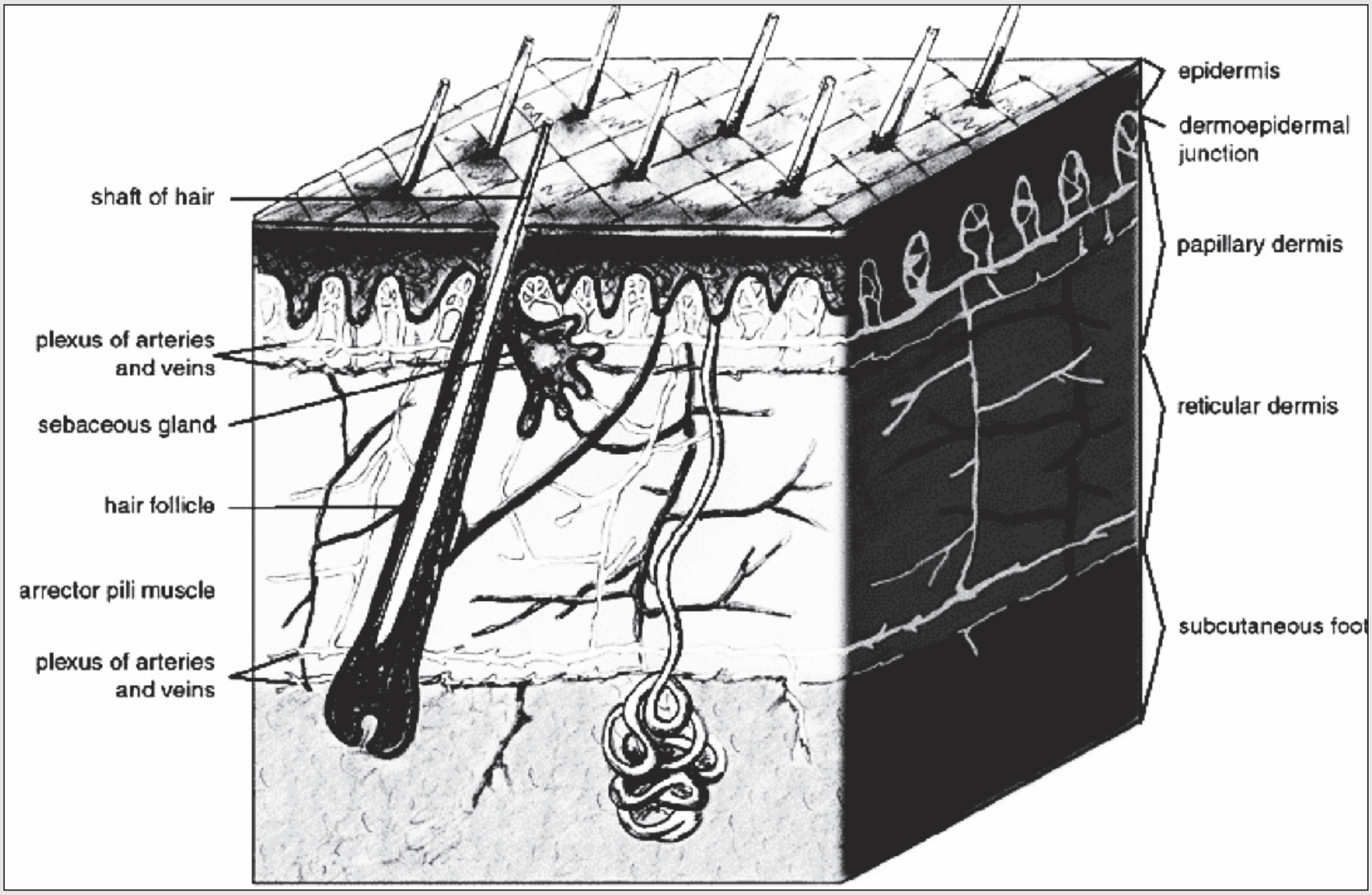


Fig. 1

Skin Anatomy

(Courtesy: http://emedicine.medscape.com/article/1294744-overview)

layer, the greater will be the degree of primary contraction. In full thickness grafts, primary contraction is greater than secondary contraction since it contains the entire dermis at the donor site. Secondary contraction is greatest in split thickness grafts. With burn contracture releases and split thickness skin grafting, re-contracture is likely over joints unless the joint is splinted out in extension for six weeks to several months.

Harvesting of Skin Grafts

(See also chapter 12 on Burn Reconstruction.) Split thickness skin grafts are usually taken with a dermatome. Small full thickness skin grafts are harvested by hand, and the donor site closed primarily. Large FTSG may be taken with a dermatome—the surgical instrument used for harvesting skin grafts. The dermatome may be manual, battery operated, electric, or air-driven. The manual dermatome is the cheapest and most practical device for most of sub-Saharan Africa, as the only needed supplies are the blades. The Humby or Watson knife is the most popular.

The width of the blade makes it difficult to use in children and over some body contours (See Figs. 4a-c). A modified shaving razor blade or a Weck (Pilling) blade is more useful in such circumstances. The illustration in Fig. 1 shows the anatomical depth of each type of graft.

Comparing Thick vs. Thin STSG

The **thinner** the graft is:

- The easier it is to cover larger areas.
- The easier the "take" of the graft.
- The less dermis will be present, leading to more contracture and scar formation. Splinting and/or pressure garments are therefore very important.
- The faster the donor area heals by rapid re-epithelialization—10 days or less—and may be re-harvested in approximately three weeks if thin (0.008–0.012).

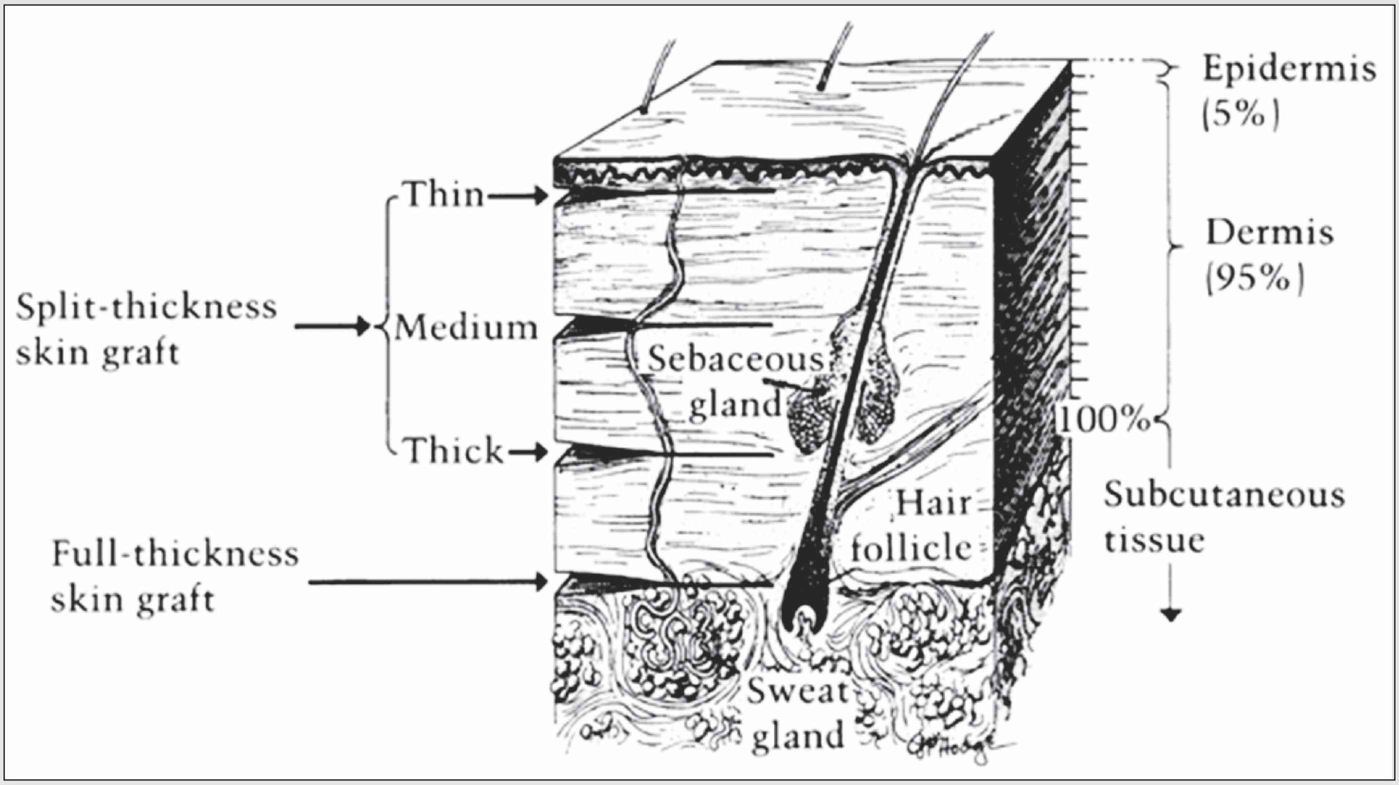


Fig. 2

Anatomy of the Skin Graft

Thicker split thickness grafts:

- May not take as well, but will have less secondary contracture.
- When very thick skin is harvested, the donor areas can take up to 3 weeks to heal.
- The healing of the donor area may be expedited by a very thin split skin taken from an adjacent area at the initial surgery and grafted on the thick donor area.
- Despite the ability to heal spontaneously, the thick split-thickness skin graft donor site is frequently scarred or discolored.

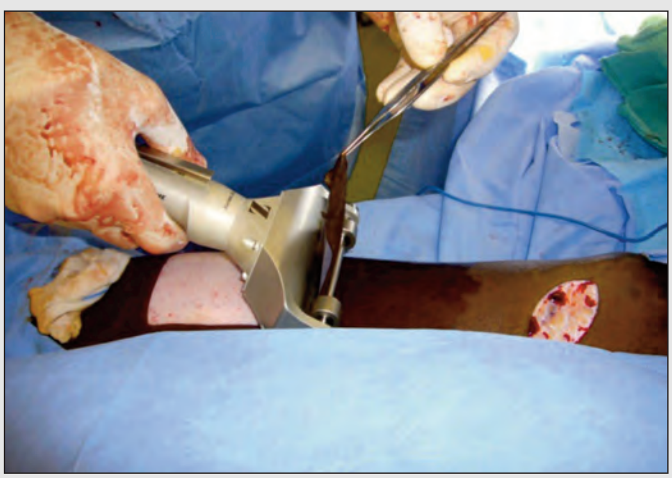


Fig. 3

Fig. 4

3) Harvest of split thickness graft by electric dermatome.

4) Split thickness donor site.

Fig. 5

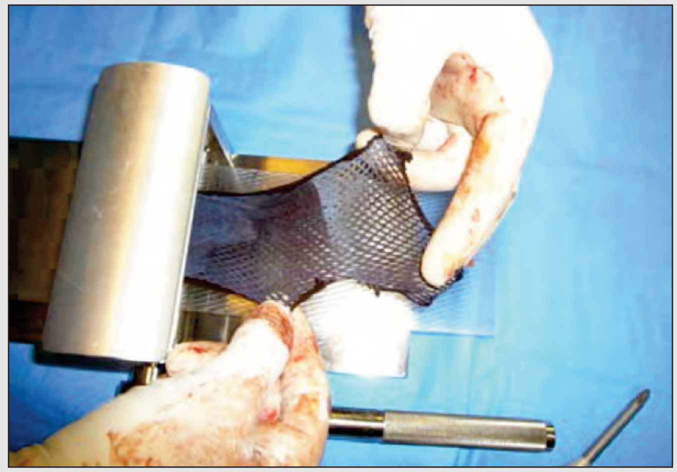


Fig. 6

5) Meshing of the split thickness skin with a Brennan mesher.

6) Demonstration of the meshed skin.

Care of the donor area is important especially with thick split thickness grafts, and when thick Vaseline® gauze is used. The outer gauze dressing must be removed on the first postoperative day if possible. (Vaseline® gauze may be produced in a hospital pharmacy but this is often thick. Thinner, more expensive, non-adherent gauze is commercially available.)

Full-thickness grafts are indicated:

- For smaller areas.
- When color match/cosmesis is important as for face.
- When skin elasticity/texture is important: fingers and hand.
- Secondary contracture must be eliminated—eyelids, fingers.
- Source: pre or postauricular, supraclavicular, upper inner arm are excellent sites for face. Also groin for larger grafts.
- Recipient bed must be ideal as graft take is more difficult—fewer capillaries for alignment.
- Donor area is closed directly.

Graft "Take"

Skin graft "take" is dependent on the recipient site providing sufficient nutrients, and subsequent vascular ingrowth into the graft. Skin take occurs through three phases:

- Imbibition phase—lasts 24 to 48 hours. Fibrin layer binds graft to bed.
- Inosculation—donor and recipient capillaries are

Fig. 7

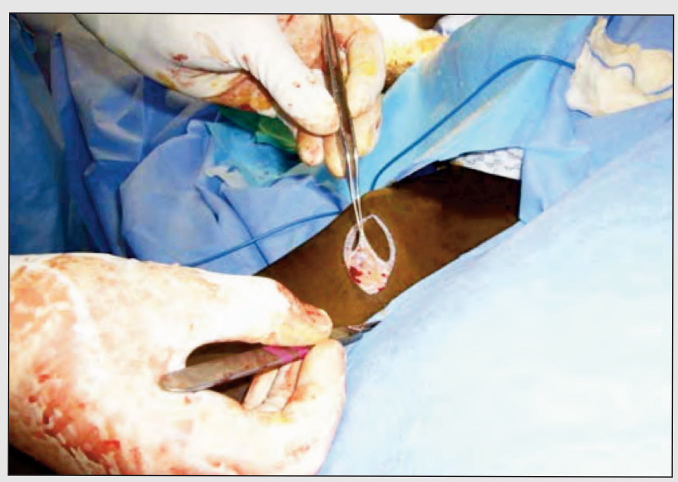


Fig. 8

FTSG: (L) donor area; (R) inguinal fold harvesting of a FTSG by hand.

Fig. 9 **Fig. 10**

9) Burn contractures of the upper eyelids.

10) Healed upper eyelids—Full thickness grafts from pre-auricular skin.

aligned.

- Revascularization—graft revascularized through 'kissing' of capillaries.

Principles of Skin Grafting—Summary

1 The recipient site must be well prepared to optimize graft take. Skin will rarely 'take' on bone, tendon or cartilage in the absence of periosteum, paratenon, or perichondrium, respectively. Exceptions to this rule include the flat bones of the skull: orbit and temporal bones, on which skin grafts may take in the absence of periosteum/pericranium.

2 **Control of bleeding from debrided areas and donor sites**: Soak gauze in a solution of 2-3 ml. of 1:1000 Adrenaline (cardiac adrenaline) in 200 ml. of saline. Apply gauze to wounds. After 5 minutes if there is still bleeding, apply this gauze again or use electrocautery.

3 Grafts will not take on infected wounds. If a gram of skin has 105 microorganisms, the wound is colonized, and a graft will not take well. Though wound biopsies may be done in major centers, they are rarely performed even there. The majority of surgeons determine the status of a wound by the appearance of the granulation tissue and the surrounding skin (erythema, presence of exudate, foul odor, etc.). When grafts fail to take on a "good" surface, bed, then the surgeon must determine the cause— infection, lack of immobilization, bleeding, etc. Usually the cause of graft failure is obvious. Occasionally it may be possible to get reliable cultures in your district hospital.

4 The skin graft must be closely applied to the recipient site. Grafts are held in place by a non-adherent dressing (such as Vaseline gauze), moist cotton which molds the graft into irregular surfaces and crevices, a bulky wet dressing and circumferential wrapping of an extremity, or bolster stent dressings. The latter are used on the face, shoulder, neck, etc. where wrapping cannot be easily done to hold the graft in close apposition to the recipient site. Also, joint and extremity immobilization with splints or casts is important after grafting to prevent movement, and possible shearing of the graft with hematomas and seromas developing under the graft. These will lead to graft failure.

5 Granulation tissue may look good, but it is infected tissue and should be debrided to optimize graft take. Granulation tissue should be debrided or shaved off down to near-normal tissue before grafting, preferably to bleeding

dermis. This is best done with a Weck blade or Humby knife. The only good granulation tissue is that obtained after a VAC dressing application.

6 Preparation of chronic wounds for grafting or a flap is discussed in the chapter on chronic wounds.

7 Skin grafts may be meshed, allowing for graft expansion and coverage of a larger defect. This is especially useful in children and patients with large defects or extensive burns. As mentioned, meshing also permits the drainage of serum and blood and a better "take" of the graft; however, it does lead to a 'pebble stone' appearance and a poor cosmetic result. This is not important in many areas of the body, but very obvious on the face, neck, dorsum of hands, etc. With large burns, there may not be an alternative to meshing. Skin grafts may be meshed with a mesher or manually using a scalpel blade to make holes. Manual meshing does not allow even spreading out of the graft but is best for full thickness skin grafts.

8 One may secure the split thickness graft to the recipient area with sutures, staples, fibrin glue, Steri-Strips® (adhesive strips), etc. The author uses absorbable suture (chronic, Monocryl®) for small areas and staples, if available, for larger areas. Absorbable sutures do not need removal and are good for children. Sutures or staples may also be used deep in the wound to hold the graft into crevices or corners.

9 Dressing of Skin Grafts

A Non-adherent dressing as Vaseline®

B Then wet cotton (cotton balls), wet gauze, and a bulky dry gauze dressing. The wet cotton (balls) is extremely important to help mold the graft into crevices and edges of the recipient wound.

C The wet dressings maintain a moist environment to ensure better healing. It has been shown that healing is better in a moist environment rather than a dry one.

D It is then wrapped with a gauze bandage or Ace type elastic bandage if an extremity. A gauze bandage around the dressing is safer than an elastic bandage that may compromise the blood supply.

E It is then splinted and wrapped with an additional non-elastic bandage. Non-elastic bandages may not be available. In this case, the elastic bandage must be carefully wrapped without tension. If there is swelling the graft could be lost.

F When the recipient site cannot be wrapped, as on the face or neck, then a **bolster or stent dressing** is used to decrease possible movement of the graft beneath the dressing. Non-absorbable sutures are used for the stent sutures. The wound is dressed as above, and the stent sutures are tied down over the bulky dressing. Stent or bolster sutures should be one or two sizes larger than the skin suture one would use for the area.

1 The donor site is covered with a non-adherent or Vaseline gauze and cotton gauze. The cotton gauze is removed in 24 hours and non-adherent gauze exposed to air. This is allowed to peel off over 10-14 days.

2 ELEVATION is very important for the first postoperative week!

3 Use of antibiotics—the author uses a single dose of a cephalosporin at the beginning of skin graft surgery. Prolonged use of antibiotics is debatable. If the grafts are on the lower extremities or if the recipient bed is not perfect,then antibiotics may be continued for 24 hours. If the surgery is in a potentially infected area as the groin or perineum, antibiotics may be continued for three days or longer.

4 The timing of first dressing change: If a graft has been meshed, one may wait 5-7 days unless there is significant drainage or a foul odor. Some inspect a sheet or full thickness graft the day after surgery to check for hematoma or seroma. The graft must be inspected by day three even if limited manual meshing has been done. If there is no collection of fluid, then the wound will not need to be dressed again for 5-7 days. Often several small holes are placed in a sheet graft or full thickness graft just to allow any collection of fluid out. These may be done at the periphery so that cosmesis is unaffected. When the wound is re-dressed, non-adherent gauze should be applied

for another week. . Some will apply a thin coat of Silver Sulfadiazine to the skin graft after the first dressing.

5 When a stent or bolster dressing is used to mold and contour a sheet skin graft in the neck to provide a cosmetically pleasing result, the dressing is carefully inspected at day 3 and 5 for excess drainage but not removed until day 7. A bulky dressing and a neck collar are then used, but the molding/contouring effect of the stent/bolster dressing is lost once it has been removed.

6 Where available, a VAC dressing may also be used over a skin graft but not directly on the graft. It should be placed on top of the Vaseline-like gauze.

7 Length of splinting and immobilization depends on the site and the initial take of the graft. Lower extremities usually require immobilization for two weeks. After grafts have taken on the lower extremities, the grafted area should be covered for at least four weeks to protect from trauma

8 Epidermis regenerates from adnexal structures after skin graft is harvested. Dermis however, cannot regenerate. The thickness of dermis determines the number of times that skin can be harvested.

9 **Source of Skin Grafts**

G Split thickness skin grafts are normally harvested from the thighs, abdomen, buttocks, etc.

H Full thickness skin grafts require primary closure or skin grafting: full thickness skin grafts are commonly harvested from the groins. The medial aspect of the arm, post auricular areas and supraclavicular fossa are other possible sources. The skin above the clavicles closely resembles that of the face. For small skin grafts on the hand, antecubital fossa, volar wrist crease and hypothenar eminence are used. One can use the Humby knife to take both full and split thickness grafts from the thigh, just by varying the angle and the pressure used. The split thickness graft can be used to reconstruct the full thickness donor site (See chapter 12 on Burn Reconstruction).

Fig. 11

Fig. 12

11) Unhealthy, infected granulation tissue.

12) Wound prepared after several debridements.

1 Thickness of grafts—location, age, size determine thickness of skin.

A 0.012 to 0.016 inch (0.3-0.4 mm) is the thickness commonly used for STSGs.

B 0.010 inch (0.25mm) is used in burns when one needs considerable skin and with the need to re-harvest from the same area in the future

C 0.020 (0.5mm) and above is a thick graft and suitable for the neck coverage after release of a contracture

1 **Causes of Graft Failure**

A Seroma or hematoma formation with lifting up the graft off the recipient site.

B Infection is the second most common cause of graft failure.

C Shearing, usually due to lack of adequate immobilization

D Skin grafts will also fail to take if inadvertently placed ‘upside-down’—dermis up. The thinner the graft the easier it is to mistakenly put the graft on upside down.

Tips from the authors:

1 Silver sulfadiazine cream can be applied on the Vaseline gauzes as a topical antibiotic. This will maintain a moist environment. This dressing is then applied on the skin grafts as well as the donor sites, and it is a much cheaper ‘antibiotic-coated’ dressing than those commercially available. Dressing changes in the ward likewise

should use gauze impregnated with silver sulfadiazine, if available.

2 When the recipient site is questionable and does not clean up quickly, a VAC dressing (as described in chapter 4) may be applied, with excellent results.

3 In cases where the recipient site bleeds excessively after debridement, and there is a question about a sheet graft taking, as on the neck, the graft may be stored overnight or several days at 4° Centigrade in a refrigerator. The recipient site is kept moist. This may be necessary after the release of burn contractures of the neck. The graft may then be placed on the recipient site 24-48 hours later without the fear of a wound infection.

4 If the skin is harvested but not needed immediately, the skin may even be stored at 4° Centigrade for up to 3 weeks, but it should preferably be used within seven days. The skin is paced in moist saline gauze and stored inside a 20 ml syringe (remove plunger to place the graft, and then replace the plunger. The syringe nipple is closed with a covered hypodermic needle).

5 Upon discharge from the hospital, the patient is directed to massage the grafts with Vaseline ointment at least twice a day. This keeps the graft lubricated before sweat and sebaceous glands develop and function. The massaging also helps protect the patient from the development of hypertrophic scars. In cases where hypertrophic scars or keloids are likely, pressure dressings should be used for several months (See Chapter 1). Cocoa butter, where available, helps to decrease itching.

6 Pinch grafts can be used when dermatomes are not available. A needle or small forceps can be used to "tent" a small area of skin up, and a blade is used to take a fingertip split thickness portion of skin. Multiple grafts can be placed, and there will be epithelialization between these to cover a wound.

Chapter 4

Wound Closure with Vacuum Assisted Closure (VAC)

Peter M. Nthumba

Vacuum Assisted Wound Closure (VAC) or Negative Pressure Wound Therapy (NPWT)

The application of controlled negative pressure may be used to create a controlled hypoxic wound environment that has been shown to:

- Stimulate angiogenesis.
- Promote formation of healthy granulation tissue.
- Remove tissue edema.
- Increase local blood flow.
- Provide a moist environment ideal for wound healing.

The risk of excessive bacterial colonization of the wound bed is reduced, as VAC therapy eliminates excess and stagnant exudative fluid, thereby reducing the bacterial burden. The accepted mode of delivery involves intermittent or continuous (preferable) suction, applied at approximately 75-125 mm Hg. VAC therapy may be used for both pediatric and adult patients with diverse wounds resulting from infection, vascular insufficiency, trauma, etc. VAC thus offers a safe and reliable alternative to traditional methods of treatment of complex soft tissue defects, including those with exposed tendons, bone, cartilage, and orthopedic hardware, while

Fig. 1

Fig. 2

Fig. 3

Wound debrided well and VAC used. In this case gauze was used.

Fig. 4

Fig. 5

Fig. 6

Suction tubing inserted, wound wrapped with food wrap, final result before grafting.

Fig. 7 **Fig. 8** **Fig. 9** **Fig. 10**

Foot wound, VAC applied, wound prepared for skin graft.

awaiting definitive wound closure.

Suggestions and Tips:

1 Commercially available VAC units are extremely expensive, far above the reach of most patients treated in sub-Saharan Africa.
2 The author uses locally available material for the assembling of affordable VAC 'units.' See figures below.

Supplies and Equipment Needed

1 Sterile gauzes or medium density mattress material (foam) that is cut into various sizes and sterilized. This foam rubber is found in chair cushions around the world. In most cases, it is too thick and will need to be divided and thinned. This foam is very close to the material used commercially. It can be cut in different sizes and sterilized. It is usually **applied directly** to the wound. It should be cut to the exact size of the wound at surgery.
2 Keep the foam within the wound bed and off of the surrounding intact skin, as this can lead to excoriation and maceration of the healthy skin.
3 Naso-gastric tubing or other non-collapsible sterile tubing. The naso-gastric tube may be passed into the middle of the foam through a hole. The hole can be made with either a hemostat or knife.
4 Cling film (food wrap)—available in most groceries/supermarkets all over the world. It is wrapped several times around the foam rubber.
5 Tape to use for wrapping around the each end of food wrap to provide a sealed wound.
6 Access to either wall suction or a suction unit (the disadvantage is the noise) and an effluent-collecting bottle.

Fig. 11

Fig. 12

Fig. 11-15 same case: Severe open fracture, debrided, soleus flap.

Fig. 13

Fig. 14

Fig. 15

External fixator, then VAC-like dressing is applied using foam from a seat cushion directly on wound. VAC was changed every 2-3 days and used for 3 weeks before ready for STSG.

Another method if foam rubber is not available: After wound debridement and hemostasis, Vaseline® gauze is applied on the wound. **3 to 4 layers of gauze are applied** over the Vaseline® gauze, and the nasogastric tubing is placed just below the topmost gauze layer. This prevents tube obstruction from the overlying cling.

1 Some home-made (made and sterilized in hospitals) Vaseline® gauze is very thick and may not allow fluid escape. If this is all that is available, then just use plain gauze. However, briskly rubbing the Vaseline® gauze with a sterile towel can remove much of the petroleum jelly.

2 Cling film is wrapped around the gauze and tubing, completely covering them. Tape is applied to either end of the Cling film to provide a seal.

3 Suction pressure is applied through the tubing, and frequently checked to ensure that there is no leakage. The gauze/foam should become hard and mold to the wound immediately after suction is applied.

The VAC may be used for 2-3 days before changing the dressing, depending on the type of wound, effluent, and sometimes the length of time it takes for the suction unit to malfunction. The VAC may be continued for as long as is necessary to obtain a well vascularized wound ready for closure, graft or flap.

Cautions

While a functioning VAC system is an excellent tool for varied and complex wound closure, the user must note the following:

- Adequate hemostasis should be obtained before the application of VAC therapy—avoid direct application over naked or repaired vessels or viscera. Viscera may be covered with Cling wrap for protection before coverage with sterile towels or foam.

- VACs must **NOT** be applied on dirty, purulent wounds or wounds with ongoing soft tissue necrosis; it is not a substitute for adequate debridement, but rather **WILL** permit complete debridement, even with the exposure of tendons, bone or hardware, without risking desiccation. **I CANNOT EMPHASIZE THIS POINT ENOUGH.**

- VACs are contraindicated in malignant and necrotic ulcers—these require appropriate treatment before the application of VAC therapy.

- VACs must function at all times, as long as applied to a wound. When working, the gauzes or mattress foam material should feel 'hard' or firm to touch, and should be well molded to the defect to which it is applied. A **non- functional** VAC that is left applied to a patient is dangerous, as it may allow for rapid development of pus and tissue death. All VACs should be checked at least twice a day to ensure that they are in functioning well and that the suction pressure remains the same. Over weekends, someone must check the VACs regularly. Otherwise, simple dressing changes may need to replace a VAC dressing in order to avoid the disaster that occurs when the VAC stops working and is not checked for 2-3

days. **Do Not Leave This to a Nurse.**
  - VACs that are not functioning will feel 'soft', and exudate may be visible on the applied gauzes or leak from the edges of the VAC dressing.
  - A foul odor will emanate from a VAC that is not working.
- The VAC may be applied over the Vaseline gauze when is placed over freshly meshed skin grafts in order to increase skin graft take. Applying the foam directly on the skin graft is not advised, as the foam may become adherent within the interstices of the graft leading to graft failure as the foam is pulled from the wound bed at initial graft evaluation.

When to Discontinue VAC

- The VAC should be discontinued temporarily when the wound needs repeat debridement
- The VAC should not be left on more than 2-4 days before changing.
- When the wound is clean with a healthy granulation bed, it is ready for delayed closure, graft or flap.
- If a meshed graft is applied, the VAC could be used for several more days to ensure graft take. Initial graft evaluation typically ranges from 3-5 days after VAC placement unless a mechanical problem occurs.

(**Editor's note**: There are several companies that are developing portable non-electric vacuum suctions. Whether or not these will become cost-effective for Africa is unknown at this time. One such company is Spiracur. Internet contact information at: info@spiracur.com. Unfortunately, these are small, battery-powered, disposable units that are not practical for large draining wounds at this time. KCI and Smith Nephew manufacture the commercial types. These are excellent though expensive products. These suction machines are small and quiet, and investing in several of these would be helpful for any mission hospital where patients are on general wards—where noise from regular suction machines may keep others awake.)

Chapter 5

Regional Anesthesia for Plastic Surgery (and Tracheostomy Care)

Mark W. Newton

Introduction

People in low-income countries, particularly in Africa, are dying for lack of the basic knowledge, skills, and equipment for the provision of anesthesia. In developed countries, the mortality rate from anesthesia is 1 in 185,000. Studies in developing countries suggest a death rate of 5-10% associated with major surgery, and the rate of mortality during general anesthesia is reported to be as high as 1 in 150 in parts of sub-Saharan Africa. There are studies currently to determine the actual anesthesia mortality in Africa.

Essential perioperative and surgical care at district hospitals typically is more cost effective than other interventions. The shortage of trained anesthesia providers makes surgery problematic, even though the impact can be profound. For example, the anesthesia for basic plastic surgical cases without the understanding of regional anesthesia could potentially increase surgical (anesthesia) morbidity and mortality.

In many areas of Africa—conflict zones, post-conflict areas, and rural regions—there are no anesthesia care providers with appropriate training at all. Recent reports clearly demonstrate this deficit: Africa is home to 11% of the world's population, 20% of the world's disease burden, and only 3% of the world's health-care workers. Because the majority of specialty physicians live in urban and capital areas, trained anesthesia care providers in rural Africa are even scarcer. As a surgeon performing plastic surgery, you must have some basic idea of the pharmacology and the physiological implications of local anesthesia drugs, including side effects. Regional anesthesia understanding for upper extremity, lower extremity, and spinal anesthesia are valuable tools for any surgeon involved in plastic surgery. At the end of this chapter, some basic guidelines for the care of the tracheostomy patient will be included.

Local Anesthesia Pharmacology

The two most commonly used local anesthetics (LA) in Africa are lidocaine (or lignocaine) and bupivacaine (or Marcaine®). Lidocaine was first used in 1948. It belongs to the classification of drugs called amino-amides. Bupivacaine was discovered in 1957. Both of these local anesthesia drugs are safe if used appropriately and are available in many African countries. These drugs have some differences that will help one determine when to use one or the other, but they have some common properties that are similar to all local anesthesia drugs.

Local anesthetics block the transmission of the action potential (what makes the nerve perform) by inhibiting the sodium channels in various locations in the wall of the nerve sheath or within the nerve cell itself. With the sodium channel blocked, the information for the nerve to feel pain or move cannot be sent within the nerve. Thus, the patient feels "numbness" and could have a motor blockade in the area of action of the LA. The time required for the nerve function to return would indicate that the sodium channels have recovered, and the LA is no longer blocking the action potential. The speed of onset of the LA, and the duration, will be impacted by the pH of the environment where the LA is being injected. It is also impacted by the lipid solubility of the LA, which governs its absorption and subsequent metabolism. When the tissue is acidotic (low pH) such as with an infection, the onset and overall quality of the LA block will be diminished. LA which are more lipid-soluble take longer for the onset of a nerve block, but will also last longer when the block has taken full effect. Typically, if a block takes longer to have a blockade, like bupivacaine, then it will last longer in comparison to lidocaine. In most countries, these drugs are available, and the decision to use one or the other can be based upon the clinical scenario and the cost.

The drugs themselves are absorbed from the site of injection of the LA, which will decrease the block time and create a situation where you may have systemic toxicity issues. The higher the protein binding and the lipid solubility, the longer the block lasts due to decreased uptake into the surrounding tissues. The LA drugs mentioned, lidocaine and bupivacaine, are primarily metabolized and eliminated by hepatic enzymes, but they can be directly eliminated by the lung circulation as well. Renal function has little impact on the elimination of LA.

In an attempt to make the LA last longer and stay in the site where it was first deposited around the nerve, epinephrine (adrenaline) is added so that vasoconstriction occurs keeping the LA in place. The epinephrine in commercially available local anesthesia is typically in a concentration of 1:200,000 which means that you have 5 mcg/ml of the epinephrine. If a surgeon or anesthesia care provider is required to mix up the local anesthesia and add the epinephrine themselves, when it cannot be found pre-mixed commercially, one must be careful to add the correct concentration of epinephrine as mentioned above. You must be cautious when giving patients epinephrine as you can create systemic hypertension and even cardiac dysrhythmias. The addition of epinephrine will also help the surgeon by decreasing bleeding and improving visualization at the surgical site. Epinephrine should be omitted when performing nerve blocks on nerves with no collateral circulation such as digital blocks for the hand, feet, and penis.

(**Addendum**: If one does not have dilute adrenaline, one may make it by: Using 1 vial of adrenaline [1 mg/1 ml] and take 0.1 ml of this drug and place in 10 ml of 2% lidocaine and this will give you 2% lidocaine with 10 mcg/ml, which is the same as 1:100,000 adrenaline. If you do not have a 1 ml syringe, then take 1 ml of adrenaline [1 mg/ml] and place in 9 ml of normal saline. This will give you 100 mcg/ml solution. Then take 1 ml of this solution and place in 9 ml of 2% lidocaine and this will give you 10 mcg/ml adrenaline in 2% lidocaine which is 1:100,000.)

LA is absorbed into the blood stream from the tissue placement of the drug and, depending upon the blood flow from that area, various amounts of blood levels of the LA would be elevated. The blood levels of the LA could produce systemic toxicity and secondary side-effects. The site of injection of LA determines the rate of absorption. LA intercostal blocks produce a greater absorption than brachial plexus and then even less absorption for the epidural block. The dose of the LA must be calculated pre-injection so that you can safely give the correct dose and prevent central nervous system (CNS) and cardiovascular (CV) systemic complications. Table 1 gives some LA comparative dosing for all of the commonly used LA. CNS toxicity will occur before CV toxicity.

Typically, if the dose were too high, you would first see numbness around the mouth, facial tingling, ringing in the ears, poor speech, and even seizures.

Table 1

Table 11–1 Comparative Pharmacology and Current Use of Local Anesthetics

Classification and Compounds	pKa	Nonionized (%) at pH 7.4	Potency*	Max. Dose (mg) for Infiltration†	Duration after Infiltration (min)	Topical	Infiltration	Intravenous Regional	Peripheral Block	Epidural	Spinal‡
Esters											
Procaine	8.9	3	1	500	45-60	No	Yes	No	Yes	No	Yes
Chloroprocaine	8.7	5	2	600	30-60	No	Yes	No	Yes	Yes	Yes (?)
Tetracaine	8.5	7	8			Yes	No	No	No	No	Yes
Amides											
Lidocaine	7.9	24	2	300	60-120	Yes	Yes	Yes	Yes	Yes	Yes (?)
Mepivacaine	7.6	39	2	300	90-180	No	Yes	No	Yes	Yes	Yes (?)
Prilocaine	7.9	24	2	400	60-120	No	Yes	Yes	Yes	Yes	Yes (?)
Bupivacaine, levobupivacaine	8.1	17	8	150	240-480	No	Yes	No	Yes	Yes	Yes
Ropivacaine	8.1	17	6	200	240-480	No	Yes	No	Yes	Yes	Yes

This table applies to 70 Kg adults. The doses for children are much lower.
From *Basics of Anesthesia*, Table 11-1, p. 127, Stoelting (Courtesy of Elsevier).

If the dose is very high, you would then see cardiovascular collapse with hypotension and arrhythmias leading to a widened QRS complex and resistance to CV resuscitation. This is especially true for bupivacaine. The most effective manner to avoid toxicity is to check and recheck the dose for the specific LA based of course on the patient's weight. **An easy dosing for lidocaine would be 5 mg/kg without epinephrine and 7 mg/kg with epinephrine; bupivacaine would be 2.5 mg/kg for both with and without epinephrine.** If the correct weight of the patient is used for the determination of the toxic dose and the above doses are used, then the patient should not have any toxicity unless the drug is accidentally injected directly into the intravascular space. The treatment of a toxic dose of the drug is supportive care of the CNS and the CV system that may require cardiopulmonary resuscitation.

Upper Extremity Nerve Block

General anesthesia carries a higher morbidity and mortality in Africa compared to the less frequently used regional anesthesia. Plastic surgeons may be working in a hospital where the anesthesia care providers are few, and their training could be inadequate for regional anesthesia techniques. Lower extremity surgeries can be completed with spinal anesthesia in the vast majority of cases, unless there are contraindications. This section will discuss upper extremity blocks that will be helpful for surgery in the arm and hand. These blocks include: brachial plexus or axillary block, wrist block, digital block (which would be for the finger) and intravenous or Bier Block. One must cautiously prepare the correct dose of LA so that toxicity is not an issue for these blocks. We will discuss important anatomical landmarks and include diagrams of the areas which are to be blocked.

Brachial Plexus Block—Axillary Approach

Anatomy: The brachial plexus arises from the cervical roots: C-5 to C-8 and T-1, which passes between the clavicle and first rib and extends then as a bundle to the axilla. Within this sheath, the axillary artery and vein with the brachial plexus will travel to the proximal part of the arm with the musculocutaneous branch (sensory fibers to the forearm) coming off before the axilla, so it will need to be blocked separately. See Fig.1, which demonstrates the anatomy of the nerve sheath high and superficial in the axilla.

Technique: See Fig. 2, which shows the placement of the needle in relationship to the palpation of the axillary artery, with the tourniquet below the axilla.

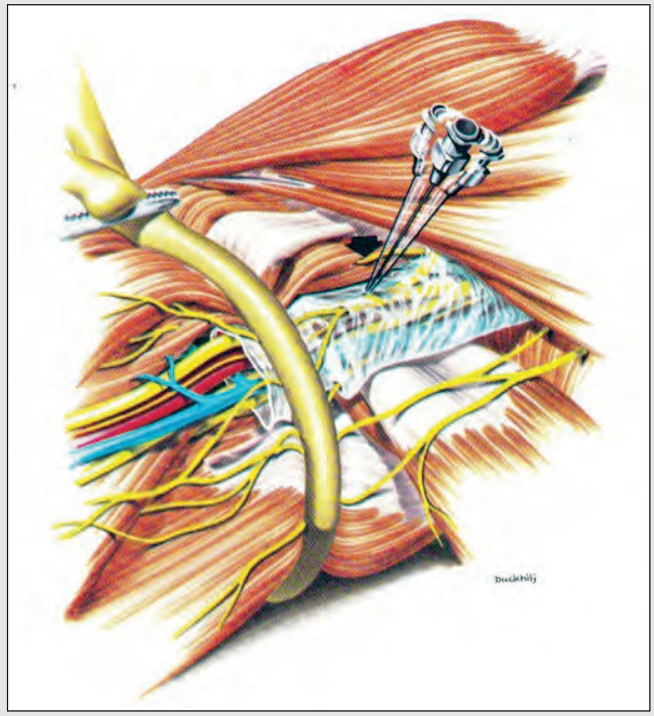


Fig. 1

From Fig. 92, *Illustrated Handbook in Local Anesthesia*, p. 82 (Courtesy of Ejnar Erikson).

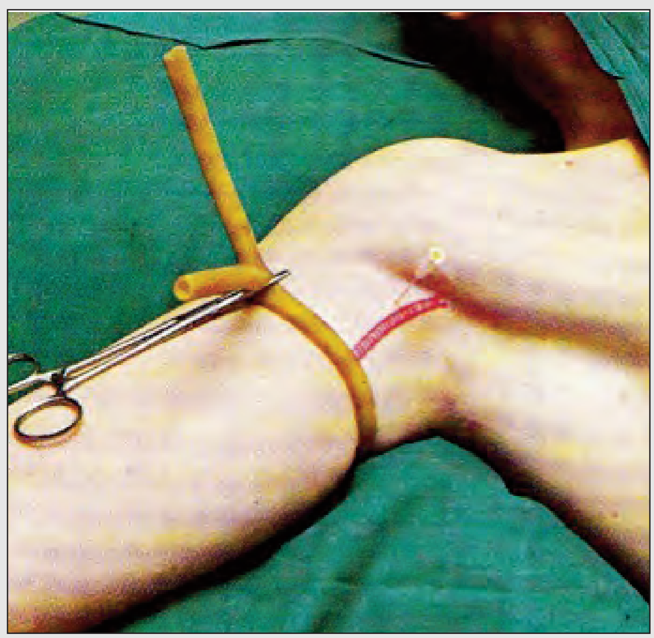


Fig. 2

From Fig. 93, *Illustrated Handbook in Local Anesthesia*, pg. 83 (Courtesy of Ejnar Erikson).

The patient should be lying on the back with the arm outstretched at a 90-degree angle, but not greater than this as the nerve sheath may be compressed. Once the tourniquet is placed, to keep the drug in the sheath area post injection, the axillary artery should be palpated, and a short needle (4-5 cm, 19-21 gauge) is directed toward but slightly above the artery pulsation with a syringe attached while slightly aspirating. If an extension tube is available, a tube can be added between the needle and the syringe, so that the arterial or venous blood can be easily visualized.

The artery should be avoided if possible, but if the artery is penetrated, then proceed to pass the needle through the artery within the sheath while aspirating until no more arterial blood is aspirated. This would confirm that you are within the sheath, and the drug can be injected if the aspiration of blood is now negative. If you do not penetrate the artery, but see pulsations and no blood, that means that you are within the sheath and in a good position. If you happen to illicit a sign of hitting a nerve (electricity down the arm), then you must not inject but withdraw the needle slightly. You are still in the sheath, and can use this as a positive finding for an injection of the LA after another aspiration check. Never inject LA if the patient is experiencing this sensation after you pull back the needle, as this may indicate an intraneuronal injection that can produce a permanent injury to the nerve. Always aspirate again prior injection of the LA to help avoid an intravascular injection.

The typical volume of LA given to adults would be 40 ml. and the total dose must be calculated based upon the toxic dose for the patient. For example, a 70 Kg person could get a total of 350 mg (5 mg/kg) of lidocaine for a toxic level. With this guideline, you could give 35 ml of 1% lidocaine, which would equal 350 mg of the drug, within the toxic guidelines for this patient. You can give the maximum volume possible, but keep within the toxic guidelines for the patient's weight by diluting the calculated maximum amount with normal saline or sterile water. If you have penetrated the artery, you can give half of the dose on the back side of the artery and the other half on the medial, more superficial side of the artery. The tourniquet should stay in place for ten minutes, and the onset of the block may be 25-30 minutes, but the patient's arm can begin being prepped once the patient indicates some heaviness of the arm. The musculocutaneous nerve can be blocked by placing 5 ml of the LA in the coracobrachialis muscle.

Ultrasound-guided peripheral nerve localization has become more popular amongst anesthesiologists, and even some surgeons, for the upper extremity blocks. Certainly the largest hurdle for this technique is the cost of purchasing a portable ultrasound machine. The advantage is the direct visualization of the nerve and needle interface, usually with a linear probe that offers better visualization but less depth in comparison to the curvilinear probe. The techniques for placement of the blocks with ultrasound are outside the scope of this chapter, but can be assessed from multiple sources online.

Complications: Pneumothorax is very rare due to the site of injection. A direct nerve injection causing damage can occur, and if one experiences a prolonged block, you should investigate. Most nerve damage injuries in the peripheral nerves should recover within 6 months. A toxic dose of LA could

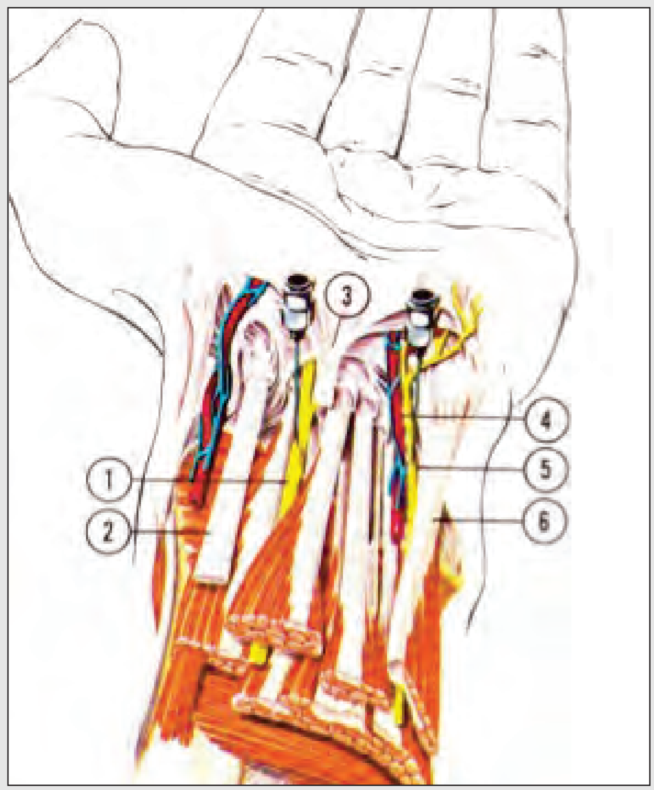
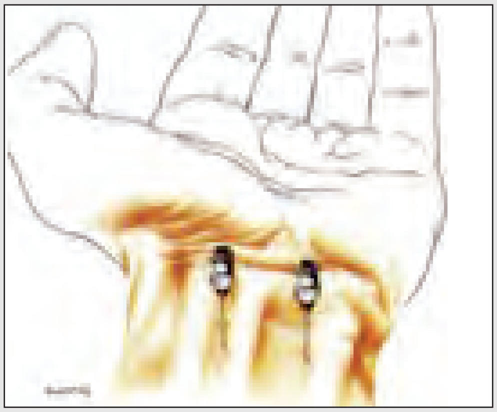


Fig. 3

1) Median nerve; 2) Flexor Carpi Radialis tendon; 3) Palmaris Longus tendon; 4) Ulnar artery; 5) Ulnar nerve (deeper than artery and vein); 6) Flexor Carpi Ulnaris tendon. From Fig. 106, *Illustrated Handbook of Local Anesthesia*, p. 90 (Courtesy of Ejnar Erikson).



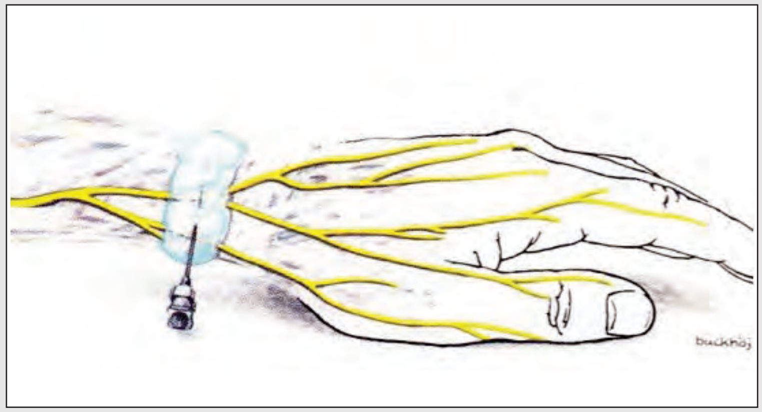


Fig. 4 **Fig. 5**

From Fig. 107, 108, *Illustrated Handbook of Local Anesthesia*, pp. 91-92. (Courtesy of Ejnar Erikson)

be given if injected directly into the artery or vein, thus one should constantly aspirate prior to injection and repeatedly after every 5 ml to avoid this complication. If an arterial injection occurs, then support the patient with CPR as required, maintaining hemodynamic and respiratory functions.

Indications: This block can be used for surgery involving the distal upper arm, the elbow, forearm and the hand.

Wrist Block

Anatomy: The median, ulnar, and radial nerves can be blocked superficially with the wrist extended and the landmarks located. See Fig. 3 to identify the proximal crease, which will help identify the location of the ulnar artery, palmaris longus tendon, and the radial artery, which are all landmarks to identify their corresponding nerves.

Technique: Median nerve can be blocked by placing the needle between the palmaris longus and flexor carpi radialis tendons, the two large tendons in the middle of the wrist on the flexor surface. 5 ml of LA can be placed in this groove. The ulnar nerve can be blocked by injecting 5 ml of LA just medial to the palpation of the ulnar artery, and the dorsal branch by adding 5 ml of LA in a ring fashion around the ulnar aspect of the wrist. The radial nerve can be blocked by placing 5 ml of LA just lateral to the radial artery palpation, and the small branches can be blocked by adding 5 ml of LA to the area of the "snuff box" just around the extensor side of the dorsum of the hand in a superficial manner. See Fig. 4 and Fig. 5.

The total dose of the LA in this manner would be 25 ml of 1% lidocaine with or without adrenaline. One should never give a ring of LA around the entire circumference of the wrist.

Complications: intravascular injection or injection directly into the nerve.

Digital Block

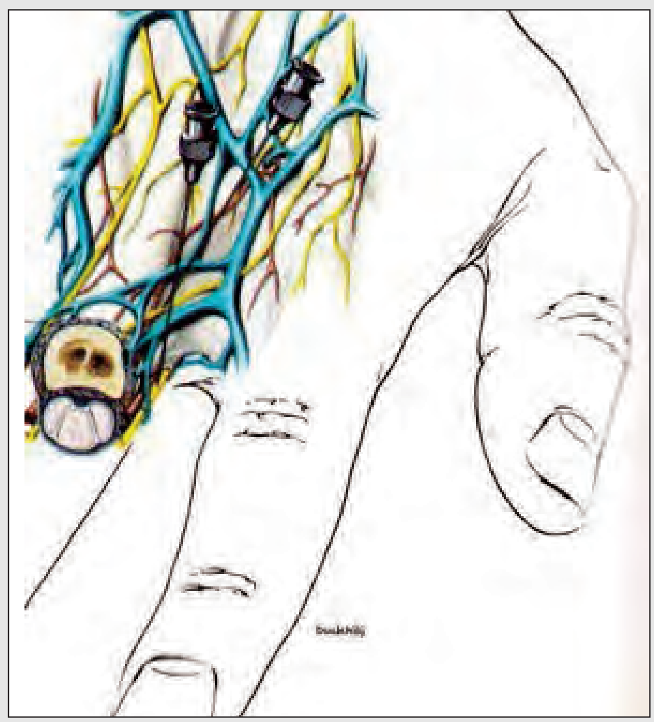


Fig. 6

From Fig. 38, *Illustrated Handbook of Local Anesthesia*, p. 50 (Courtesy of Ejnar Erikson).

Anatomy: Each finger is supplied by four branches, two dorsal and two palmar, which run on each side of the finger or toe. At the base of each finger, the nerve can be reached with a short, 22 gauge needle. See Fig. 6.

Technique: At the base of the finger, make a deep injection of 1 ml of LA, always without adrenaline, and then 1 ml of LA superficially. This process should be repeated on both sides of the finger, or toe. The syringe should be aspirated before injection to avoid intravascular injection.

Editor's Comment—as a hand surgeon, I block the fingers through the web space with a short 25 gauge needle. I attempt to place the LA slightly volar through the web space, aiming just to the side of the flexor tendons. This will also block the dorsal branch of the digital nerve. For the lateral side of the thumb, I follow the instructions above for the volar digital nerves. There are additional branches from the radial sensory nerve, and these must be blocked with 1-2 ml. of LA on either side of the extensor tendons to the thumb.

Complications: The only potential complication is rare. It would be if too great a volume of LA was given, which would then prevent perfusion to the finger and, secondarily, if one were to give LA with adrenaline, that could also prevent perfusion to the end of the finger and thus complications. Otherwise, this is a very safe block and useful for surgical procedures on the finger or toe. Recent studies (Am. Journal of Hand Surgery, September 2005) have shown no long-term ischemia/necrosis in fingers where adrenaline has been given in the usual low dose concentration, 1:100,000, found in commercial 1% lidocaine with adrenaline. It usually takes 6 hours for the finger to return to the same color as non-injected fingers. If phentolamine (epinephrine antagonist) is also used, the finger returned to normal in 1 ½ hours.

Intravenous Regional Block or Bier Block

Anatomy: This block can be performed in the arm or the leg and provides anesthesia for about 2 hours. Local anesthesia is injected into the veins,which are then under pressure with a tourniquet proximal to where the drug was injected. The LA will diffuse out of the venous system and into the surrounding nerves which provides anesthesia in the area under pressure from the tourniquet. This block does not block a specific nerve but the nerves in the forearm and hand generally.

Technique: See Fig. 7 for the visual of performing this block. A 22 gauge IV catheter is placed in the hand of the extremity that is desired to be blocked in a distal position. A second IV is placed elsewhere in the body, so that you can have access in the case of complications and for IV fluids. The extremity that is to be blocked must be elevated and the blood removed with an Esmarch bandage as seen in the diagram and a tourniquet inflated on that arm before removal of the bandage. Then with the tourniquet still inflated, 40 ml of lidocaine 0.5% without adrenaline can be injected. **NEVER inject <u>bupivacaine</u>** as this can kill the patient. The **length of the tourniquet insufflation must be more than 45 minutes** so that the toxic impact of the local anesthesia agent is minimal. (If one places a separate tourniquet below the first tourniquet that was inflated, then when the patient experiences pain from the first tourniquet, the second, **more distal** tourniquet can be inflated. This second tourniquet

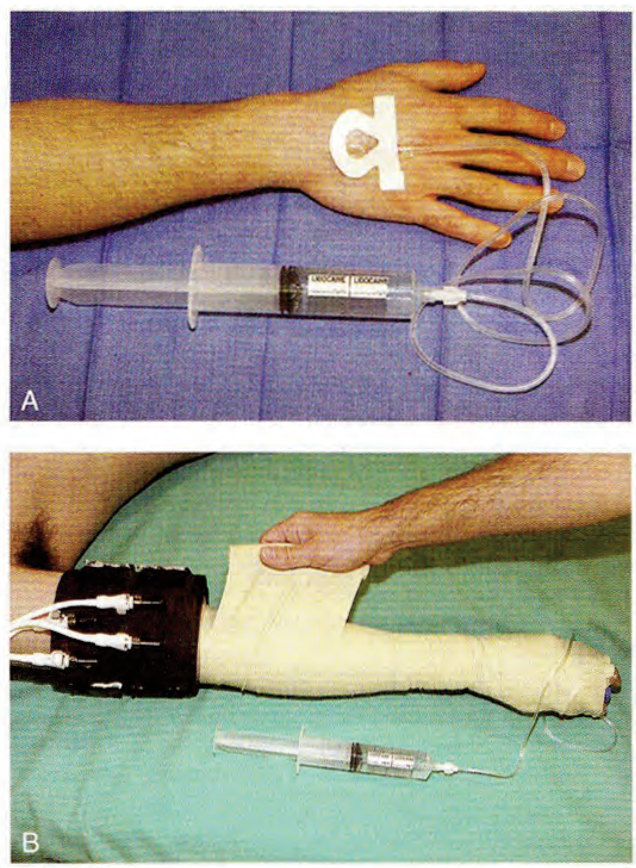


Fig. 7

From Fig. 18-20, *Basics of Anesthesia*, p. 289, Stoelting (Courtesy of Elsevier).

is in an area that has been anesthetized, and the patient will then no longer experience "tourniquet pain." The first tourniquet can now be slowly deflated. Be sure the second tourniquet is inflated before deflating the first, more proximal tourniquet.)

Complications: This is a block with minimal side-effects if the technique is followed appropriately, and the tourniquet stays inflated for more than 45 minutes. If the surgery lasts less than 45 minutes, then leave the tourniquet inflated for the 45 minutes, and then release the tourniquet slowly allowing for the local anesthetic to be distributed without toxicity. Anytime the tourniquet is deflated, the patients should be observed for signs of impending seizures within the first few minutes.

If the tourniquet fails, and drug enters the blood stream in a high dose, then one must manage the airway and cardiovascular system with oxygen, airway, fluids, and vasopressors to keep the blood pressure normal as in any toxic injection of lidocaine.

(**Editor's comment**: This is an excellent block for **hand** surgery. The editor will often place the tourniquet on the forearm—over tendons and not muscles. In this way, there will not be as much ischemic muscle pain and the patient will not experience discomfort as quickly from the tourniquet.

This block will last 1.5 hours, especially if one uses two tourniquets as described above and if the patient is sedated. There are double Bier Block tourniquets available commercially, but these are expensive. BP cuffs may be used but may not be reliable. If a BP cuff must be used as a second tourniquet, then the tubing should be clamped to ensure that the cuff does not deflate accidentally during the surgery.

If the surgeon realizes during the case that it will last longer than expected, then the patient will need further sedation and a local wrist block or digital block anesthetic may be given before the release of the tourniquet.)

Lower Extremity Block

The vast majority of lower extremity surgery can be performed with a spinal block. This will not be described in detail in this section, since it is a common block performed in many urban and rural hospitals in Africa. Primarily, you must remember the contraindications to performing a spinal anesthesia. The following would be the common contraindications: hypovolemia, shock, infection at the proposed site of injection in the back, low platelets, patient on anticoagulants such as aspirin and heparin, and increased intracranial pressure.

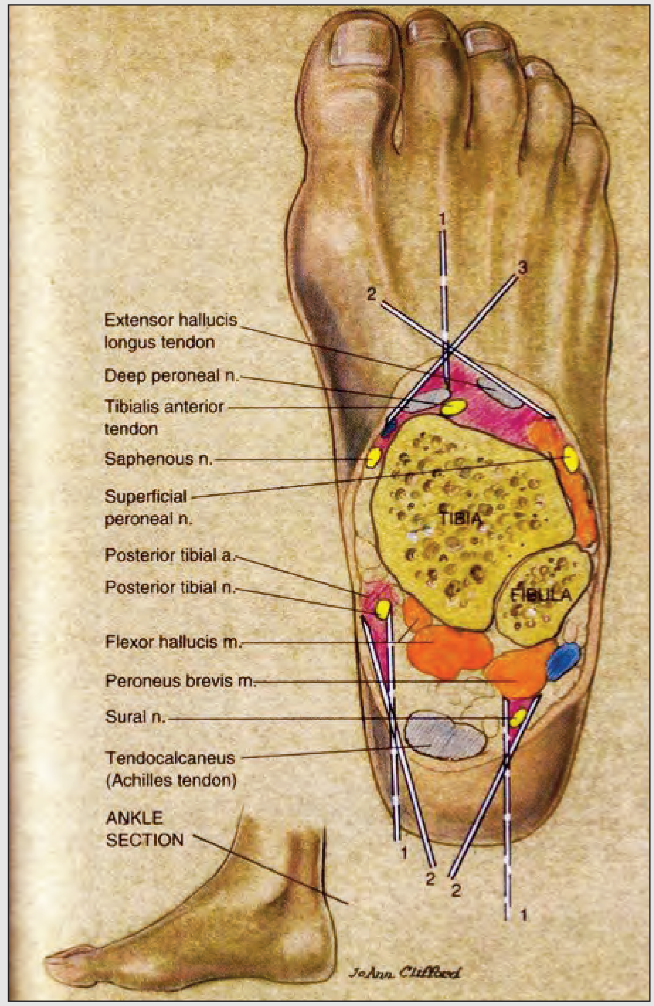


Fig. 8

From Fig. 18-18, *Basics of Anesthesia*, p. 288, Stoelting (Courtesy of Elsevier).

Ankle Block

Anatomy: There are five nerves that supply the foot for plastic procedures below the medial malleolus. See Fig. 8, which shows the nerves and their location in the ankle. The five nerves are: the sural, posterior tibial, saphenous, deep peroneal, and superficial peroneal. Each nerve can be blocked by placing 5 ml of local anesthesia drug next to the nerve. If the patient experiences pain that is severe and lasting when the needle is placed, remove the needle so that an intraneuronal injection is not made which can be damaging to the nerve.

Complications: Very few, if the local anesthesia drug is not injected into the nerve or intravascularly. Regular aspiration of local anesthesia drug prior to the injection of the drug, will prevent the vast majority of intravascular injections and thus severe complications.

Ketamine

Ketamine is a "dissociate anesthesia" drug that seems to separate the activity of the brain with the body. In doing so, you have a patient who seems excited and makes strange noises, but has pain control for a surgical procedure. The patient appears to be awake but is, in essence, under a level of anesthesia. The drug is unique in that it stimulates the sympathetic nervous system, thus producing a rise in heart rate and blood pressure, and acts as a bronchodilator that is good for patients with asthma. This drug can be used for sedation for minor procedures, for induction of anesthesia and for a continuous infusion of the drugs used for total anesthesia. The drug is unique also in the sense that it can be given IV, IM, and even orally. The most common negative side-effects of the drug would be excessive secretions and hallucinations or delirium. These two side-effects can be treated with atropine (for the secretions) and benzodiazepine drugs as valium and midazolam (Versed®), which will treat the hallucinations.

The drug can be given for induction: 1-2 mg/Kg IV with an onset of less than 10 seconds; 4-8 mg/kg IM with an onset of 3-5 minutes; and by continuous infusion for total anesthesia or for a supplement to another anesthetic plan at 15-30 mcg/kg/min. The addition of atropine and valium should be given at the beginning of the case for good impact. The patient will develop tolerance to ketamine, so you will need to monitor the response to the dosing that has been given in the past. Some patients who have been given the drug many times over a short period may need even 4-8 mg/kg IV for initial dosing required procedures, such as daily dressing changes. Ketamine has a wide "therapeutic window", which means even if you give a slightly high dose, the patient will still usually have spontaneous ventilation. The one risk would be adding a narcotic to the ketamine. When you give ketamine you do not need to add a narcotic, since the ketamine is a very strong analgesic and there is no need to add narcotics.

Bolus ketamine IV could be given every 5 minutes based upon the patient's response and even IM every 10 minutes based again on the patient's response. The patients can develop a tolerance to the drug so that the second and third time the drug is used on a patient in a period of less than 2 weeks, you may need to give larger doses. The continuous infusion of the drug needs to be stopped 10-15 minutes prior to finish time.

Basic Tracheostomy Care for the Plastic Surgical Postoperative Patient

Tracheostomy tube placement in plastic surgery in the African setting will be necessary at times, especially when the postoperative care is not able to manage an endotracheal tube that becomes dislodged. Extensive surgery in the face and neck areas can lead to extensive postoperative swelling that would then make the emergency placement of an endotracheal tube impossible, or at least very difficult, and this placement could affect the surgical repair. The placement of a tracheostomy tube will not be discussed, but some general guidelines for care and complications will be mentioned in this section.

Tracheostomy Care

1 Humidified oxygen should always be used, even if the patient does not have an oxygen requirement, since it keeps the newly placed tracheostomy tube without thick secretions and secondary obstruction.

2 One should place non-absorbable sutures in each side of the trachea and tape these to the neck/chest. If the tracheostomy tube is dislodged, these sutures may be pulled up to re-insert the tube.

3 The tube itself must be secure with a tie, such as umbilical tape or thick string, and checked every 8 hours for the first 72 hours post tracheostomy placement.

4 Dry dressing must be used and changed every 6 hours, as necessary, for 72 hours, and the area cleaned with a bactericidal agent with each dressing change.

5 Suctioning done with a sterile catheter set using sterile gloves, which can be reused for the same patient. At times, 5 ml of sterile water can be used to assist in suctioning the secretions. An

Ambu bag can be used to force the fluids distally followed by suction. Obstruction of the trach tube is the primary concern with the placement of a trach tube. Always have a suction machine available for potential problems with the trach tube.

6 The trach tube should not be electively removed until the track is formed, usually after 7 days. If the trach tube becomes dislodged, use the sutures to pull up the trachea so that the tube can be replaced with confirmation of breath sounds. **You must remember that you can always use the Ambu bag and mask, if the tube does not work or gets displaced, as if you never had a trach in place. Do not forget this aspect of trach care.**

7 **Always have an Ambu bag and suction available** to maintain the patency of the trach during the first 7 days until the track is formed.

Complications

1 Bleeding, pneumothorax, air embolism, emphysema, and cricoid damage with placement of the trach tube.

2 Placement in the right main stem due to the length of the tube

3 **Blockage with secretions. This is the most common complication.** This can be early or late, but with humidification and suctioning, this will be decreased.

4 Infection.

5 Damage to the trachea due to the cuff pressure or the tip of the tracheostomy tube. If the trach tube has a cuff, make sure that the cuff pressure is not above 20 cm H2O pressure. You will need to take the air from the cuff every 48 hours, and do not add more that 5 ml of air or water in the cuff to avoid post-trach stenosis in the trachea.

6 Dislodgment of the trach tube, which can be difficult to replace in the ward setting or ICU.

Conclusion

This chapter which includes basic regional anesthesia and post tracheostomy guidelines will assist the plastic surgeon working in an African context with less infrastructure but more advanced pathology. This is a challenging area of medicine with huge rewards, as you care for some of the most disfigured people in the world, and you can have a safe and immense impact on this patient population. Most complications of regional anesthesia can be prevented with good preparation and appropriate dosing regimens, since an overdose with some of these drugs can be tragic in a limited resource setting.

Chapter 6

Facial Trauma and Reconstruction

Tertius H. J. Venter

Soft Tissue Injury of the Face

Facial injuries, per se, are seldom life threatening, but can certainly be a serious threat to the victim's immediate and future physical and emotional well-being.

Apart from the obvious functional consequences that can potentially result from a facial injury, there are breathing, mastication, speech, and vision deficits that need to be addressed. Aesthetic restoration of the face is an important goal, since the greater the facial deformity, the greater the social disability. Severe facial deformities can lead to near total social isolation for the patient due to rejection by society. This is as true for citizens in the most modern cities of the world as well as for those in the deepest jungles.

The facial tissues are unique in shape, texture and color. A particularly unique feature in its anatomy is the close association of the skin with the underlying muscle architecture which constitutes the unique combination of function, facial expression, and aesthetics. Whenever possible, local tissue should be used for repair and reconstruction. Local reserves are certainly available. (E.g. a lower lip can be repaired with direct closure, even when up to a third of the lip is lost, or with upper lip tissue loss, the lower lip can be utilized for reconstruction [i.e. Abbé flap].) To use tissue from distant sites is the last resort, but sometimes the only option with major tissue loss.

Facial injuries often occur in isolation, and can be dealt with under controlled circumstances and at an appropriate time for an optimum outcome. But these injuries can also present as part of major head and neck trauma, or in the multiple trauma patient with concomitant head injury, trauma to the airways, chest injuries, or other injuries causing major blood loss. These vital organ and system injuries, by their nature, demand priority over facial injuries; however, facial injuries should be treated definitively as soon as feasible, preferably within the first 6 hours, and certainly within the first 48 hours. If the closure is delayed because of major trauma, then antibiotic therapy would be indicated.

Patients that present late (after 48 hours) will need debridement and then closure once the wound is clean.

Fig. 1

Fig. 2

Fig. 3

Injuries from a motor vehicle accident. Initially the eyelids could not be identified, as they had been avulsed from the lateral canthus. As the wounds were closed from the edges, the eyelids were finally identified, and the lateral canthus was reattached to the inside of the lateral orbital rim. Very little tissue was lost and very little needed to be debrided. Fig. 2 is one week later, and Fig. 3 is two weeks later. The patient was able to slightly open the left eye on discharge. The arrow in Fig. 1 points to the eye.

An Approach to Facial Injury

It is important to remember that once a muscle is cut, it will retract because of its inherent muscle tone. Facial skin is attached to the underlying muscle (panniculus carnosus) for facial expression, so it retracts as the muscle retracts, and the defect often appears to be much larger than the actual tissue deficit. The elasticity of the dermis also pulls the wound apart.

Whether or not general anesthesia is used, lidocaine with adrenalin/epinephrine 1:100,000 local infiltration should be used, both for pain control and for wound edge vasoconstriction that facilitates visualization. The surgeon should wait at least 7 minutes after infiltration for effective vasoconstriction. The wound is then cleaned and carefully assessed before approximating wound edges. Traumatic flaps must be rotated back to their original position, very much like fitting the pieces of a puzzle together. Usually, it becomes apparent that there is little to no actual tissue loss when the wound is closed, though the perceived loss was initially great, due to muscle retraction. Wounds are carefully sutured in layers, with care to close muscle fascia, deep dermis, and epidermis. It is very important to put in buried deep dermal sutures prior to the superficial skin sutures. If there is tissue loss, then immediate flap closure with local tissue may be possible if the acute wound is clean. If not, staged washouts and debridements are indicated until the wound is clean. Then, either flap reconstruction or skin grafting can be done. The elastic facial skin is quite mobile, and even large defects can usually be closed primarily or with local flaps. Skin grafting is rarely necessary.

If the repair cannot be done within the first 12 hours due to other systemic injuries, it is appropriate to treat the patient with an antibiotic, such as amoxicillin-clavulanate (Augmentin), which covers the oral flora as well as Staphylococci. With gross contamination or doubtful tissue viability, the aim should be to acutely debride and repair the wounds within the first 48 hours after injury. If the wounds are badly contaminated, crushed, or presenting outside the first 48 hours, the wounds should be debrided and dressed with a moist dressing with plans to return to the operating room within 48 hours for further cleaning and debridement. When clean, the wound should be closed or reconstructed with local or distant flaps or skin grafts. Delayed primary closure should be

Fig. 4

Fig. 5

Injuries from a motor vehicle accident (before and after), treated by careful debridement, approximation of all tissues, and composite graft from ear to alar rim.

Fig. 6

Fig. 7

6) Injuries from motor vehicle accident after repeated debridements.

7) After local muscle/periosteal flap and split skin graft

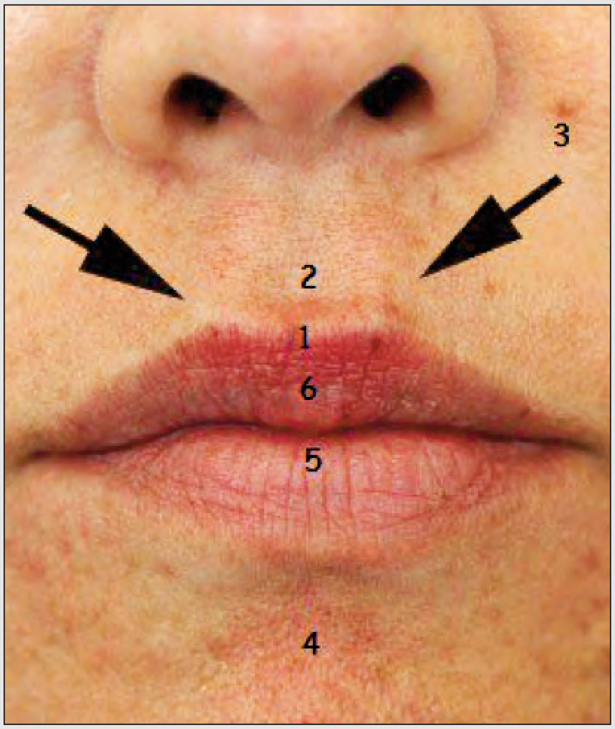


Fig. 8
Lip Anatomy

Arrows: Philtral Columns; 1) Cupids Bow; 2) Philtral Dimple; 3) Naso-Labial Fold (superior section); 4) Curved Mental Crease; 5-6)Vermillion (red part of the lip); and 6) Tubercle of the upper lip

carried out before seven days (see chapter 2). In the closure of complex facial injuries, as the case seen in Figs. 1-3, one should start the closure at the periphery and then suture toward the center of the wounds.

Soft-tissue trauma may vary in degree of severity, but can be categorized as contusion, abrasion, puncture, laceration, avulsion, or accidental tattoo. **Contusions**, **abrasions**, and **puncture wounds** can usually be managed by cleansings and protective dressings. If a **hematoma** is apparent, it should be evacuated and not allowed to resorb. **Retained foreign bodies** and **accidental tattoos** require removal of the embedded foreign material. The exception to this is **metal fragments from missiles**. Bullets or missile fragments are usually sterile and commonly penetrate deeply; more harm is done to the tissues with attempts at removal than from leaving them in place.

After wound cleansing and irrigation, simple lacerations are treated by primary closure. When wound edges are beveled, or when there is obvious devitalized tissue, appropriate debridement is performed. Sharply beveled wounds containing vital skin for closure should be closed in one layer. It is difficult to place deep dermal sutures and line up the wound edges. Most facial wounds should be managed with very conservative debridement. The questionably viable facial tissue will often survive because of the excellent blood supply of the face. Unnecessarily aggressive debridement may result in the loss of vital soft tissue needed for repair. It is important that soft-tissue repair is done with careful attention to the symmetry of facial features. Tissue should always be returned to its position of origin.

A **traumatic avulsion flap** occurs from an undermined laceration; its blood supply restricted to its skin attachment. If the flaps are small, they can be totally excised. Larger avulsion flaps should be preserved if possible. The thinnest peripheral portions of the flap should be excised to form perpendicular edges and the flap sutured in position. This should be done even if the viability of the flap is not certain—a final decision can then be made post-operatively with serial examinations.

When anatomical approximation is not possible because of tissue loss, coverage by skin grafts or flaps would be necessary and done as a primary surgical procedure when the wound is clean.

When a defect is relatively small, and the base is clean, a **full-thickness graft** can be a good option for coverage, with elastic properties, thickness, and color closely resembling adjacent skin. Full-thickness grafts are usually taken from areas close to the face and where the donor site can be closed primarily such as the pre- or post-auricular areas, upper eyelid, and supraclavicular area. When small defects cannot be closed, local flaps rather than skin grafts should be used, if available. **Split-thickness grafts** are used for defects with a less than ideal recipient bed, as thin grafts tend to vascularize more readily, but will result in greater graft contraction and poorer color match. These are rarely used on the face.

Flaps are used where more bulk is required for contour, or if bone is exposed. These can be:

- Rotation advancement.
- Transposition.
- Direct or tubed pedicle.
- Island pedicle.

- Free direct transfer (microvascular anastomosis).

Reconstruction of Different Anatomical Areas of the Face

I. Reconstruction of the Lip, Oral Commissure, and Cheek

The lips are important for oral competence, articulation, expression of emotion, sucking, and playing various musical instruments. The lips are also important sensory organs, in that they provide pleasure and protect the oral cavity from ingestion of unacceptably hot or cold materials.

Functional and aesthetic restoration of deformed parts is, therefore, very important, and the aims of reconstruction in the lips and cheeks are both for the restoration of form and reinstitution of function. This often involves the repair of several layers of missing tissues, and, if lost, the need for reconstruction to achieve a good final result.

The external landmarks of the lips are the philtral columns and interposed philtral dimple extending from the columella of the nose down to the Cupid's bow at the central upper vermilion border. The central portion of the upper lip has a central tubercle. The upper and lower lips are joined laterally at the commissures. The upper lip is set apart from the surrounding cheek by the naso-labial fold; the lower lip is divided from the chin by a curved mental crease. (See Fig. 8 for anatomical diagram.) The naso-labial and mental creases are important to facial aesthetics and afford locations for camouflaging scars.

The lower lip has no structure at its center or shape to draw attention to asymmetry, unlike the upper lip. The lower lip can sustain a loss of one-third of its breadth before tightness or asymmetry begins to show.

In contrast, the symmetry of the upper lip, derived from Cupid's bow and its symmetry in relation to the nose, is important to consider in repair and reconstruction. It is only possible to close small defects without producing a cosmetic deformity sufficiently obvious to be unacceptable. The upper lip in the normal face also protrudes in front of the lower lip, and any post-excisional tightness which reduces or eliminates this normal relationship is not acceptable.

The lower lip can be used as a source of tissue to reconstruct the upper lip. In the case shown in Figs. 9-10, an Abbé flap can be used later for secondary reconstruction of upper lip midline. See under Abbé flap below.

The lips have a rich blood supply. Each lip has an artery that consistently runs parallel to the margin.

Fig. 9

Fig. 10

9) Central upper lip loss.

10) After full thickness v-excision, direct closure could only be done as the defect was exactly in the center and this did not disturb the symmetry of the lip.

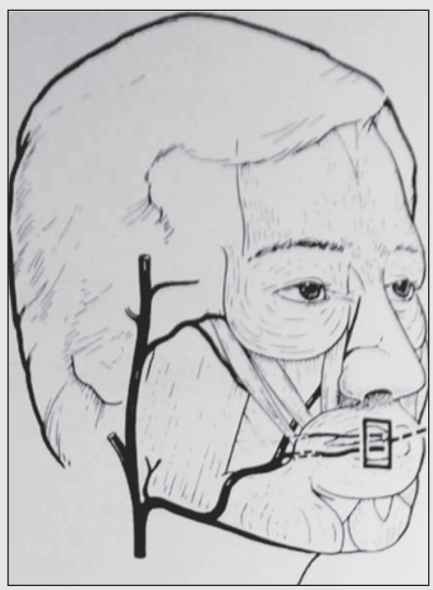


Fig. 11

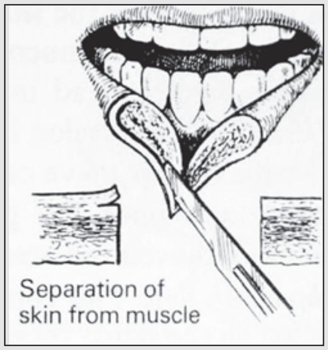
Fig. 12

11) Labial Artery –branch of the facial artery.

12) Note the position of the labial artery on the oral side of the lip.

(From Rob and Smith, *Operative Surgery—Plastic Surgery*, Elsevier. Used by permission.)

This artery arises from the facial artery on each side and anastomoses to the other in the mid-line (Fig. 11). The labial arteries lie between the orbicularis muscle and the mucous membrane at the level of the junction between ordinary skin and the red margin-mucocutaneous line (Fig. 12). These vessels make it possible to transfer large sections of the lip on a pedicle that contains little more than the vessels themselves.



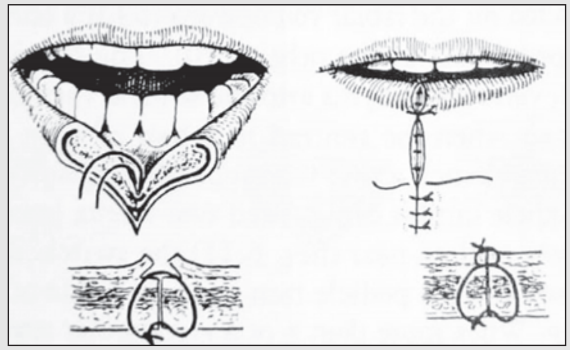


Fig. 13 **Fig. 14**

Repair of lower lip in three layers.

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1) **Loss of Lower Lip Tissue**

If less than a third of the lower lip is lost, direct closure in three layers can be done (mucosa, muscle, and skin) without significant functional or aesthetic consequences. In significant but partial thickness loss of less than a third of the width of the lip, the best result is often achieved by converting the defect into a full thickness defect by a full thickness V-excision and direct repair in layers similar to the central upper lip defect repair above.

Fig. 15 **Fig. 16**

15) One-third of lower lip missing from human bite.

16) Wedge resection and direct closure, with short advancement flaps from both sides.

- **Cheek Advancement Flaps**: If more than one-third of the lower lip is lost, the least complicated and very effective reconstruction is the Karapandzic flaps shown in Figs. 17-18.

- **Karapandzic Flaps**: These flaps are full thickness lip advancement flaps that also preserve the nerves. Karapandzic flaps may be taken from one side or both sides to close lower lip defects with

Fig. 17 **Fig. 18**

Karapandzic flaps.

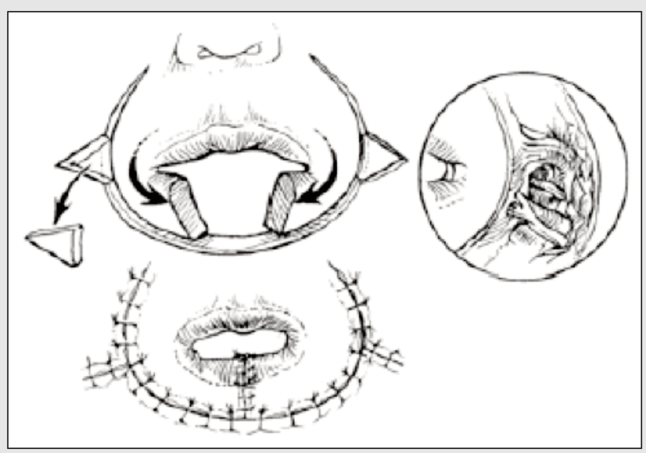

Fig. 19

Karapandzic flaps.

(Fig. 17-19 courtesy of Dr. David Chang)

Fig. 20

Fig. 21

Fig. 22

Squamous cell carcinoma of the lip, with resection and wide reconstruction with Karapandzic flap.

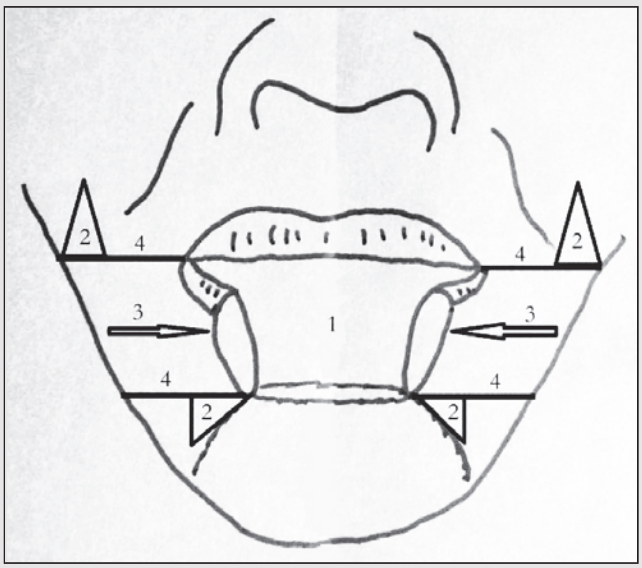

Fig. 23

1) Defect lower lip; 2) Burow's triangles to be excised–triangles might be rather large depending on the elastic properties of the cheek skin and only skin needs to be excised to protect the branches of the facial nerve; 3) Cheek advancement flaps; 4) Flap incisions along straight black lines.

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like tissue. The incisions are full-thickness up to the commissure/angle where they become superficial to the muscles to preserve the nerves and labial vessels (See right hand view in Fig. 19). It can be further extended into the upper lip along the nasolabial folds. This is an excellent reconstruction as it preserves continence and the orbicularis muscle. The stoma is smaller, but it will expand over time, and eating will not be a problem. Reverse Karapandzic flaps with partial upper lip reconstruction is also possible.

Fig. 23 shows another method of mucosal advancement and vermillion reconstruction, with relaxing incisions around the chin, excision of lateral triangles—Burow's triangles—and cheek advancement.

2) Loss of Upper Lip Tissue

- **Partial Thickness Defects:** These can be managed either by using a skin graft only or a local flap. The graft is taken from the pre- or post-auricular area for color and texture match—these grafts will not contract, and the contour of the lip will be maintained. It will not grow hair, however, which can be a problem in the male patient.

  Local flaps are usually transposition or

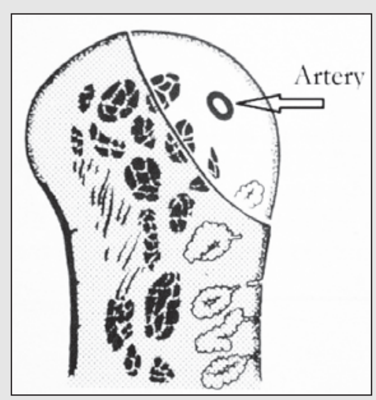


Fig. 24

Note the position of the artery on the **oral** side.

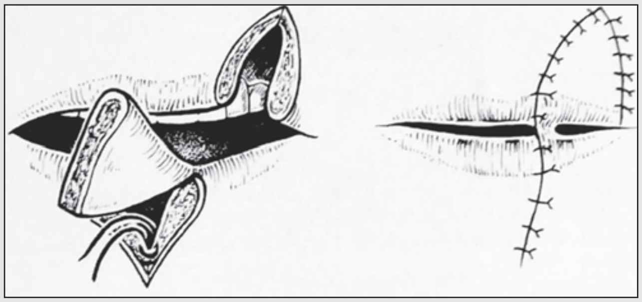


Fig. 25

The Abbé flap. The pedicle is divided after 3 weeks.

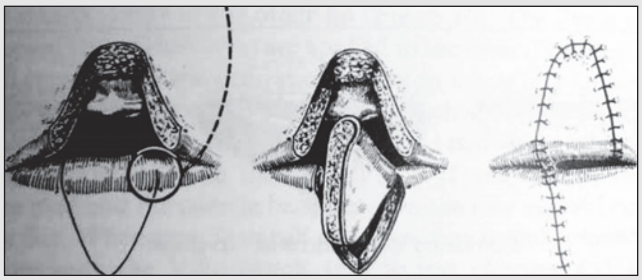


Fig. 26

Midline defect.

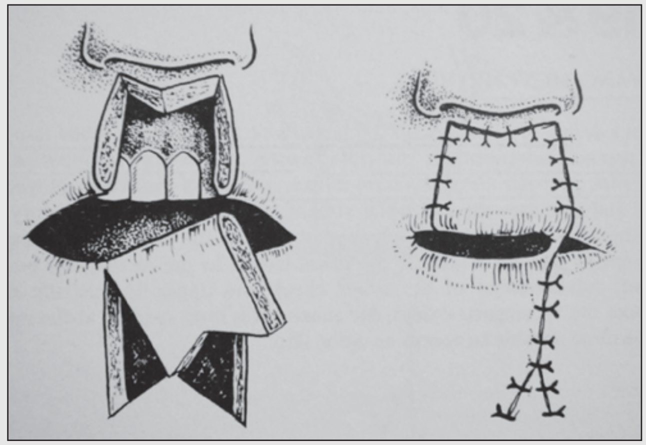


Fig. 27

W modification for better animation.

(Fig. 24-27, Rob and Smith, *Operative Surgery—Plastic Surgery*, Elsevier. Used by permission.)

naso-labial skin flaps (mostly superiorly based). The naso-labial fold usually has adequate skin, and the donor area can be closed directly, with the resultant scar well camouflaged in the naso-labial fold (see description under "Reconstruction of the Nose" section).

- **Full Thickness Defects:** The simplest procedure is a V-excision and repair, but it is less satisfactory and limited to relative small defects (<1cm) for the reasons of noticeable asymmetry, as has been pointed out. Flap repair is therefore often necessary, of which the most common is the Abbé flap.

Less than One Third Loss of Upper Lip

- **The Abbé Flap**
  One-third of the full thickness of the lower lip can be excised without increasing its tightness excessively, and this makes the lower lip available for reconstruction of the upper lip. With its structure corresponding almost perfectly to any defect of the upper lip, it is ideal for the purpose. The lack of significant anchorage of the lower lip from angle to angle also means that a triangle of

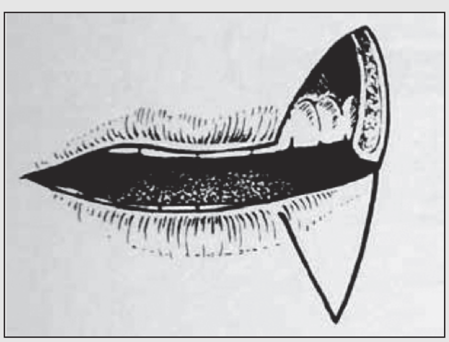


Fig. 28

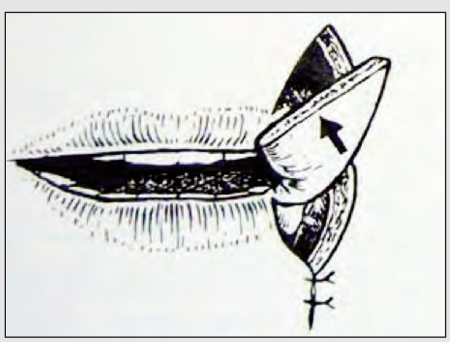


Fig. 29

Fig. 30

The Estlander flap. No pedicle to be divided after 2-3 weeks, but often needs a secondary commissure reconstruction (Z-plasty) to correct the round appearance at the angle of the mouth.

(Rob and Smith, *Operative Surgery—Plastic Surgery,* Elsevier. Used by permission.)

Fig. 31
Estlander Flap in noma patient.

lip required for a particular part of the upper lip can be taken with little or no regard to the symmetry of the lower lip.

A useful modification is to design the flap as a "W" (Fig. 27) and then fitting it into the philtral area of the upper lip with the nostril floor above. A W-defect on the lower lip can be closed easily.

The flap is rotated through 180° and sutured to the upper lip defect. It is very important to make sure that the feeding labial artery is not caught by the sutures in the pedicle of the flap.

- **Estlander Flap**
  The Abbé flap does not include the corner (commissure) of the mouth, while the Estlander flap does. They are the same except that there is no pedicle that needs to be divided after 2 to 3

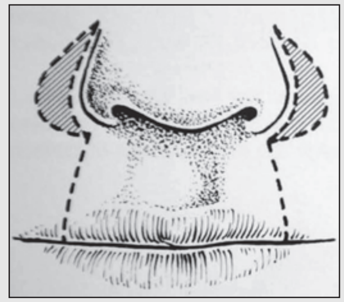


Fig. 32

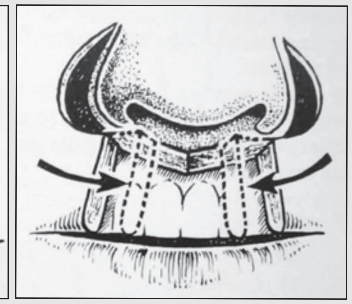


Fig. 33

32) Bilateral advancement flaps excising Burow's triangles, curvilinear ellipses (striped areas above).

33) Advancement of flaps.

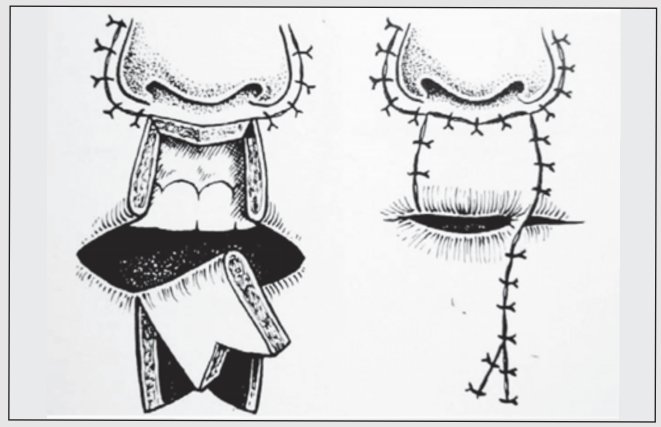


Fig. 34
Reconstruction completed with an Abbé flap.

(Fig. 32-34 from Rob and Smith, *Operative Surgery—Plastic Surgery*, Elsevier. Used by permission.)

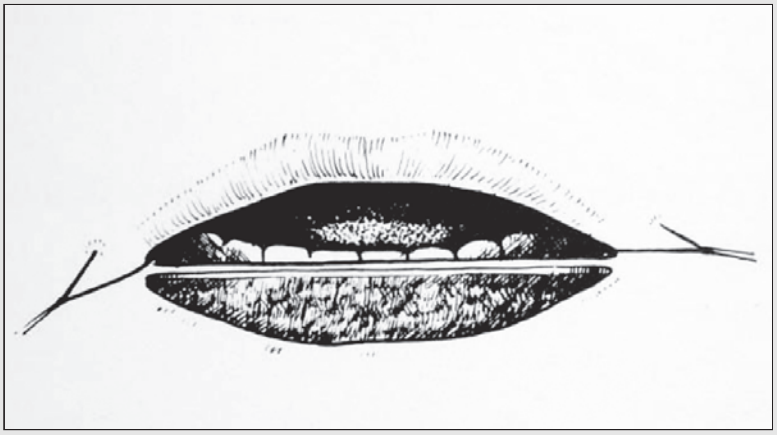
Fig. 35

Fig. 36

Fig. 37

Fig. 38

Lip hemangioma widely excised in a young girl. Reconstructed with Burow's triangles bilaterally, modified reverse Karapandzic flap on the right side, and Estlander flap on left. Fig. 38 was taken at 3 months postoperatively.



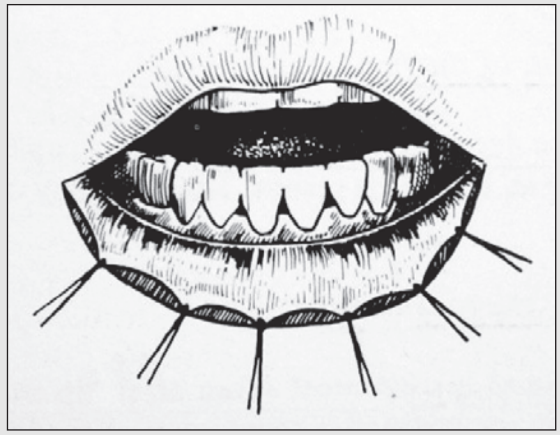


Fig. 39 **Fig. 40**

39) Vermillion loss; 40) Intra-oral mucosal advancement (lip peel with mucosal slide).

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weeks, as in the Abbé flap.

- **More Than One Third Loss of Upper Lip**
  A combination of local bilateral advancement flaps and lower lip flap (Abbé Flap) is necessary to reconstruct these large defects.

  With complete or near-complete loss of the upper lip, a distant flap is often the only option.

3) Vermillion Tissue Loss
Vermillion defects smaller than 1 cm^2 will often close by secondary intention with minimal scarring. Larger defects need repair.

- **Mucosal Advancement—Vermillion Reconstruction (Lip Slide)**
  Mobilization of a mucosal flap from the inner surface of the lip is in the natural (and relatively avascular) plane between the submucosa and the muscle, so that the minor salivary glands of the lip are mobilized with the mucosa. The sutures, braided absorbable 5/0 (e.g. Vicryl®) sutures, are evenly spaced along the suture line so that tension is distributed evenly. Partial width defects need cover with the appropriate size flap—these usually need two vertical side release cuts the width of the flap on the intra-oral surface.

4) The Angle of the Mouth
Most defects in the region of the angle are actually of one or the other lip that, though they extend to the angle, do not actually involve the other lip. If the angle of the mouth is lost and both upper and lower lips involved, it will demand a rather complicated reconstruction to recreate the angle. The best way to approach this is to ignore the angle initially and concentrate on the reconstruction of the upper and lower lip separately. Once this is done, attention is turned to the angle of the mouth to consider different options depending on the residual defect (this reconstruction is beyond the scope of this chapter, but may be found in major plastic surgery texts). A simple *z*-plasty in the commissure and correct positioning at approximately the mid-pupillary line (and also symmetrical to the contralateral commissure) will achieve much.

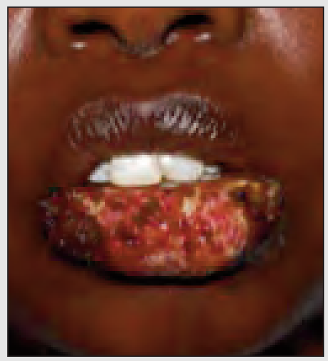
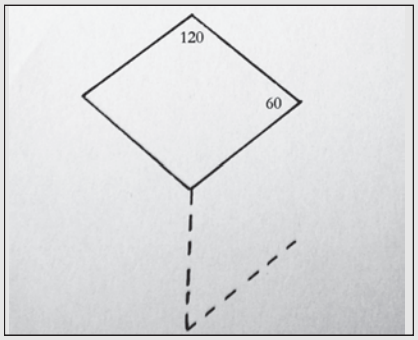


Fig. 41 **Fig. 42**

Premalignant mass involving vermillion of lower lip: mass excised with lip shave and mucosal advancement. Mucosa undermined into sulcus so it could be advanced to the vermillion border. Muscle not involved. (Courtesy Dr. Bill Rhodes)



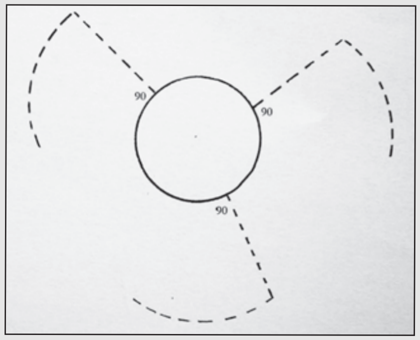


Fig. 43 **Fig. 44**

43) Rhomboid flap

44) Modified "rhomboid" flap with multiple flap position options

5) Reconstruction of the Cheek

In injuries of the cheek, the underlying structures, which are the facial nerve, facial muscles, parotid duct, and bone, must always be a conscious concern. The facial nerve and parotid duct will be discussed separately later in this chapter.

Most partial thickness defects can be covered by full thickness skin grafts or local flaps. The most useful local flap is the rhomboid (Limberg flap) or modified 'rhomboid' flap (defect and flap are designed in a "round" fashion instead of as a rhomboid shape that allows one to position the flap anywhere around the defect).

In larger defects, a cervical or cervicofacial flap (Mustardé flap) might be necessary (see Fig. 48). Full thickness defects will need inner 'mucosal' lining; a simple split skin graft on the deep surface of the flap is often all that is needed. A defect of 1-2 cm2 does not need a graft on the intra-oral surface, as it will rapidly re- epithelialize. A platysma flap is an option for mucosal reconstruction. This is a thin myocutaneous flap, as seen in the noma reconstruction shown in Figs. 48-49 (note arrow). The patient had trismus from bony

Fig. 45 **Fig. 46**

Wound edges cut on periphery and turned in to form intra-oral lining. Defect closed with modified "rhomboid" flap/round flap from submental area.

Fig. 47 **Fig. 48**

Wound edges cut on periphery and turned in to form intra-oral lining. Defect closed with modified "rhomboid" flap/round flap from submental area.

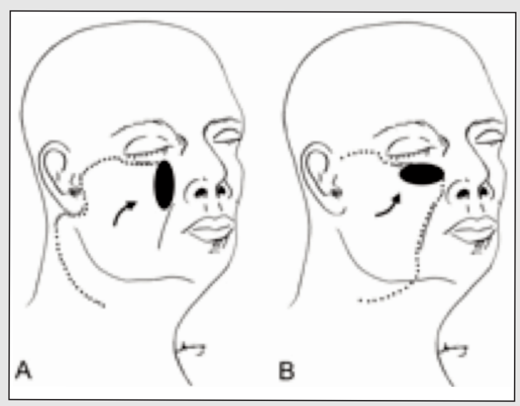


Fig. 49

Cervicofacial flap (Mustardé Flap). If this flap is used, bone anchors (if available) should be used to anchor the flap to the zygomatic arch and orbital rim. This flap is used for large cheek defects. The incision extends into the neck. (Courtesy Dr. David Chang)

Fig. 50

Fig. 51

Fig. 52

50) Gunshot wound, years before; 51) after first stage reconstruction with platysma flap for oral mucosa and forehead flap for cheek/lip; 52) After second stage Estlander flap on left side.

First stage: reconstruction of GSW involved using a platysma turnover flap for mucosal reconstruction, forehead flap for cheek and lip reconstruction (distal end of forehead flap split for both upper and lower lips), and TMJ release bilaterally. Second stage: use of Abbé-Estlander flap for corner of mouth. Fig. 52 is taken soon after second stage (see also chapter 16 on noma reconstruction).

block—mandible to maxilla. A deltopectoral flap was used for cheek reconstruction.

6) Complex Reconstructions

Some injuries are unpredictable, such as a gunshot wound or an animal bite. If seen acutely, they can be irrigated, debrided, and closed primarily. This was the case with the buffalo injury in Figs. 53-54.

Gunshot wounds (GSW) are treated initially with irrigation, debridement, and delayed primary closure. Often they will be seen for reconstruction years later. Figs. 50-52 show a case that involved multiple operations over several years.

II. Reconstruction of the Nose

The nose's prominent position on the face places it at risk for frequent trauma. If these deformities are not adequately managed at the time of injury, they may result in distorted appearance and nasal obstruction from the loss of tissue, misalignment of normal structures, and later from subsequent scarring.

The nose consists of a skin, subcutaneous fat, and muscle envelope. The support structure, composed of cartilage (lower third of the nose) and bones (upper two-thirds of the nose), gives the nose its shape. An inner mucosal lining filters particulates and exchanges heat and moisture.

Fig. 53

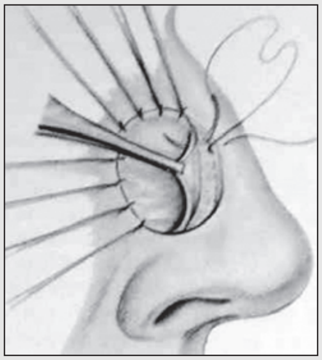
Fig. 54

Cape buffalo injury; required repair of near complete tongue laceration and ORIF of mandible and MMF.

General Principles of Repair

Partial-thickness defects of the upper two-thirds of the nose (above the sebaceous gland-bearing area) most often only need a full-thickness skin grafts, unless large areas of bone or cartilage are exposed.

Partial-thickness defects of the lower third of the nose can be reconstructed with a composite graft or resurfaced with local or naso-labial flaps.



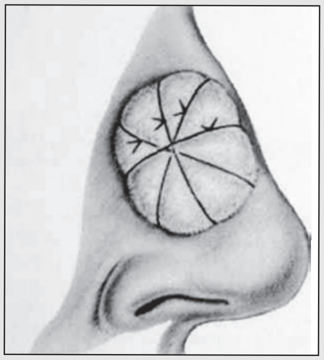


Fig. 55 **Fig. 56**

55) Full thickness skin graft sutured in position; 56) tied over with a "bolus" dressing.

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- **Composite grafts**: for small partial and full thickness defects of the alar rim (see Figs. 4 and 5). The donor site is the auricle (Fig. 57) and can include fat, cartilage, or both depending on the need. The rounded ear rim makes a good graft to reconstruct the rounded alar rim. Composite grafts undergo progressive changes during the process of revascularization. After an initial dead-white color, the graft turns pale pink between 6 and 24 hours due to erythrocyte invasion. By approximately 24 hours, the graft becomes cyanotic from venous congestion, which gradually disappears over a period of 3-7 days to become a healthy pink color. It is more difficult to observe these changes in darker pigmented skin. For composite grafts to take, the recipient bed must be ideal. In general, any tissue more than 0.5 cm away from the nearest vascular bed will not predictably survive. Therefore, a composite graft used in a full-thickness defect must not exceed 1.0-1.5 cm when the only vascular contact is the periphery of the wound. In reconstructing the alar rim, it helps to enlarge the vascular bed by turning down a flap on the wound margin to be used for nasal mucosal lining, and the composite graft can be correspondingly thinner, increasing the surface area in relation to the volume and enhancing vascular contact.

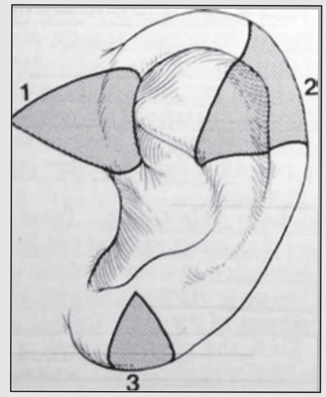


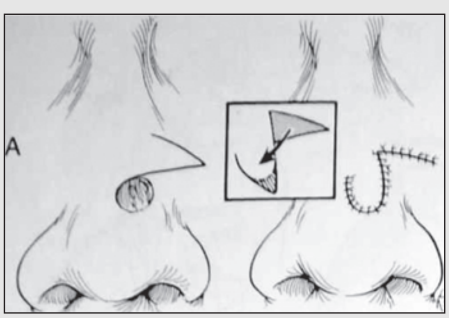
Fig. 57

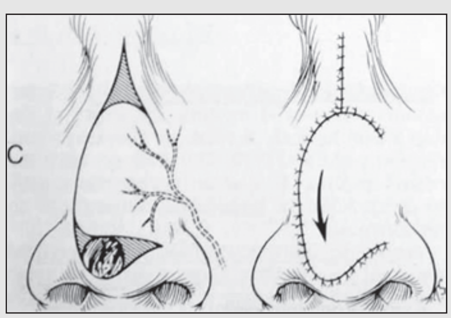
Donor areas for composite grafts.

- For small full-thickness defects, the naso-labial flaps, banner flaps, and dorsal nasal flaps provide excellent reconstructive material; larger full-thickness defects are best repaired with flaps from the forehead. See **Flap Repair of the Nose** below. Distant flaps are used only if these are not available.

Flap Repair of the Nose for Partial or Full Thickness Defects

The successful relocation of tissue from one body site to another requires adequate blood supply for the viability of the flap. Flaps for nasal reconstruction usually come from residual nasal tissue, adjacent cheek, forehead, temporal scalp, or distant tissue.





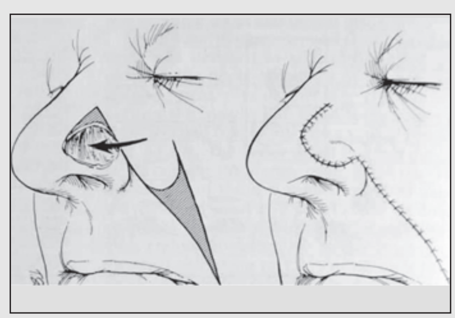


Fig. 58 **Fig. 59** **Fig. 60**

58) Banner flap; 59) Dorsal nasal flap; 60) Naso-labial flap.

(Figs. 57-60 courtesy Georgiade, *Essentials of Plastic, Maxillofacial and Reconstructive Surgery*, Lippincott, Williams, and Wilkins. Used by permission.)

Fig. 61

Fig. 62

61) Full thickness alar defect; 62) Naso-labial flap repair.

Local Nasal Flaps for Lower Third of Nose

- The **banner flap** is a horizontal triangular flap based at the margin of the defect and rotated into a vertical position. The donor defect is closed directly by advancing the dorsal nasal skin. The mechanism of tissue movement involves standard rotation around a 90° axis to close the donor site along lines of relaxed skin tension. Based ipsilateral to the defect, the banner flap suffices for small defects up to 1.2 cm while based on the contralateral side of the nose, defects measuring 1.5-2.0 cm in diameter may be closed with minimal secondary asymmetry of the nasal tip.

- The **dorsal nasal flap** is used to repair larger defects of the nasal dorsum by using the redundant skin in the glabellar area. The flap is based on the angular vessels in the nasolabial fold and consists of the downward rotation of the entire skin of the nasal dorsum. Vertical closure in the glabella completes the transfer. The flap gains maximum arc when designed on the contralateral angular vessels sufficient for coverage of defects 1.5-2.0 cm. The dorsal nasal flap is usually based above the alar crease and will not reach the columella without causing secondary distortion of the nasal tip.

- **Flaps from the Cheek—The Nasolabial Flap**. The nasolabial tissue is elevated as a subdermal skin flap and can either be utilized as a transposition or advancement flap. Alternatively, it is advanced as a subcutaneous vascular island. Approximately 2.5-3.0 cm of redundant tissue is available in the cheek for reconstructive use in the nose.

- It can be based either inferiorly or superiorly; the superior pedicle technique is most useful. The flap may be designed to border the junction of the lateral ala with the cheek, preserving the nasofacial crease. The superiorly based flap is a good method of reconstructing defects of the alar wing and lateral lobule. When made longer than the distance to the defect, it can be thinned and folded onto itself for the nasal lining.

Flaps from the Forehead for Larger Defects and Upper Two-Thirds Defects

- **Glabellar Flap—Technique for the Mid-Line Forehead Flap**: The flap is rotated through 180° when it is transferred, and care must be taken to

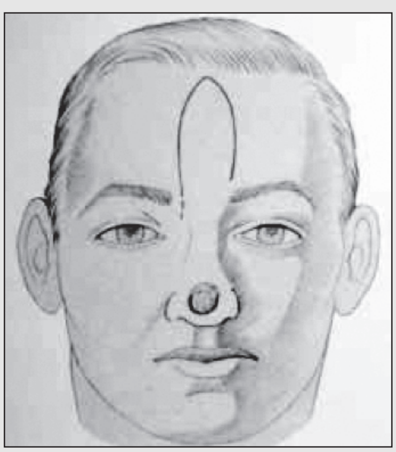


Fig. 63

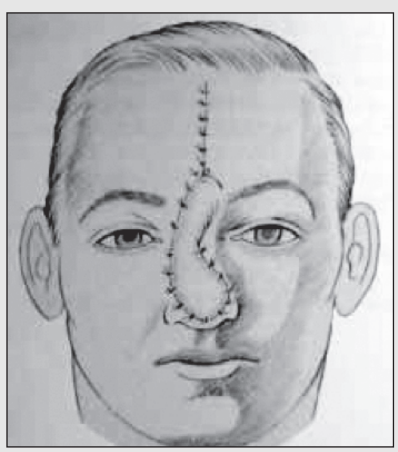


Fig. 64

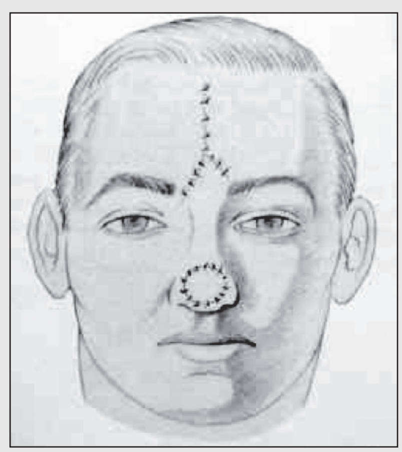


Fig. 65

63) Glabellar flap or mid-line forehead flap; 64) Flap rotated and sutured; 65) Division of flap and inset at three weeks.

(Rob and Smith, *Operative Surgery—Plastic Surgery,* Elsevier. Used by permission.)

ensure that it is sufficiently long to reach its destination without any tension at the pivot point. Flap width can be no more than that which will permit primary forehead closure, unless more complicated repair techniques are to be employed—usually not more than 2 cm.

The mid-line flap is carried on either one or both supratrochlear arteries (and distal extension of the angular arteries); these must be protected where they enter the flap in the glabellar area. The superior part of the flap is raised above the periosteum. **At the base of the flap in the glabella area, the periosteum is taken with the flap for 1-2 cm. above the supraorbital rim to ensure the blood supply is taken with the flap. The base of the flap should be no wider than 1.5 cm**. It is rotated into the defect, properly trimmed, and sutured in place with subcutaneous (deep dermal) 5/0 absorbable sutures and 5/0 nylon to approximate skin. The forehead defect is closed directly and in layers

The pedicle can be divided at approximately 2-3 weeks after the initial procedure. The proximal margin of the transferred portion is trimmed and sutured in position. The base of the pedicle is trimmed and sutured back into the surgical defect in the glabellar area (see Fig. 65). If a large flap is needed, the donor site in the upper forehead may be allowed to close by secondary intention, which works well with little scarring. When repairing or reconstructing large nasal defects, defatting of the flap is carried out 10-14 days after the initial surgery to contour the flap. A week later the flap may be divided.

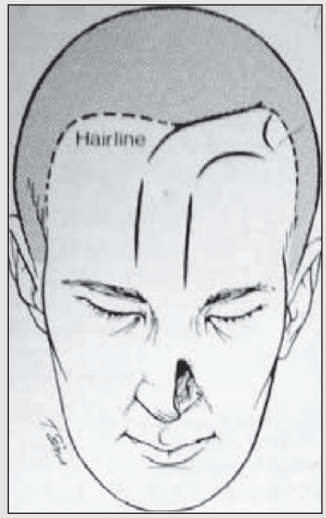


Fig. 66

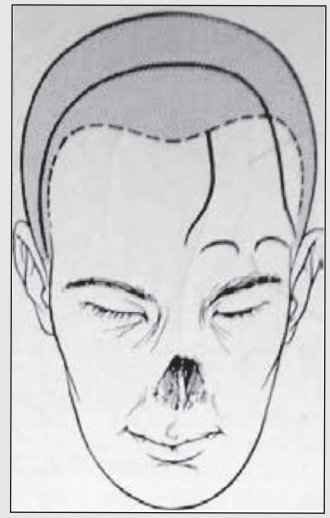


Fig. 67

66) Forehead flap based on the supratrochlear vessels; 67) Forehead flap based on the temporal vessels.

(Georgiade, *Essentials of Plastic, Maxillofacial and Reconstructive Surgery*, Lippincott, Williams, and Wilkins. Used by permission.)

(**Editor's note**: This is also an excellent flap to reconstruct the nose. For inner nasal lining, the flap can be turned over so the forehead skin becomes nasal mucosa. Lateral forehead skin based on the contralateral superficial temporal vessels can be used for skin cover.)

- **Flaps from the Forehead and Temporal Area:** Axially vascularized flaps from the forehead and temporal scalp can be based upon either the supratrochlear or the superficial temporal vessels. In patients with generous foreheads, the flap can

Fig. 68

Fig. 69

Fig. 70

Traumatic nose injury: reconstructed with turnover flaps for nasal lining and forehead flap be designed in a straight vertical line. For those with low hairlines, obtaining adequate flap length while avoiding hair-bearing skin may be a problem. For this situation, the design has been modified to angle the flap laterally along the hairline. Greater length may be acquired by extending the pedicle dissection into the glabellar area. It is important to protect the supratrochlear vessels near the base of the pedicle and close to the periosteum. As stated above, the dissection in the glabellar area should be subperiosteal, taking 1-2 cm of periosteum above the supraorbital ridge. Even the angulated flaps can be safely transferred. The vascular pedicle can be divided at a second stage and the glabella portion replaced on the forehead.

Procedures that base the flap on the superficial temporal vessels have been designed to avoid central forehead scarring. The upper lateral forehead skin is elevated based on the contralateral superficial temporal vessels, and the scar is essentially hidden by the hairline. Sufficient skin for total nasal coverage may be made available by this technique; the resulting forehead defect usually requires skin grafting. A tissue expander may be used later to expand normal skin so that the skin graft can be removed.

III. Reconstruction of the Eyelids

Effective and early treatment of eyelid injuries is important to preserve the vital functions of the eyelids: protection of the globe, prevention of drying, and appearance.

Repair of full-thickness eyelid lacerations must include repair of the conjunctiva, the tarsal plate, and the skin. The lash line or gray line is used as the guide to ensure proper alignment of the lid margin with the repair. The eyelids are composed of skin, areolar tissue, orbicularis oculi muscle, tarsus, septum orbitale, tarsal (meibomian) glands, and conjunctiva. At the lid margin, the conjunctiva meets the skin at the gray line. Embedded within the margins of the lids are the hair follicles of the eyelashes. The tarsal plates support and give form to the eyelids and keep the conjunctiva in apposition to the globe.

The zygomatic branches of the facial nerve (CN VII) innervate the orbicularis oculi muscle for eyelid closure, while the oculomotor nerve (CN III) innervates the levator muscle that elevates the upper lid for eyelid opening.

The lacrimal gland is located in the upper outer margin of the orbit and produces tears that flow across the surface of the cornea toward the medial canthus, where they enter the superior and inferior puncta. The canaliculus is situated approximately 2 mm perpendicular to the lid margin before turning medially toward the lacrimal sac and naso-lacrimal apparatus, and from there draining into the nose through the inferior meatus.

Eyelid wounds may either be partial thickness or full-thickness and may be with or without tissue loss. Eyelid skin is very elastic, and what may appear to be tissue loss may actually be due to the significant retraction of the wound edges.

The primary purpose for early repair or reconstruction of the deficient eyelid tissue is to provide cover for the sclera and cornea. The cornea is responsible for visual acuity, and is very sensitive to drying and abrasion. Normal motion of the upper eyelid is responsible for wetting of the cornea, as well as protecting it from trauma.

The lids are also important aesthetically. The eyes are the focal point of the face. The shape of the lid can be seen from a distance while scars are usually visible at conversational distance. It is important to reconstruct the shape and motion of the lid as close to normal as possible.

Reconstruction of Partial Thickness Injuries

No tissue loss. Injuries caused by glass or cutting objects may run in any direction.

- If the wound lies in the line of the fibers of the underlying orbicularis muscle, a continuous 6/0 intradermal monofilament non-absorbable suture may be used.
- If the wound lies across the line of the orbicularis fibers, there will be retraction of the wound edges and an interrupted 6/0 monofilament non-absorbable sutures should be used to close the skin wound.
- If the underlying orbicularis muscle has been cut across its fibers, it must be repaired with interrupted 6/0 absorbable sutures. The skin sutures are removed in 3-5 days.

Partial-thickness loss of tissue is best treated by application of a skin graft. When the defect is on or

Fig. 71

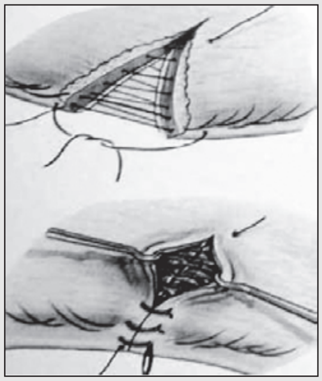


Fig. 72

Full thickness eyelid laceration, and repair in layers.

(Courtesy of http://emedicine.medscape.com/article/868651-treatment#a1133)

close to the lower lid, in the medial canthal or the lateral canthal regions, or in the pre-tarsal area of the upper lid (the region immediately superficial to the tarsal plate), a full-thickness skin graft should be inserted—post-auricular skin as it is most suitable because of its color, texture and thickness.

Full-thickness skin grafts should be cut to fit the defect so that edge-to-edge apposition is obtained, and there should be no overlapping of graft edges with subsequent necrosis. The graft must put on the stretch, leaving the sutures long and 'over-tying' them under slight tension across a pad of moist cotton wool—a bolus/stent dressing. These sutures are removed in five days, and the graft left open. It is probably wise to suture the upper and lower lid together (temporary tarsorrhaphy) to limit eyelid movement in the first five days and to allow suturing of the graft under stretch. Horizontal mattress sutures are placed through the skin and out through the “gray” line on each side, and one or two are used.

In the upper lid above the pre-tarsal zone, a split-skin is used as split skin is supple and will produce the normal eyelid fold more readily than the full-thickness skin graft.

Reconstruction of Full Thickness Injuries

Full-thickness injuries of the eyelids caused by cutting instruments are usually in an oblique direction because the lids are protected from vertical slashes by the prominent eyebrows and cheeks. The underlying cornea is at risk for damage and should always be carefully examined with a drop of 1 percent fluorescein, if available.objects may run in any direction.

The essential requirement in closing a full-thickness wound of the eyelid is to re-align the divided tarsal plate. If this alignment is carried out accurately, there will be no deformity of the lid's margin, but if it is incorrectly carried out, a deformity will result, regardless of the precision of the remaining repair.

The two edges of the tarsal plate and its underlying layer of conjunctiva are carefully approximated using a 6/0 interrupted absorbable suture. A separate 6/0 monofilament non-absorbable suture is inserted exactly in the gray line on each side to give accurate approximation of the margin. The rest of the wound is closed in two layers: the orbicularis oculi (absorbable suture) and skin (monofilament non-absorbable suture). The skin sutures are removed in 3-5 days.

Canaliculus Damage and Repair

An attempt must be made at the time of injury to locate the divided medial end of the canaliculus, which usually is identified as a pale structure, if normal saline is used to cleanse the wound. A 1 mm silicone tube is passed via the punctum and the peripheral part of the canaliculus into the medial opening and into the lacrimal sac. The tube is sutured along the lid margin, and the conjunctiva is closed with 6/0 absorbable suture. A permanent 5/0 nylon suture is used to approximate the medial end of the tarsal plate to the medial canthal tendon. If this is not done, the powerful action of the

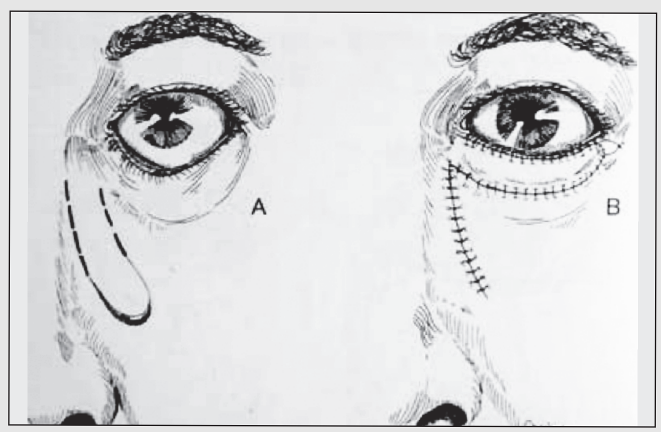


Fig. 73

Nasolabial flap.

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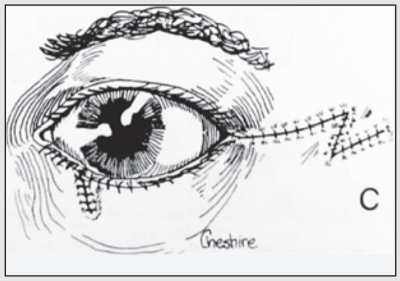

Fig. 74 **Fig. 75**

Lateral cheek flap with lateral canthotomy (cantholysis).

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orbicularis oculi will drag the lid laterally, and the scar will stretch considerably. The rest of the closure is done as described above. The tube is left in place for six weeks, and after that, gentle weekly probing will help keep the repaired canaliculi patent. At least 60 per cent of these repaired canaliculi will remain patent. Fine gauge silicone tubing and loupe magnification are required to perform this repair. If this equipment is not available, repair should not be attempted. This tubing is commercially available, and is manufactured with a probe attached to both ends that can be passed from both upper and lower canaliculi into the lacrimal sac, and then down the nasolacrimal duct into the nose. The two ends of the tubing are then tied together so they will not retract. This is the ideal method if the tubing and metal probes are available. This system is called Guibor Canaliculus Intubation Set® in the U.S.

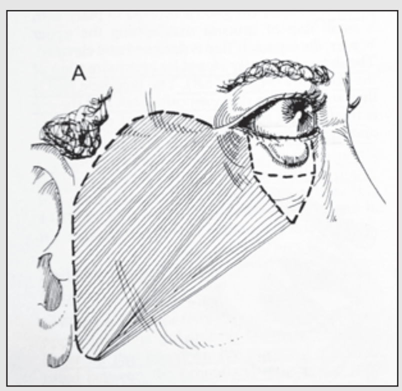
Local Flaps in Eyelid Reconstruction for Full Thickness Injuries

- **The Naso-Labial Flap:** A high, superiorly based naso-labial flap is a versatile and often used method of reconstruction of the lower lid. It may be anchored at the lateral canthus by sutures, or bone anchors if available.

  The chief disadvantage of the naso-labial flap is that the thick skin gives an abnormal appearance because it lacks the supple and delicate attributes of eyelid skin. When necessary in large defects, however, the naso-labial flap is reliable and easy to use.

  The technique involves raising a flap of properly measured size, with care to maintain a relatively thick amount of tissue at the base to preserve the blood supply. The distal portion may be thinned to dermis. The tip of the flap may be anchored into the lateral canthal tendon at its periosteal insertion, giving added support. Further defatting may be carried out six months later.

- **Lateral Cheek or Temporal Skin Flaps:** With full-thickness injuries and tissue loss of the lid margin, primary closure should be the goal. Primary closure is possible for defects of up to one-third of the original lid margin, especially in older patients with greater tissue laxity. Closure is performed by placing 6/0 non-absorbable sutures at the gray line, matching up the lid edge. An absorbable suture is used to close the tarsus, which brings the conjunctival edges together. If there is excessive tension, a lateral canthotomy (cantholysis) may provide the necessary relaxation. The canthotomy is an incision through the lateral angle of the eyelid which



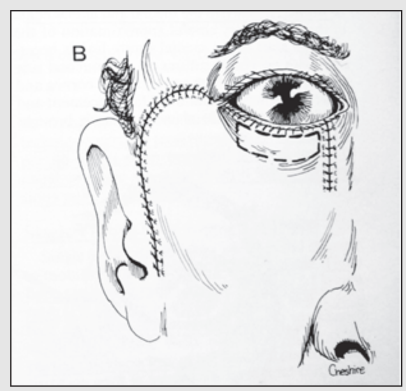


Fig. 76 **Fig. 77**

Lateral Cheek Flap (cervicofacial flap) with chondromucosal graft. This is taken from one side of the nasal septum, leaving the mucosa intact on the opposite side (See plastic/ENT textbooks or Google the procedure).

(Georgiade, *Essentials of Plastic, Maxillofacial and Reconstructive Surgery*, Lippincott, Williams, and Wilkins. Used by permission.)

divides the lateral canthal tendon and allows mobilization of the lower lid (see Figs. 74-75).

An incision is made horizontally, from the lateral canthal angle with dissection down to the periosteum of the lateral orbital rim, severing the inferior crura of the lateral canthal tendon. The skin is undermined and assessed as to how much cheek skin will be needed. If a small amount of relaxation is needed, then simple undermining and advancement may be done. If a larger amount of skin is needed, then a back-cut may be performed to allow better mobility. This is closed with a Z-plasty. This approach also gives the lateral incision an upward sweep, enhancing the support of the lower lid.

Fig. 78

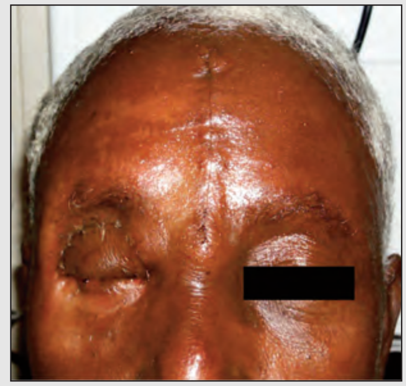


Fig. 79

Complete partial thickness loss of the upper eyelid and loss of the eye. Thick tunneled glabellar island flap utilized to improve appearance.

With much larger lid defects, a larger cheek flap (commonly known as a Mustardé flap) may be indicated together with a septal chondromucosal graft (Figs. 76 and 77). Design of the cheek flap is important, with the lateral sweeping incision in the temporal area in a curvilinear manner to the pre-auricular area as far down as the lobule. The level of dissection is in the subcutaneous fat, and care must be taken to avoid damage to the branches of the facial nerve that run on the surface of the facial muscles. It is necessary to make a V-shaped cut to complete triangulation of the lower part of the defect to prevent a "dog-ear," from forming. To prevent sagging, this flap should be anchored to the zygomatic arch and orbital rim with bone anchors or sutures (preferably wire sutures).

- **Glabellar Flap for Eyelid Reconstruction:** If the previously described techniques are not available, a mid-line glabellar flap or median forehead flap based on the supratrochlear vessels can he used to reconstruct the upper or lower eyelids, or both with a split flap, and also defects in the medial canthal area. The skin in this location is thicker than eyelid skin and should be used only if other procedures are not feasible.

- **Lid-Sharing Techniques:** Lid-sharing procedures can be utilized to reconstruct full thickness eyelid defects very similar to the Abbé flap of the lips.

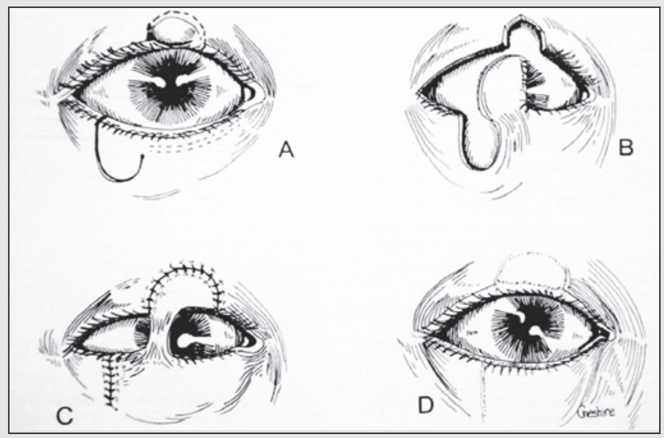


Fig. 80

Lid-sharing flap.

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- **Dissection of Flaps:** A full thicknesses lower lid flap should be dissected using scalpel and scissors, taking care not to approach closer to the margin in the area of the hinge than 5 mm, to preserve the comparatively large arcade of marginal vessels running 3 mm from the margin. The defect in the lower lid is closed in three layers. Pulling the base of the lid flap into position will allow the flap to lie in the upper lid defect without tension on the hinge. The flap is sutured into the upper lid in three layers; conjunctiva, orbicularis muscle and skin. A dressing is not necessary. The vascular pedicle can be divided two weeks later and the eyelid margins revised.

Defects of more than half the lid length
Where a defect exists which is greater than half of the width of the eyelid, the secondary defect created will not close directly, as it is over a quarter of the normal lid length, and the remaining lid tissues will not stretch to this extent. A cheek flap of suitable size is outlined and undermined, as described in lower lid reconstruction (limited Mustardé-like flap).

In very large upper lid reconstructions, it will be impossible to locate the lower lid flap on the lateral side of the pedicle, because it would encroach on the check. In such cases, it should be retained on the medial side of the pedicle hinge.

Two and a half weeks later, the pedicle is divided and the lid margins revised. The punctum and canaliculus of the lower lid should be protected in all stages of this procedure.

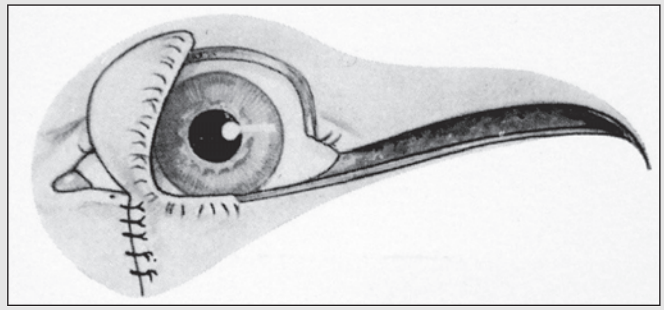

Fig. 81

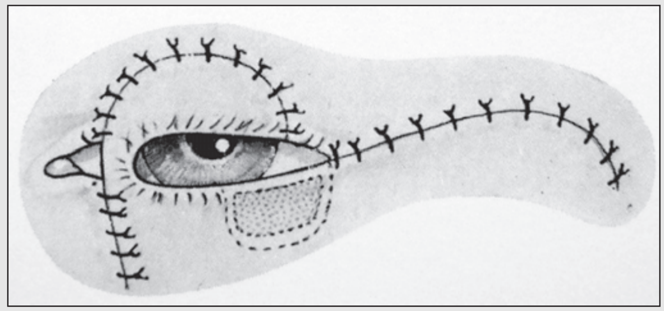

Fig. 82

81) Lateral release (cheek flap) in large defects.; 82) The pedicle is divided after 2.5 weeks Note: the chondromucosal graft is often necessary and taken from nasal septum.

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IV. The Facial Nerve

In wounds of the cheek, damage to the facial nerve is of primary concern, and the function of the five different branches must be specifically examined.

The facial nerve exits the stylomastoid foramen. It divides into five main branches within the substance of the parotid gland. The temporal branches run over the mid-section of the zygomatic arch, and the buccal branch travels over the masseter, along with the parotid duct, at the level of a line from the tragus to the center of the upper lip. The mandibular branch runs below the inferior border of the mandible, but not more than 2 cm, and then crosses the mandibular border anterior to the facial artery and vein. The frontal, zygomatic, and buccal branches are at particular risk from cheek lacerations. The buccal branches usually have some interconnections, and, therefore, a laceration of a single buccal branch may not be clinically apparent. Furthermore, injuries medial to the lateral canthus will almost without exception recover spontaneously.

The function of facial nerve branches should be tested before administration of local anesthetics. Some patients will exhibit asymmetry in facial movement simply because of pain and edema, and it may not be related to any underlying facial nerve injury.

Facial nerve injuries should be primarily repaired. Surgical exploration with loupe magnification (2.5 – 3 x), good lighting, and hemostasis will assist in locating the cut ends of the nerve. A nerve stimulator, if available, can be used to locate the distal nerve segments within 48 hours of injury. After 48 hours, the distal nerve segments will no longer conduct an impulse to the involved facial musculature. If the proximal ends of the facial nerves cannot be located, the uninjured proximal nerve trunk can be located and followed distally to the cut end of the nerve, as in a superficial parotidectomy.

The nerves should be repaired primarily with 6-0 to 9-0 nylon. One should use the smallest suture which adequately maintains the nerve coaptation (that is, the smallest suture you have available that you can see!) If primary repair is not possible, nerve grafts (sural nerve or post auricular nerves are good donor sources) should be placed, or the proximal and distal nerve ends should be tagged with non-absorbable suture for easy location during later repair. As mentioned, primary repair is best, and primary nerve grafting is advisable if the patient is stable. Most often one can find local donor nerves for grafting, as the post auricular nerve. (**Editor's note:** It is much easier to see and repair the facial nerve acutely or within the first 24 hours.)

V. The Parotid Gland and Duct

The parotid gland is a single-lobed gland with superficial and deep portions, determined by their relation to the facial nerve running between them. The superficial part of the gland is lateral or superficial to the facial nerve and extends anteriorly to the border of the masseter. The parotid duct exits the gland anteriorly and passes over the superficial portion of the masseter, penetrating the buccinator to enter the oral cavity opposite the upper second molar. The course of the parotid duct may be visualized on the external face by locating the middle third of a line drawn from the tragus to the middle of the upper lip. The parotid duct travels adjacent to the buccal branches of the facial nerve. If buccal branch paralysis is noted in conjunction with a cheek laceration, parotid duct injury should be suspected.

If parotid duct injury is suspected, a 22-gauge catheter may be inserted into Stensen duct, and a small quantity of saline or methylene blue solution can be injected. If blue discoloration of the fluid in the wound is noted, the diagnosis of parotid duct injury is confirmed.

Laceration to the substance of the parotid gland without duct injury may result in a sialocele, an accumulation of saliva, but will rarely cause any long-term problems. If a gland injury is suspected, the overlying soft tissue should be repaired, and a drain left in place. If a sialocele develops, serial aspirations and a pressure dressing should be sufficient to resolve the problem.

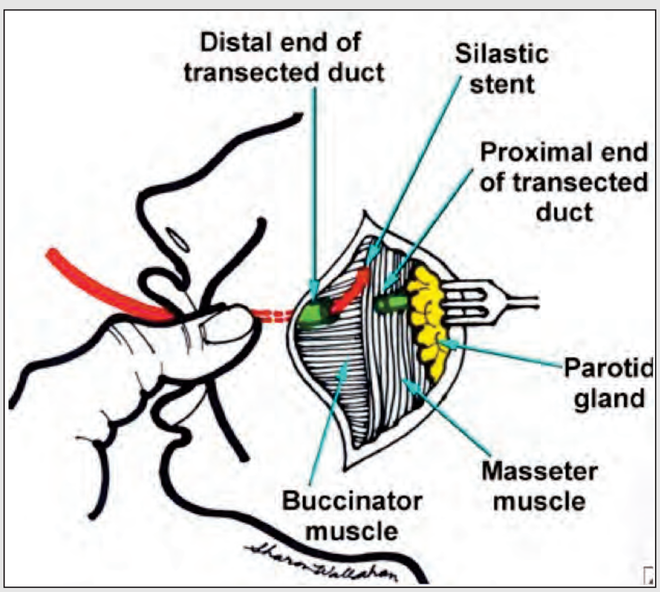

Fig. 83
(From http://emedicine.medscape.com/article/868651-treatment#a1133)

Three operative techniques have been debated: repair of the duct over a stent, ligation of the duct, and fistulization of the duct into the oral cavity.

The facial wound is often extensive enough to allow adequate visualization of the structures and their repair, but further exploration of the parotid gland and duct might be necessary.

The most important initial step is the identification of the buccal branches of the facial nerve and the parotid duct itself. If the buccal branch was transected, repair it with a 6-0 to 9/0 nylon suture and with magnification if available.

Repair of the parotid duct is done over a silastic stent with interrupted sutures, using loupe or microscopic magnification. The duct is sutured into the cheek mucosa near the papilla with non-absorbable suture, ideally a non-absorbable braided suture, such as silk. See below.

The distal end of the parotid duct is identified by the silastic tube, which was placed in the Stensen's duct via the intraoral papilla. The proximal parotid duct can usually be identified by the flow of saliva into the wound.

If the duct is **injured near the papilla**, but the papilla is uninjured, the proximal parotid duct may be dissected free and reimplanted into the papilla. The papilla may be gently dilated if this technique is chosen. If the papilla is injured or if the proximal end of the duct does not reach the papilla, the duct may then be reimplanted into the oral mucosa posterior to the papilla. This should be performed under loupe magnification with fine interrupted 6-0 to 8/0 absorbable sutures. Again a stent should be used and anchored to the cheek mucosa with a non-absorbable suture. If the **length of the proximal duct is insufficient** to be reimplanted into the oral mucosa without undue tension, then it is best to ligate the proximal duct.

Injuries occurring over the masseter muscle are the most common cause of injuries to the parotid duct, and may be treated by repair or ligation. Primary repair should be attempted if enough length remains.

Cut the edges cleanly and perform anastomosis over the silastic stent. (In sharp lacerations, the duct ends only need simple cleaning prior to repair.) A single layer repair with interrupted 6- 0 to 8-0 nylon sutures is used under loupe magnification. If a portion of the duct is damaged beyond repair or is missing, the proximal and distal duct should be ligated.

Injuries of the proximal duct near the parotid substance are usually best treated by ligation of the duct. Laceration of the gland itself without disruption of the parotid duct may be oversewn with fine absorbable sutures (5-0 or 6-0 Vicryl®).

If a repair of the duct is performed over a stent, the stent is trimmed at the level of the oral papilla and sewn to the oral mucosa or around the maxillary second molar with a non-absorbable **braided** suture. This is designed to hold the stent in place for the recommended 2-3 weeks while the injured duct heals, and to help prevent stenosis at the repair site. A non-absorbable braided suture is preferred since the patient's tongue continually rubs against the suture and may loosen or dislodge it, especially if it is a chromic suture or even a Prolene® suture.

The remaining facial and intraoral lacerations, as well as any incisions required for exposure, are then closed in the standard fashion

Human and Animal Bites

Human bites of the face are serious injuries. Not only is the potential for infection always present, but these wounds may result in gross disfigurement. The main objectives in the management are prevention of infection and functional closure of the wound with the best possible cosmetic result.

Human bites of the lip are potentially heavily contaminated, but primary closure of such wounds under antibiotic coverage (amoxicillin clavulanate—Augmentin) is recommended for early recovery and the best possible aesthetic outcome. Early flap design permits primary closure of many wounds.

The excellent blood supply of the face, the use of antibiotics, and early surgical repair make infection of human bites of the face a rare occurrence, even when patients seek help at a relatively late stage.

Many studies show low rates of infection in early repair under antibiotic coverage. It is a safe procedure with all the advantages of short hospital stay, low morbidity, and good cosmetic results.

Wounds should be thoroughly irrigated with a povidone-iodine solution, and good surgical debridement achieved without sacrificing tissue unnecessarily. This is followed by primary closure. Where primary closure is not possible because tissue has been avulsed, the defects are closed immediately with various skin flaps or Wolfe grafts—full thickness skin grafts. The aim should be to do a definitive single-stage procedure, or, where this is not possible, to commence with the first stage of a reconstructive procedure—e.g. Abbé rotation flap or post-auricular advancement flap.

When patients present late with wounds and signs of infection (i.e. cellulitis, erythema, and tenderness), debridement of the wound and aggressive antibiotic treatment is recommended. Once the cellulitis has settled, and the infection is under control, the wound edges should be excised, creating a new, clean wound for closure. This requires 2-3 mm of tissue to be removed from all the edges. The wound edges are closed directly, or local flaps are used for closure.

Chapter 7
Maxillofacial Fractures

Tertius H. J. Venter

The restoration of normal facial features and function after facial injury can be very challenging. If certain basic principles are meticulously applied, good functional and aesthetic results can be achieved. Attention to detail and early surgical management of the damage caused by trauma will often circumvent even more difficult, and sometimes nearly impossible, secondary reconstruction.

Prompt and definitive repair of the aesthetic defect (restoration of the pre-injury appearance) and restoration of function to minimize disability (including normal dental occlusion, mastication, speech, airway, and vision) are the goals of management of facial injuries.

Timing of Intervention for Facial Fractures

Facial trauma victims often sustain injuries to other organ systems. Definitive care of maxillofacial injuries should be rendered only after a thorough multisystem evaluation is done, with an emphasis on the respiratory, cardiovascular, and central nervous systems (head and cervical spine). Securing a safe airway is paramount. The oral cavity must be cleared of fractured teeth, fractured dentures, foreign bodies, and clots that may cause obstruction. The nasal passages should be evaluated for patency. If the patient cannot maintain a safe and totally unobstructed airway pre- or post- operatively, a temporary oropharyngeal airway should be considered for placement. Endotracheal intubation or tracheostomy may be necessary until the fractures have been treated and the edema resolves. With any facial fractures, the cervical spine must be evaluated early, most often with plain x- rays after a clinic examination.

Once life-threatening injuries have been managed, and the patient is stable, the maxillofacial injuries should be treated as soon as possible.

Principles in the Management of Facial Fractures

The management of facial fractures depends on the initial clinical evaluation and radiologic examinations. Ideally, the radiologic evaluation would include Panorex® of the mandible (orthopantomogram) and a CT scan of the facial bones. In situations where neither Panorex® nor CT scans is available, the x- ray views described later in this chapter (see "Plain Facial Films") can give helpful information for fracture management.

When dealing with maxillofacial injuries it is important to keep the maxillofacial bony complexes in mind:

- Mandible.
- Maxilla.
- Malar bones.
- Nose.

The last three constitute the middle third of the face, as shown in Fig. 1.

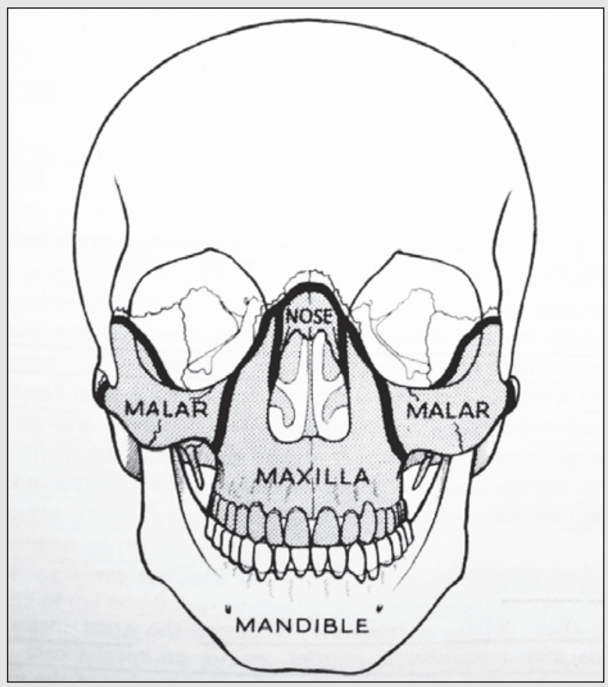

Fig. 1

The maxillofacial bony complexes: maxilla, nose, mandible, and malar bones. The stippled segment indicates the middle third of the face.

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These complexes each have its distinctive injury patterns, either as a single pattern or combination of several patterns of fractures. Maxillofacial fractures may involve a solitary bony complex or multiple ones. In jaw fractures, it is not uncommon for isolated fractures around the teeth to occur within the upper dental arch, lower dental arch or both. This type of fracture is known as a **dentoalveolar fracture**. This is a localized fracture of the alveolar plate of the maxilla or mandible with a varying number of teeth attached to the fractured segment.

Fractures of the facial skeleton can also be categorized as:
- Fractures that involve dental occlusion—mandibular and/or maxillary fractures (Fig. 2).
- Fractures that do not involve dental occlusion, such as malar and nasal fractures.

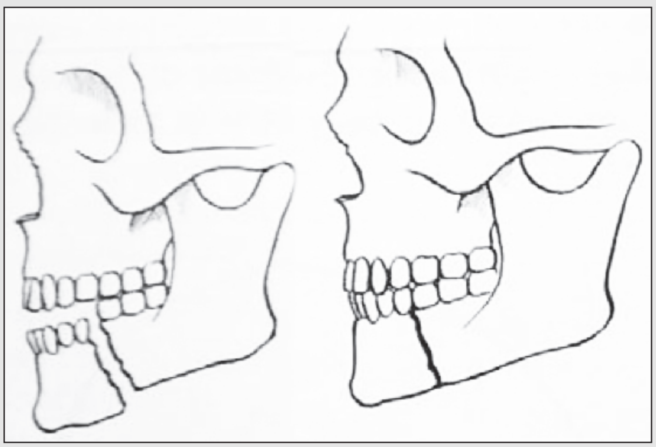

Fig. 2

In a fractured mandible, if the teeth are not occluding correctly, the fracture is displaced. Due to poor dentition, many patients may have had malocclusion prior to their jaw fracture. If so, then proper occlusion will not be achievable even with perfect fracture reduction. It isimportant to ask the patient if their bite feels like it comes together differently than before the injury—this would indicate a displaced fracture. The first figure demonstrates an unreduced, displaced fracture, with the teeth not occluding. The second figure shows a non-displaced or reduced fracture with teeth occluding correctly.

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It must be emphasized that to achieve and maintain proper **dental occlusion** is the core of all treatment of fractures that involve the teeth. The surgeon who has to deal with such a fracture in the absence of dental support will do very well to prevent a permanent and largely irreparable deformity by making **accurate and precise occlusion the main aim**, either by closed reduction and interdental wiring, by open reduction and plating, or, if necessary, a combination of wiring and plating after open reduction of fracture fragments.

With suspected fractures involving the orbit, a good eye exam should be done, including checking for **diplopia**. Diplopia is a symptom, not a sign, and, thus, **can only be elicited in a conscious patient**. The patient should be asked about any double vision while performing an extra-ocular muscle examination—during lateral and upward/downward gaze. If present, it may suggest an orbital fracture which, if appropriately treated in a timely manner, may resolve the diplopia. If persistent, it is a very debilitating disability.

Clinical Examination of the Face

Overlying soft tissue signs—like edema, contusions, abrasions, ecchymosis, and distortion of the facial proportions—must raise the suspicion of underlying bony injuries. Subconjunctival hemorrhage with ecchymosis and edema in the region of the orbit or a palpebral hematoma may suggest a fracture of the zygoma or orbit. Bilateral periorbital hematomas suggest a Le Fort, nasoethmoid, or anterior cranial fossa fracture. Contused intraoral tissue, loose teeth, and malocclusion suggest possible maxilla or mandible fractures.

An orderly examination of all facial structures from either superior to inferior or inferior to superior in a systematic fashion, as well as meticulous examination in search for dysfunction of the orbital, masticatory, and neurosensory systems of the face will often reveal the anatomy of the underlying fracture pattern to the facial skeleton.

Systematic palpation of all bony surfaces must be carefully performed:
- Superior, inferior and lateral orbital rim.
- Nose.
- Zygomatic arches.
- Malar eminence.
- Outline of the maxilla.
- Inferior border of the mandible.

Specific symptoms and signs produced by facial injuries include:

- Pain or localized tenderness overlying a fracture site.
- Crepitation from areas of underlying bone fracture.
- Hypoesthesia or anesthesia in the distribution of a specific sensory nerve, e.g. infra orbital or mental nerves.
- Malocclusion.
- Visual acuity disturbance, double vision (diplopia) as a result of severe swelling, muscle paralysis or dystopia.
- Facial asymmetry, facial deformity.
- Obstructed respiration.
- Lacerations, bleeding, and contusions.

Particular Attention to:

1) Periorbital Region

Signs/symptoms of an orbital fracture are:

- Tenderness, crepitus.
- Contour defects.
- Unequal globe levels (dystopia of the globe).
- Enophthalmos or proptosis.
- Double vision (diplopia).

Any of these structures may be injured: orbital rim, orbital floor/roof, medial/lateral orbital walls, along with the zygoma and/or maxilla.

Visual acuity, as well as extra-ocular muscle and pupillary function, should be assessed before any surgical treatment is undertaken. Intraocular pressures should be measured if possible.

In uncooperative patients, the response to light stimuli, such as photophobia, pupillary constriction, aversion of the head, or lid closure, indicates probable light perception.

An assessment of pupillary reactivity is of critical importance, because the direct pupillary response to light is the most reliable sign of the extent of optic nerve injury. The absence of pupillary reactivity is an indication of serious visual compromise.

Pupillary size and symmetry, the speed of pupillary reaction, globe turgor, globe excursion, eyelid excursion, double vision, visual acuity, and visual loss are noted.

Extra-ocular movements (cranial nerves III, IV, and VI) and the muscles of facial expression (cranial nerve VII) are examined in the conscious, cooperative patient.

Signs of injury to the globe and/or any confirmed orbital fracture should initiate ophthalmology consultation if available. Examples of globe injury may include the presence of hyphema, corneal abrasion, visual disturbance (field defect), double vision, decreased vision, or absent vision.

2) Masticatory Dysfunction

Careful inspection of the intraoral area should be made to detect lacerations, loose teeth, and abnormalities of the dentition or malocclusion. Palpation of the dental arches is done, noting any mobility of dentoalveolar arch segments. The maxillary and mandibular dental arches are carefully visualized and palpated to detect an irregularity of the bone, loose teeth, intraoral lacerations, bruising, hematoma, swelling, movement, tenderness, or crepitus.

- Fractures of the facial bones may be diagnosed on the basis of **malocclusion** of the teeth or an **open bite deformity**, due to fracture displacement involving the upper and/or lower jaw.

- Pain with restricted movement of the jaw, **trismus**, may be caused by a fracture of the zygoma, upper jaw and/or lower jaw.

- The **excursion and deviation of the jaws** with motion, the presence of pain on opening of the jaw, the relationship of the teeth, the ability of the patient to bring the teeth into occlusion, the symmetry of the dental arches, and the intercuspal dental relationship are all important to the diagnosis of fractures involving the dentition.

- One finger in the ear canal and another over the condylar head can detect **condylar movement, or crepitus**, either by the patient's movement or when the jaw is pulled forward.

- A gingival laceration, a fractured or missing tooth, or a split alveolus should imply the possibility of more significant maxillary or mandibular injuries. This must be confirmed by further examinations for mobility and by appropriate facial X-rays and/or CT radiographs.

- Fractures of the mandible may be detected by pulling forward on the jaw or by applying "up-and-down" manual pressure on the anterior portion of the mandible, having supported the angle, or lateral pressure on the dentition. Instability, crepitus, and pain may be noted when this maneuver is performed. Edema and hemorrhage may mask the perception of facial asymmetry.

3) Cerebral Spinal Fluid (CSF) Leak
Bleeding from lacerations of vessels accompanying facial fractures may disguise a CSF leak.

- Bleeding or fluid draining from the ear canal may indicate a laceration in the ear canal, a condylar dislocation, or a middle cranial fossa fracture with a CSF leak

- Bleeding from the nose may indicate nasal or septal injuries, a Le Fort, naso-ethmoidal, or orbital fracture, or fractures of the anterior cranial fossa.

- Mobility of the middle third of the facial skeleton indicates a Le Fort fracture.

- Anterior or middle basilar skull fractures or cribriform plate fractures should be suspected when CSF rhinorrhea or clear drainage from the ears is present.

Radiographic Examination of the Face

- **Plain facial films**: The Waters, Caldwell, submental vertex, Towne, and lateral skull films are the most helpful. Antero-posterior and lateral oblique views of the mandible are important, as is the Panorex® (orthopantomogram) examination if available. The middle and upper facial structures are most accurately evaluated with a detailed CT examination if available.

- **Nasal bones, lateral views:** Fractures of the nasal bones, the anterior nasal spine, and the frontal process of the maxilla are demonstrated.

- **Temporomandibular joints**: Oblique anterior-posterior and oblique lateral views are taken by the lateral, transcranial projection and demonstrate the temporomandibular joints in open and closed mouth positions.

- **Panoramic Films:** Panoramic films (orthopantomograms) are helpful in defining location and displacement of mandibular fractures.

Definitive Management of Facial Fractures

Early care: Before the definitive treatment is begun, the great majority of patients with maxillofacial injuries require no special care of the fracture, other than adequate and repeated cleansing of the mouth. Maxillofacial fractures, apart from mandibular fractures, do not tend to be sufficiently mobile to make pain from this source a problem.

In the small group who require special care, the difficulties are either respiratory or those caused by hemorrhage.

1) Hemorrhage: Bleeding, particularly in maxillary fractures, may occasionally be brisk but usually stops spontaneously if a free airway is provided. It is important to prevent blood from trickling back into the pharynx, where it can potentially cause respiratory difficulties with restlessness. This can increase the bleeding. Though very rare, severe and uncontrollable bleeding may call for ligation of the external carotid artery.

2) Respiratory difficulty: This can vary greatly in severity and is due either to swelling of the tongue, from hematoma spreading from a mandibular fracture, or to an inability to control the tongue in those bilateral mandibular fractures where the anterior fragment that carries most of the muscular attachments of the tongue is mobile. Also, gross soft tissue swelling after severe facial trauma may impair the airway in combination with fractures that, on their own, may not typically cause airway difficulties.

The measures to maintain a safe airway required in any particular patient depend on the severity of the respiratory embarrassment. Adequate **suction** should always be available. Patients breathe more easily if their head can be **elevated**; but, when this is not possible, it is most important **not to leave them lying supine**. The correct position is **prone with head turned to the side**. A suture through the tongue to hold it forward may be necessary.

It must be stressed, however, that any suggestion of serious respiratory difficulty is an indication for immediate **tracheotomy** since respiratory embarrassment tends to increase rapidly.

3) **Associated injuries**: Maxillofacial fractures do occur as isolated injuries. When there are severe vehicular collisions, other severe injuries are liable to be sustained simultaneously. The injuries most likely to affect the management of the maxillofacial component are soft tissue facial injuries, cranial and neck injuries, chest injuries, and eye injuries.

- **Soft tissue facial injuries** should be treated with the minimum of delay.

- **Brain damage** following cranial injuries, with or without a skull fracture, is quite common in association with a maxillofacial injury. If the patient is unconscious, then with this score alone would be considered for tracheotomy. The presence of a fracture of the maxilla or mandible with additional breathing difficulties leaves little argument against early tracheotomy. (**Editor's Note**: It is realized that the care of a tracheostomy is difficult in many locations without an ICU or nurses experienced to care for it. See notes on this at the end of Chapter 5.)

- **Cerebrospinal rhinorrhea**: leakage of cerebrospinal fluid from the nose is evidence of a fracture of the cribriform plate with a tear of the dura. It is an easy clinical diagnosis—a water-clear fluid dropping from the nose that sometimes increases in volume by dropping the head forward or straining. It usually develops within 48 hours of the injury though it may suddenly appear some days or even weeks after the injury.

  Some leaks stop spontaneously when the fracture is fixed, and there is no further trouble. Some appear to stop, but meningitis can develop after a variable and sometimes quite long period of freedom from all symptoms. Some continue to leak fluid with the eventual development of meningitis, even after reduction and fixation of the fracture of the maxilla.

  The presence of a cerebrospinal leak and the potential for meningitis necessitates adequate antibiotic coverage. It is well recognized that movement of the fractured maxilla causes considerable movement of the cribriform plate and the fractured neighboring bony fragments. The fracture should, therefore, be reduced and fixed at the earliest possible moment so that the dural tear may have the best chance to heal.

  If the leak is small in volume and lessens fairly rapidly, it can safely be left to stop spontaneously. The chances of late meningitis are probably remote.

  If the leak is large in volume or persists, it should be surgically closed if possible in your hospital. This is rarely necessary, but if necessary, one will need to refer the patient to a neurosurgeon when the patient is stable.

- **Chest injuries**. The maxillofacial injury is likely to make treatment of the chest injury more difficult by adding to the respiratory embarrassment if there is a flail segment with paradoxical respiration. In such a situation, a tracheotomy will help to solve both problems.

- **Eye Globe Injuries**. This is surprisingly rare except with orbital fractures. When it does occur, the damage tends to be irreparable either with disruption of the contents of the eyeball or severe damage to the optic nerve. Patch the eye until the patient can be seen by an eye doctor or someone experienced in eye surgery. An exception to this is hyphema which is a vision-threatening problem that may be worsened with orbital fracture surgery. The operation should be delayed in the presence of a hyphema.

- **Sympathetic ophthalmia** is a granulomatous uveitis and inflammation that occurs following trauma to one eye. It may occur several days to several years after a penetrating eye injury. Though rare, if a serious non-reversible injury occurs to one eye, it could affect the other eye and lead to blindness. Therefore, it may be prudent to remove the injured eye and prevent damage to the good eye.

Treatment of Specific Facial Fractures

I. Mandible

Patterns of Injury

The sites of fracture (Fig. 3) are condylar neck, angle, body, and symphysis. Fractures at these sites may occur singly but usually in combination. Fracture patterns may exist as both condyles, both angles, body and opposite angle, body and opposite condyle, and both sides of body. **If one fracture is diagnosed, a second fracture should be excluded.**

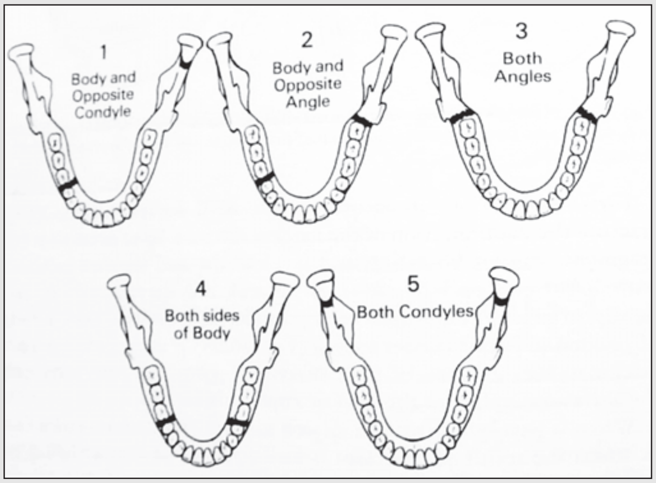

Fig. 3

The common sites of fracture of the mandible.

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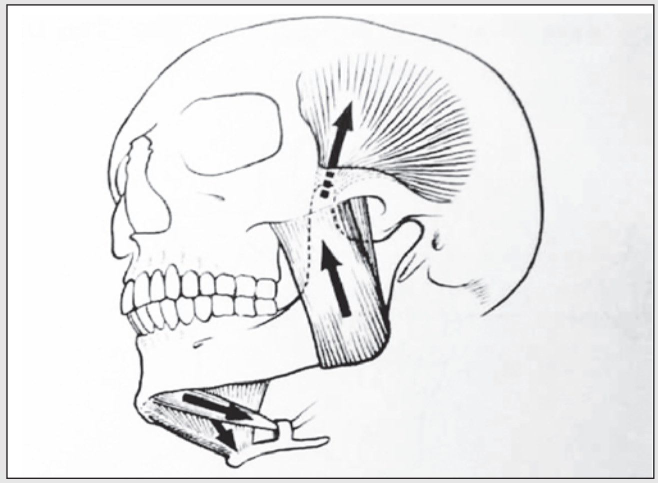

Fig. 4

The lines of muscle pull which influence displacement of fragments in mandibular fractures.

Upward pull—masseter, temporalis, medial pterygoid. Downward pull—geniohyoid, mylohyoid, digastric.

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Fracture displacement may be the result of the direction of the violence, but they result largely on muscle pull. The muscles that elevate the mandible–masseter, medial pterygoid, temporalis–are all inserted behind the first molar. The muscles that depress the mandible–geniohyoid, mylohyoid, digastric–are all attached in front of the first molar (Fig. 4). Consequently, the most common displacement of a posterior fracture segment is upward, and the anterior fracture segment is downward. The direction of the fracture line, particularly near the angle, may considerably influence the amount of displacement, either permitting or preventing it (Fig. 5).

The **condylar fracture** is a special case. In a condylar neck fracture, the condylar head is hinged forward by the lateral pterygoid muscle, displacing the fracture. When both condyles are fractured, the displacement of both heads causes the mandible to rotate downward due to loss of condylar support producing an "open bite" malocclusion (Fig. 6).

Clinical Picture of Mandible Fractures

The **site of the fracture** is usually indicated by swelling and local pain on movement or manipulation of the mandible. In fractures other than those of the condylar neck, there is often a sublingual hematoma; if the fracture is compound into the mouth, there is tearing or at least bruising of the mucosa.

Displacement in the tooth-bearing segment of the mandible may be clinically apparent, with an obvious break or step in the line of occlusion. The patient may volunteer the information that "the teeth don't close properly".

A **condylar fracture** is less obvious, and the only sign may be pre-auricular pain with or without swelling. There is restriction of movement and **deviation of the mandible to the damaged side on opening**, with an open bite on the contralateral side. The great majority of patients with a fracture elsewhere in the mandible and who complain of pain in the vicinity of the temporomandibular joint are found to have a fracture of the condylar neck.

In displaced fractures between the angle of the mandible and the mental foramen, there may be **damage to the inferior alveolar nerve** since it runs within the bone. On exam, there may be anesthesia of the lower lip.

In a suspected fracture of the mandible, bimanual

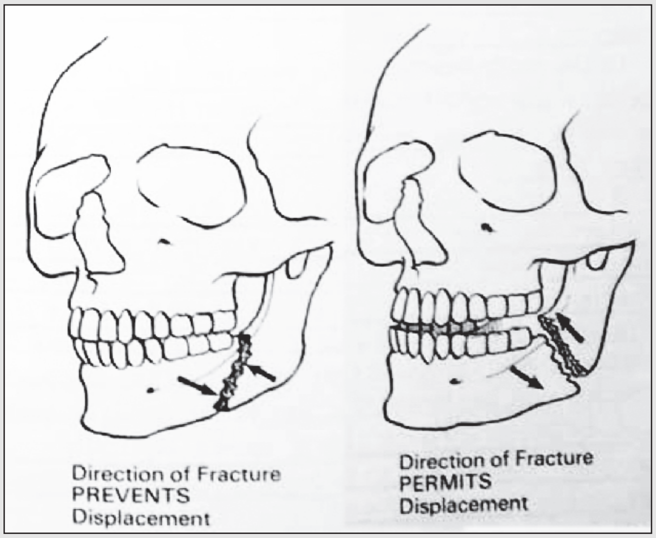

Fig. 5

The effect of the direction of the fracture line on the displacement of angle fractures of mandibleunder the influence of muscle pull. On left, the muscle pull engages the fragments; on right it distracts the fragments.

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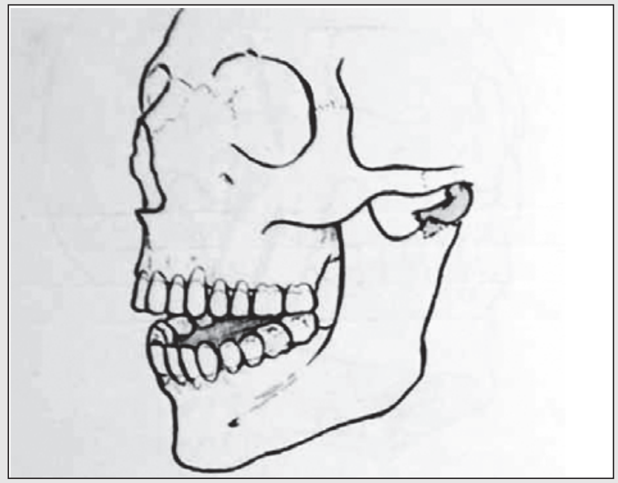

Fig. 6

'Open bite' produced by a bilateral condylar fracture.

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palpation along the inner and outer plates of mandible intra-orally and along the lower border extra-orally will often confirm the diagnoses. Local swelling and tenderness are suggestive of a fracture while an actual step off is diagnostic.

X-Ray Diagnosis

The two most useful views are the posteroanterior projection (to diagnose symphysial fractures) and the lateral oblique projection.

Treatment

(Reduction and fixation methods are described in the section immediately following) A fracture **of the tooth-bearing segment** is managed by eyelet wiring, or mini-plates and screws if the latter are available. MMF (mandibulomaxillary fixation) is the same as IMF—intermaxillary fixation, which is an older term.

If there are **no teeth present on both sides of the fracture line**, internal fixation by either interosseous wiring or mini plate and screw fixation will be necessary, with or without MMF, but not MMF alone. When **gross displacement** is present, or the fracture is unstable, intermaxillary fixation with eyelet wiring and reduction will often be necessary before mini-plate and screws can be applied. If plates and screws are not available, then interosseous wiring is done before the eyelet wiring can be completed. Occlusion and dentition should be treated prior to any fracture fixation.

Fractures of the edentulous mandible are managed with gunning splints or mini-plates and screws. Interosseous wiring on its own is seldom stable enough. (Gunning splints may be made by a local dentist.) (**Editor's Note**: Most will not be able to obtain these splints and this will be a difficult fixation. Interosseus wiring should be tried. Hopefully, fractures of the edentulous mandible will be rare. Some may have appropriate plates and screws.)

Dentoalveolar fractures are treated by arch bar wiring.

Unilateral condylar fractures can usually be treated without open reduction. Open reduction may be considered when the condyle is in the middle cranial fossa, displaced lateral to the joint capsule, or the occlusion is incorrect with closed reduction. Closed reduction treats the joint as a pseudarthrosis, and re-education of the muscles is relied on to establish good function. Some patients with a single, non-displaced condylar fracture will be able to chew soft foods fairly quickly, with or without a period of rest depending on the degree of initial discomfort. If pain is severe, MMF with eyelet wires may be necessary for two to three weeks. In subsequent re-education of the muscles, a training flange on the splint may be required to train the mandible to close in correct occlusion.

Bilateral condylar fractures require open reduction of **at least one** of the condylar fractures to re-establish condylar support. This corrects the "open bite" deformity associated with this fracture pattern.

Reduction and fixation methods
The teeth can be used as an indirect method of fixing jaw fractures, especially if mini-plates and screws are not available. Their firm attachment to the alveolus and the fact that their occlusion is of prime importance to subsequent function makes them extremely effective for this purpose. It is usually only when teeth are absent that the alveolus is approached more directly for splinting purposes.

In reducing a fracture of the mandible or maxilla, the aim is to bring the teeth of the fractured fragments into a normal relationship with those of its non-fractured counterpart. Establishing the occlusion helps the fracture reduction by placing the fractured segments in good position. In an edentulous patient, the fractured alveolus, for similar reasons, is brought into the position that it would occupy if dentures were being worn.

In fixing a fracture of the mandible or maxilla, the fractured bone, once reduced, must be anchored to an immovable structure unless mini-plates and screws are used on their own. The mandible, when fractured, is thus anchored to the maxilla; the maxilla, when fractured, is anchored to the skull (at the zygomaticofrontal suture if fractured) as well as to the mandible.

When teeth are present in sufficient numbers on both fragments, they are fixed in proper occlusion (MMF) by eyelet wiring, arch wiring or cap splinting (gunning splints).

1) Eyelet Wiring (Mandibulomaxillary Fixation)
The wire used is a 0.4 mm diameter stainless steel wire which has been doubled on itself and twisted tightly two or three times, leaving a small eyelet at the end. In some countries, the 0.4 mm wire will be a 24 gauge wire.

The double wire is passed inwards between the necks of two adjacent teeth until the twisted segment is lying between the necks with the eyelet on the outer side. The wire is then separated into its two strands, one being turned forward and one backward, and each is passed outwards through the next interspace so that a loop is formed round the necks of the two adjoining teeth. The loops are completed by bending the wires towards one another, passing one through the eyelet, and finally twisting them tightly together before cutting off the excess and turning in the end, so that it will not catch on tongue or cheek.

Several sets of these wires are applied at intervals around the alveolar arch, and also at corresponding points on the opposite jaw. When the fracture has been manually reduced and the mandible closed on

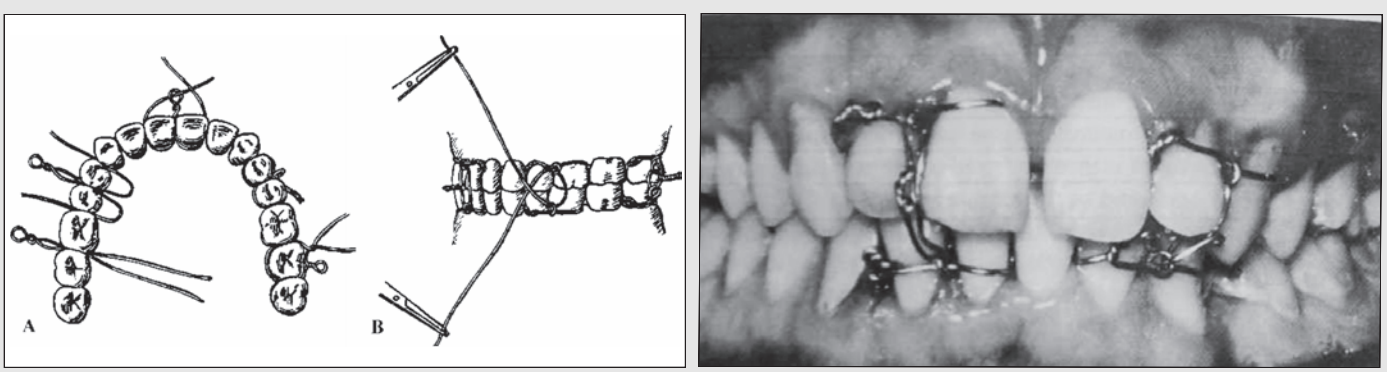

Fig. 7

The steps in eyelet wiring and a patient showing the upper and lower teeth wired together
From McCarthy JG (ed.): *Plastic Surgery*. Philadelphia, W.B. Saunders, 1990.

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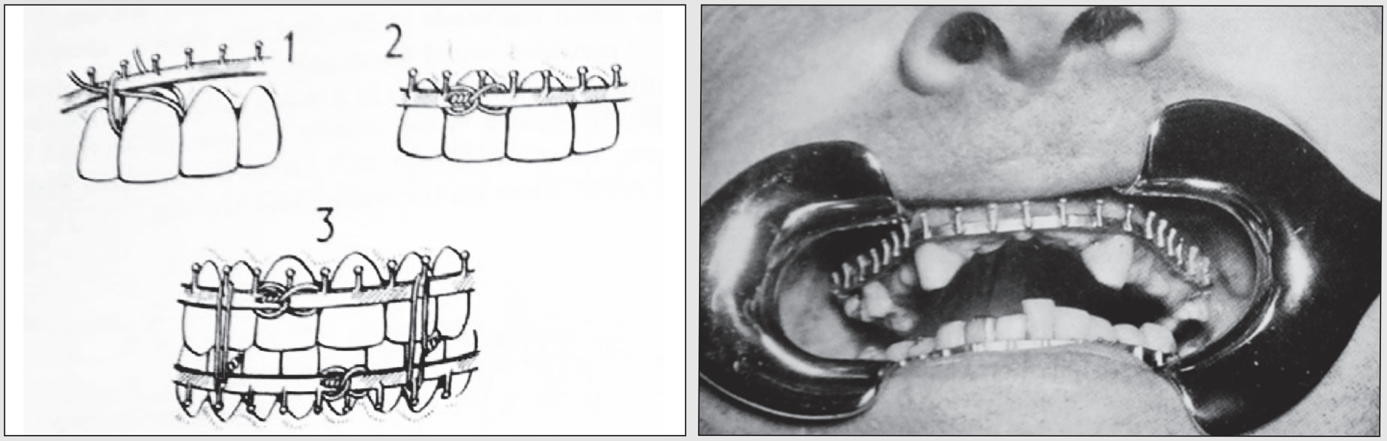

Fig. 8

The Winter or Erich arch bar and the steps in its application, with a patient showing bar in position ready to be wired to the upper and lower teeth.

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to the maxilla, it is held in this position by looping further wires through the eyelets that oppose one another, twisting them tightly together.

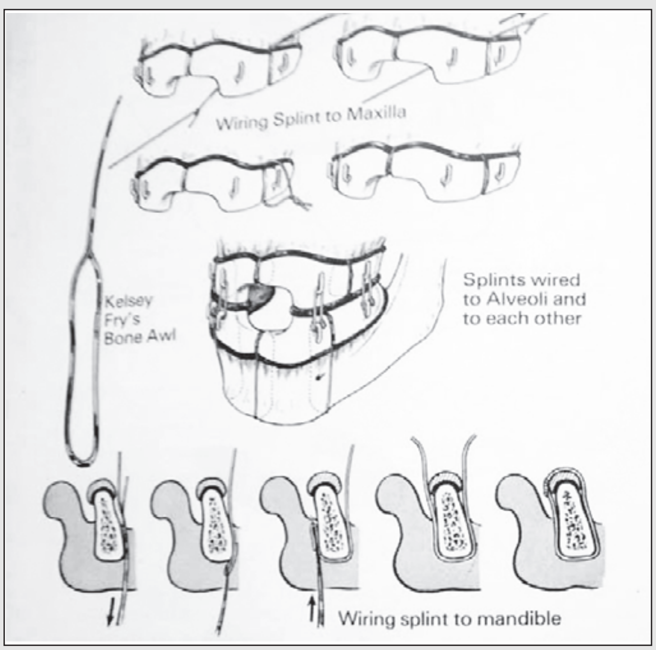

Fig. 9

Gunning splints, or dentures with teeth, circumferentially wired to mandible and maxilla, and to each other.

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2) Arch Bar Wiring
This technique is an alternative to eyelet wiring and uses arch bars (Erich) with hooks at intervals along their length (See Fig. 8). The bar is accurately molded around the alveolar arch on its outer aspect, at the level of the necks of the teeth to which it is then wired. With an arch bar similarly applied to the maxilla, the two can be fixed together with wires. This technique is most useful to fix **dentoalveolar fractures** (also known as an alveolar ridge fracture) and needs only one arch bar placed across the fractured segment fixing it to at least two stable teeth on either side of the fracture.

3) Gunning Splints (These will rarely be available at district hospitals with or without a dentist available) When teeth are not present, and the patient has dentures, the fracture can be reduced on the dentures, with upper and lower teeth occluding correctly. If the dentures are broken, or the patient has no dentures, impressions can be taken and 'dentures without teeth,' the so-called "gunning splints", made (Fig. 9). If the patient's dentures are intact, however, they can be used as gunning splints. These splints are circumferentially wired on to the upper and lower jaws, and subsequently to each other, to obtain fixation.

4) Internal fixation
Interosseous Wiring: When displacement of a fracture is considerable, and it cannot be readily reduced manually in preparation for fixation by one

of the methods described, it may be necessary to fix the bones in a reduced position by interosseous wiring.

Exposure of the mandible can be by an **internal (transmucosal) or an external (transcutaneous) approach**. External approaches are dictated by where the fracture is located, and may include a submandibular, submental, or retromandibular incision. The submandibular and retromandibular approaches carry the danger of injury to the mandibular branch of the facial nerve to the lower lip, apart from the visible scar. The intra-oral approach has none of these drawbacks, though the technique of wiring has to be modified somewhat. It is more difficult for the occasional surgeon with this approach.

The internal approach, most often utilizes upper border wiring in the **non-tooth-bearing segments**. The fracture site is exposed; holes are drilled near the upper border of the mandible immediately adjoining the fracture site, and a simple loop is inserted. When the fracture is reduced, the wire is twisted tight to maintain reduction (see Fig. 10). Alternate patterns of wiring can be used to maintain more effective fixation depending on the direction of the fracture. An upper border wire is a tension band, and it should be combined with lower border wiring or MMF. Ideally this is placed through the same incision, but if not, through an external approach.

Lower border wiring usually makes use of a figure of eight wire and requires an external approach. It is only really ideal when there is an appropriate soft tissue laceration.

Mini Plates and Screws: (It is understood that most district hospitals may not have these)

The use of mini-plates and screws are the preferred method of fixation of maxillofacial fractures, as they offer the advantage of immediate mandibular mobility and a very limited time of a liquid-only diet. It is sometimes used in combination with inter dental wiring (MMF). MMF is recommended in difficult reductions, to get the teeth in good occlusion and to keep them in position, while also applying the plates. The wiring can then be removed within 7-10 days.

The plates and screws can be applied through an intra-oral approach on the buccal side of the mandible. If maxillofacial plating set is not available, then a hand surgery mini-plating set is a good alternative to use. Anterior to the mental foramen (Fig. 11), two plates need to be applied to counteract the rotation forces in this area. Posterior to the mental foramen, a single plate is sufficient with MMF. The screws in the upper plate along the alveolar ridge need to be uni-cortical through the buccal cortex to protect the root of the teeth. The level where the plates are applied should be no closer than one-third of the height of the mandible from

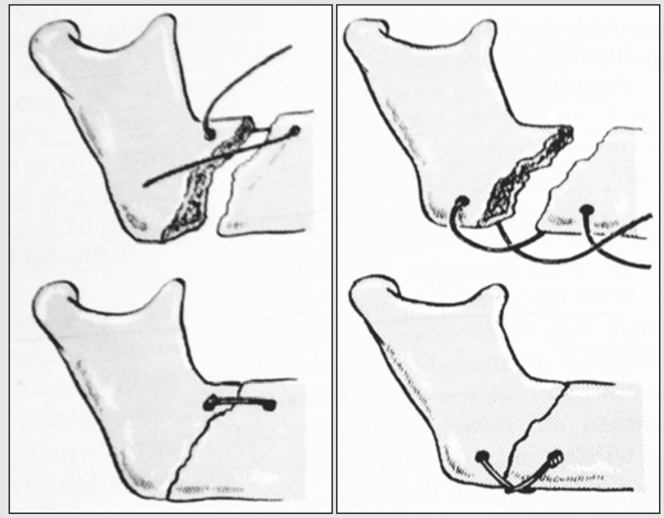

Fig. 10

Upper Border Wiring (internal approach) and Lower Border Wiring (external approach).

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Fig. 11

Position of the mini plates.

the dental margin of the jaw to avoid damage to the roots of the teeth. In order to obtain secure fixation, an inferior plate should be used with bicortical screws.

Infection around plates/screws or wires that are well covered by the soft tissues is very uncommon, and the plates and screws are usually left permanently. However, infection of a mandibular fracture can occur occasionally, particularly if the fracture is through a tooth socket in the line of the fracture. The remarkable thing about infection is its rarity. If infection does occur, the wire or plate must be removed but it should, if possible, be retained until the fracture is 'sticky' so that displacement will not recur. The upper border wire is exceptional; it is so close to the underlying mucosa that it usually becomes exposed in the mouth eventually, but removal under local anaesthesia is straightforward.

Fractures are usually united by six weeks. This can be confirmed clinically and by X-ray examination, but it should be recognized that **X-ray evidence of union may not be present for many months**. In fractures where only MMF was used, the wires between the mandible and maxilla are removed by six weeks. If there is clinical union, the rest of the wires (loops around the teeth) can be removed, but if the fracture is still mobile and springy, the mandible and maxilla should be wired together again until union is **clinically** apparent. Fractures of the symphysis and those that have become infected tend to be slow to unite.

II. Malar Fractures

There are three main types of fracture.

- **Simple fracture** (Fig. 12—first 3 diagrams): The fractured bone, consisting of the malar complex, remains in a single piece that is displaced medially and backwards, often tilted either medially or laterally, and usually impacted. The line of fracture runs from the infra-orbital foramen downward and laterally over the anterior wall of the antrum, compressing the infra-orbital nerve and tearing the branches of the superior dental nerve that cross the fracture line.

- **Comminuted fracture**: The fracture pattern is similar to that of the simple fracture, but the bone is comminuted with depression of the orbital floor. A comminuted fracture of the floor of the orbit with depression of the floor and escape of some of the orbital contents into the antrum may occur as an isolated injury—**the blow-out fracture**. Classically it results from direct force by a blunt object, e.g. a fist, on the eyeball. The loss of the orbital fat is responsible for the main clinical feature, namely enophthalmos, often with diplopia.

- **Arch fracture**: This consists of a localized depression of the zygomatic arch. In its medially displaced position, it tends to impinge on the coronoid process of the mandible. A clearly palpable depression is felt in the contour of the arch.

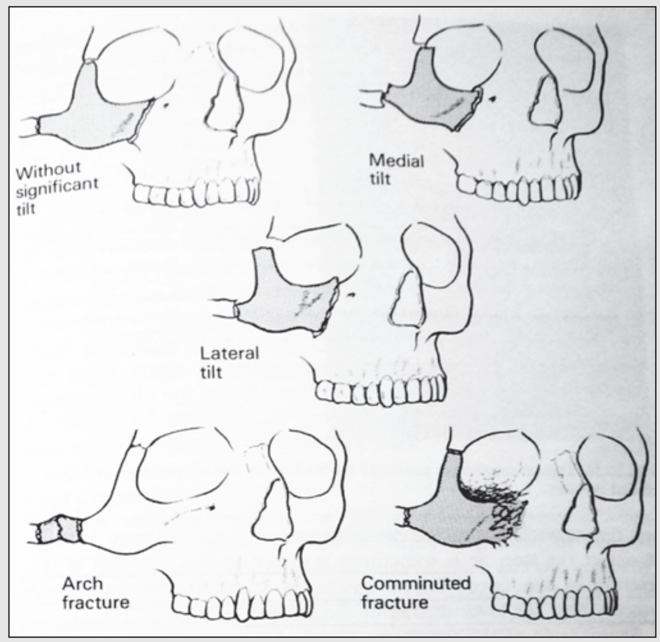

Fig. 12

The types of malar fractures, clinical picture.

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Clinical Picture

- Swelling and bruising of the overlying soft tissues. It might be absent, but sometimes it progresses rapidly until it is severe enough to virtually close the eye and mask any underlying bony deformity.

- Subconjunctival hemorrhage is often present.

- Flattening of the cheek prominence. Comparing the inferior orbital margin with the normal on the opposite side, a step-off in the vicinity of the infra-orbital foramen can usually be felt.

- Areas of anesthesia: the superior dental nerves may be divided by the fracture making the teeth of the affected segment anesthetic to percussion. Damage to the infra-orbital nerve is variable, but the two areas most noticeably are the upper lip and the alar region of the nose.

- Diplopia may occur as a transient phenomenon in the simple fracture, and temporal reduction cures it. When it persists postoperatively, it is usually found that the lateral part of the orbital floor has been severely comminuted and depressed.

- Trismus is very variable and tends to be more severe if there is significant depression of the zygomatic arch. Indeed, apart from the clinically obvious local depression, trismus with marked restriction of lateral movement of the mandible may be the patient's sole complaint in the localized arch fracture.

X-Ray Diagnosis
Irregularities or definite fracture lines near the infra-orbital foramen, the zygomatic arch, the lateral wall of the antrum, and the line of the orbital floor should be compared with the normal side. Blood in the antrum may make it appear opaque.

Treatment
The finding of a malar fracture on an X-ray plate does not always mean that surgical treatment of the fracture is necessary. The need (or not) for surgery is decided, rather, on the clinical examination.

Indications for surgery are:
- Infraorbital nerve anesthesia—lip and nose. Anesthesia of the teeth by itself is not an indication, as the elevation of the malar will make no difference with this symptom
- Trismus.
- Diplopia.
- Obvious flattening of the cheek prominence.

Surgical treatment consists of elevation of the malar complex or zygomatic arch through a temporal approach. The temporal approach is suitable for most of the simple fractures. The deciding factor is whether or not the malar is more or less in a single piece and capable of being reduced by exerting leverage on the anterior part of the zygomatic arch. The arch fracture falls into this group. Levering the arch in comminuted fracture would only reduce part of the bone, and has to be reconstituted and supported by an antral pack. Following reduction, most fractures maintain their reduced position. If the fracture appears to be unstable, and displacement tends to recur, then direct interosseous wiring or fixation by mini plate and screws at the zygomaticofrontal suture is often necessary—see below.

1) Temporal Reduction
This method depends on the anatomical fact that, while the temporal fascia (superficial and deep layers) are attached along the inner and outer border of zygomatic arch, the temporalis muscle runs under it to the coronoid process of the mandible, and a lever inserted between fascia and muscle can slide down deep to the arch to exert its leverage.

An oblique 2 to 2.5 cm incision is made in the temporal area in the hairline, and just anterior to the superficial temporal artery. The artery is usually clearly palpable. The incision is carried as far down as the temporal fascia. As a pathfinder for the lever,

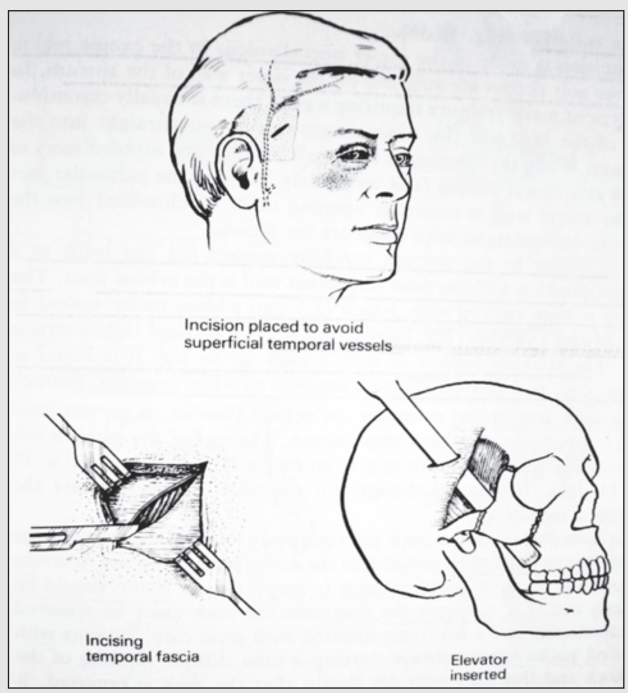

Fig. 13
Temporal reduction of zygoma.

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McIndoe's scissors are inserted under the fascia and slid along the surface of the temporalis muscle deep to the zygomatic arch.

Various levers have been devised and used to elevate the bone, but the most commonly available (and an eminently satisfactory one) is an orthopaedic (Bristow) periosteal elevator. It is slid along the path found by the scissors, and once under the arch, it should be brought as far forward as the arch allows, so that leverage can be exerted anteriorly (if necessary) as well as laterally. If added leverage is required, a swab may be placed between elevator and scalp. The degree of force needed depends on the degree of impaction and the delay in treatment, but considerable force can safely be used. In closing the incision, it is only necessary to suture the skin.

2) **Antral Reduction in Comminuted Fractures**
(**Editor's Note**: The following is an old technique. If one can elevate the orbital floor using the procedure given [under orbital floor fractures below], then this will not be necessary.)

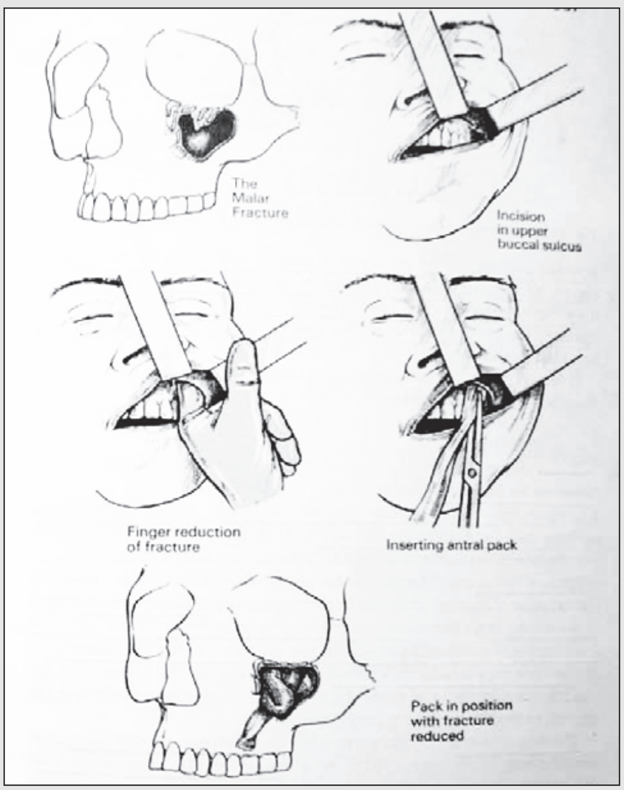

Fig. 14
Antral Reduction by packing (an old technique).

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An incision is made in the upper buccal sulcus in the canine region, and the soft tissues are stripped off the outer wall of the antrum. If, as very rarely happens, the particular part of the antral wall is intact, an opening must be chiseled into the antrum and enlarged with rongeurs for access.

The finger in the antrum carefully pushes out the walls to a correct position, and the most important wall is the orbital floor. The cavity is then packed with 1-inch (2.5 cm) ribbon gauze soaked in Whitehead's Varnish (Pig. iodoform Co. B.P.C.) and tightly wrung. In this way, it is found as clean, dry, and non-smelling on removal as when inserted. Enough packing is inserted to maintain the orbital floor at its correct level and buttress out the cheek prominence. The end of the gauze is left protruding into the mouth to give an easy start for its removal in 10 to 14 days. It is usual, though not essential, to partly suture the mucosal incision. It is important not to pack too vigorously towards the orbit, in case some of the pack gets pushed into the orbit itself giving rise to severe proptosis.

Fixation with Interosseous Wiring or Plating
Once a non-comminuted malar fracture is reduced, many of them will be unstable and will need fixation. The fractures are exposed with small incisions directly overlying, one in the subtarsal area of the lower eyelid—see below—and one over the zygomatic-

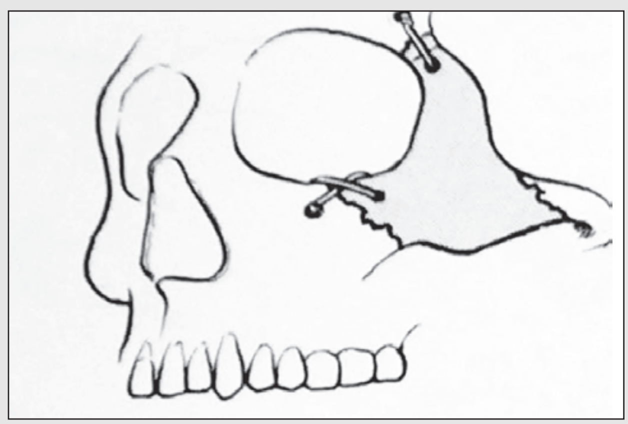

Fig. 15
Reduction and fixation of a fractured malar by interosseous wiring.

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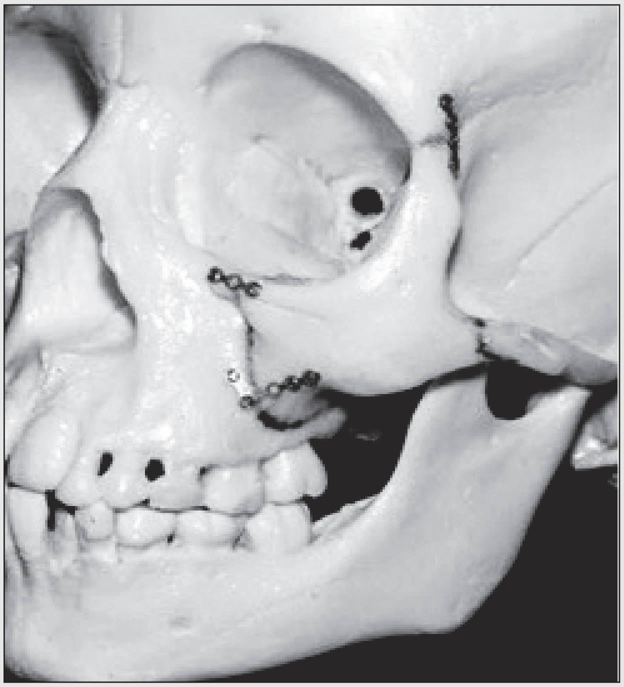

Fig. 16

Reduction and fixation with small plates and screws if available and plating of the buttress.

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frontal fracture line. With the bone exposed, holes are drilled on each side of the fracture site and wiring is carried out with a simple loop or figure of eight as dictated by the situation. The wires are left buried permanently. If a plating set is available, a 4 hole plate (1.1, 1.3 or 1.5 mm.) can be fixed over the fracture sites. One may also approach these fractures through a buccal sulcus incision.

III. Orbital Floor Fractures ('Blowout Fracture')

These are caused by the patient being struck in the orbital region with a ball, a fist, or some other round object, causing a sudden increase in pressure in the orbit. The floor of the orbit is concave, dipping downward behind the rim of the orbit and is the thinnest section of the orbit, prone to be "blown out" with "escape" of the orbital contents through the fractured floor, potentially causing enophthalmos.

The most important, but not most common, signs are peri-orbital bruising, enophthalmos, and restricted eye movement. Examination of the eye might also reveal any of the following: edema, corneal abrasion, laceration, contusion, or hematoma. Enophthalmos might not always be present or might not be apparent immediately. A subconjunctival and peri-orbital hematoma confined to the distribution of the orbital septum is evidence of a facial fracture involving the orbit until it is proved otherwise.

If the extraocular movements are affected, it is noted by double vision or restricted globe movement. Limitation of forced rotation of the eyeball, **the forced duction test** or the eyeball traction test, provides a means of differentiating entrapment of the ligaments of the inferior rectus muscle in the fractured floor from weakness, paralysis, and sometimes contusion. The test can be done under local anesthetic or while the patient is under general anesthetic; the sclera is gently grabbed with a non-toothed forceps and the eyeball moved in the different directions.

Visual acuity should be assessed prior to anesthesia, also, the **globe pressure** by tonometry (if available) should be less than 15 mm Hg. A **funduscopic examination** is also important.

Treatment

The two main indications for surgery are the presence of enophthalmos or restricted eye movements caused by entrapped musculature.

An incision is made in the lower eyelid in the subtarsal area, 7-10 mm. below the eyelid margin. Incisions just below the eyelashes were once advocated, but when these heal, there is often eyelid retraction even with the best of surgeons. The dissection is carried directly through the orbicularis muscle aiming for the infraorbital rim. The periosteum is cut on the orbital rim and the periosteum elevated from the floor. The inferior rectus muscle, the orbital fat, and any orbital soft tissue structures should be carefully dissected free from the areas of the blowout fracture using a Freer type elevator. Any pieces of orbital floor that had been dislocated into the maxillary sinus should be removed. Intact orbital floor must be located around all the edges of the displaced blowout fracture. The floor must be explored sufficiently far back into the orbit that the posterior edge of the intact orbital floor beyond the defect can be identified. The ocular globe and its surrounding structures are freed from the fracture site. Proper rotation of the ocular globe after freeing of this orbital soft tissue may be confirmed by an intraoperative forced duction test.

Restoration of the continuity of the orbital floor is required in all orbital floor fractures, except in small fractures where there is no tendency of soft tissue to herniate into the fracture defect. Large bony fragments can sometimes be used to help reconstitute the floor. If available, a Medpor implant, thin silastic sheet, or thin titanium mesh may be used to cover the orbital floor defects. A thinned outer layer calvarial bone graft from the parietal calvarium can also be used. The last resort would be the conchal cartilage of the ear that works acceptably when the other possibilities above are not available. Once the ear is injected with Xylocaine with adrenalin, an incision can be made around the edge of the concha, and a segment of concha removed for the graft.

IV. Maxillary Fractures

The fracture patterns depend on two factors—the site and direction of the violence, and the anatomical lines of weakness of the maxilla.

- **Le Fort I Fracture**. The palatal segment of the complex shears off the remainder through a horizontal line corresponding in level to the floor of the nose and the lower part of each antrum. The palate as a whole can be displaced backwards

- **Hemi Le Fort I Fracture**. On occasion, when the violence has been predominantly unilateral, one-half of the maxilla is fractured in this way, an added fracture line running back along the midline of the hard palate.

- **Le Fort II Fracture**. The maxillary complex is fractured as a whole. The fracture lines run upward, medially across the anterior wall of the antrum toward the infra-orbital foramen on each side, and across the nasal bones to meet in the midline at the glabellar region. Displacement is usually backward, and the inclined plane of the fracture line has the effect of forcing the maxilla downward also. This gives rise to an open bite, as the mandible is pushed down into an open position. The degree of impaction varies greatly, from the massively displaced and impacted fracture to the so-called “floating” fracture where impaction is minimal.

- **Le Fort III Fracture.** The fracture line runs transversely through the zygomaticofrontal suture, through the nasal suture in the midline, and across the floor of the orbits to effectively separate all mid-facial structures from the cranium. The zygomatic arch may or may not be fractured. These fractures are usually minimally displaced and present only with "black eyes" and with subtle occlusal problems.

Any combination of the above fracture patterns is possible.

When the maxilla is displaced as described above, the nasal complex is clearly involved, would be displaced with the fracture, and might in itself be fractured independently.

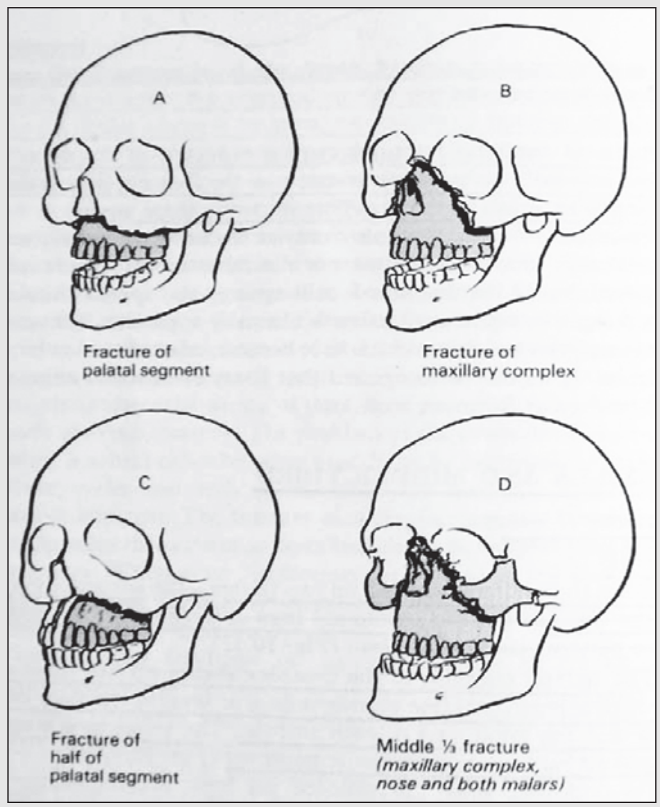

Fig. 17

Fractures of maxillary complex.

A) Le Fort I; B) Le Fort II; C) Hemi Le Fort I; D.) Le Fort II and III (Le Fort III through the Malar bones)

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Clinical Picture

It is often possible to make a diagnosis on inspection alone. The face as a whole, but predominantly the middle third, is diffusely swollen with edema of cheeks and eyelids and looks "like a football."

In the severely displaced fracture, there is an obvious "dish-face" deformity, despite the masking effect of the edema. There is failure of the teeth to occlude properly when the patient closes his mouth. The upper incisors may occlude behind the lower incisors, due to posterior displacement of the maxilla, or they fail to occlude at all because of the presence of an open bite.

Mobility of the maxillary complex is tested by grasping the maxilla just above the incisors between finger and thumb of one hand while the other finger and thumb feel across the bridge of the nose and hold the head steady. The maxilla is rocked backward and forward while independent movement of maxilla is felt for. Movement of the maxilla with detectable movement at the nasal bridge suggests that the entire maxillary complex is fractured, while movement of the maxilla without detectable movement at the nasal bridge suggests a fracture of the palatal segment alone. Each half of the palatal segment is then tested against the other for independent mobility, and loose teeth are tested for to exclude alveolar fractures.

X-Ray Diagnosis

The diagnosis should be made on clinical examination and nearly every case can be diagnosed and treated without the need for an X-ray. The interpretation of the X-ray is often more difficult than that of the clinical examination.

Treatment

These fractures should be treated with the minimum of delay because they tend to fix rapidly in their displaced and often impacted position.

The first step then is to reduce and fix the maxilla. If the maxilla is floating or only slightly impacted, it may be possible to reduce it by finger manipulation. If this fails, it is necessary to disimpact it with disimpaction forceps. The malar is then reduced and, depending on the specific fracture pattern, fixed with interosseous wiring or plating at the zygomaticofrontal suture, the infra-orbital rim, and/or palatal segment to the rest of the maxilla as with a Le Fort I fracture. The maxilla is then reduced on to the mandible and wired (IMF) to the mandible.

Where there has been a longitudinal fracture of the palate, this should be reduced and fixed with a wire across the palate, from the first or second molar to the opposite corresponding molar, with wire fixation through a cut metal tube (like a liver biopsy trocar cut at the appropriate length which will prevent overcorrection). Direct plating of the palate may also be done.

The wires from maxilla to mandible providing accessory fixation can safely be removed in four weeks.

V. Frontal Bone Fractures and Sinus Injuries

Treatment consists of broad exposure of the frontal bone, orbital rims, all fracture sites, and frontal lobes through a coronal incision. Localized incisions or lacerations do not provide the access or flexibility that open treatment often requires. The fractured area is exposed with subperiosteal dissection, and the fracture fragments are repositioned or removed for evaluation of the dura. A precise debridement is performed, and any dural lacerations are closed after evacuation of epidural hematoma. Injuries to the frontal lobe are appropriately managed by removal of devitalized tissue. Frontal sinus fractures demonstrating significant displacement involving the anterior or posterior walls are treated by thorough removal of mucous membrane, light abrasion of the surface of the bony frontal sinus cavity and replacement of the anterior frontal sinus wall bone fragments. The cavity may be obliterated by a cancellous bone graft. The bone fragments are cleared of any remnants of missing or unstable frontal sinus mucosa by thorough removal and light burring of the walls. The bone fragments are replaced and stabilized with small wires or rigid fixation with small plates. Replacement of frontal bone fragments avoids late cranioplasty. Primary reconstruction of the frontal skull is usually safe. Elimination or obliteration of the sinus is not necessary for patients with an isolated fracture. One must always be aware of inferior and medial sinus fractures, as these may involve the nasofrontal duct. The mucous membrane may be locally debrided or removed as necessary; full sinus ablation may not be required unless the function of the duct is compromised. One can always instill sterile methylene blue or fluorescein dye and observe for the dye when gauze is inserted in the nostril.

(**Editor's Note**: Many craniofacial surgeons just obliterate nasofrontal duct with bone graft, muscle, fat or pericranial or galeal flaps and then leave the actual sinus empty after removal of all mucous membrane. Rigid fixation may be just wiring or suturing the fragments together, or even the use of SuperGlue® if small plates and screws are not available.).

Posterior wall frontal sinus fractures are treated as depressed skull fractures, with repair of the dura and appropriate assessment of the frontal lobe, especially if the displacement exceeds the thickness of the bone of the posterior wall. Undisplaced posterior wall fractures may be carefully observed, but meningitis, intracranial abscess, and sinus obstruction are possibilities in any posterior wall injury. If the posterior wall is comminuted with a CSF leak, then cranialization of the sinus should be considered, with removal of the entire posterior wall of the sinus and removal of all the mucosal lining. The duct must be obliterated with bone, muscle, pericranium or galea. Cranialization allows the brain to expand into the sinus area. The anterior table of the sinus must be carefully repaired.

VI. Nose

Patterns of Injury

The nose consists of the nasal bones and the nasal septum, and both may be damaged. Fractures follow two patterns due to lateral violence and head-on violence (Fig. 18).

Lateral violence. The nasal bone on the side of the injury is fractured and displaced towards the septum, the septum is deviated or fractured, and the nasal bone, on the side away from the injury, is fractured and displaced away from the septum so that the upper part of the nose as a whole is deviated.

Head-on violence causes saddling of the nose and broadening of its upper half as a result of the depression and splaying of the fractured nasal bones. Such a displacement naturally cannot take place without severely damaging the septum, and this takes the form of gross buckling of the septum or actual septal fracture.

Clinical Picture

The clinical appearance of the nose and septum is the index of diagnosis. Some swelling is inevitable in patients in whom the diagnosis is being considered, but a change of bridge contour or a new asymmetry are diagnostic, and frequently the best judge of this is the patient himself. In any case, a fractured nose, apart from its septal element, is treated on the grounds of appearance alone, and an X-ray showing a fracture is of no significance unless there is associated nasal deformity.

Even when the nose is not appreciably deviated or depressed, the septum should be examined for hematoma. This shows with gross bulging of the septal mucosa and may be either unilateral or bilateral.

X-ray Diagnosis

The fracture is treated on the basis of the clinical examination, and X-rays are quite unnecessary

Treatment

Nasal fractures requiring reduction **should be treated with the minimum of delay, for they tend to fix in their displaced position in a matter of days**. The surgical approach depends on whether the fracture has resulted in deviation or collapse of the nasal bones.

Deviation

This type of displacement is **caused by lateral violence**, and it can **sometimes be corrected by simple thumb pressure** (Fig. 19) particularly if the fracture is very recent.

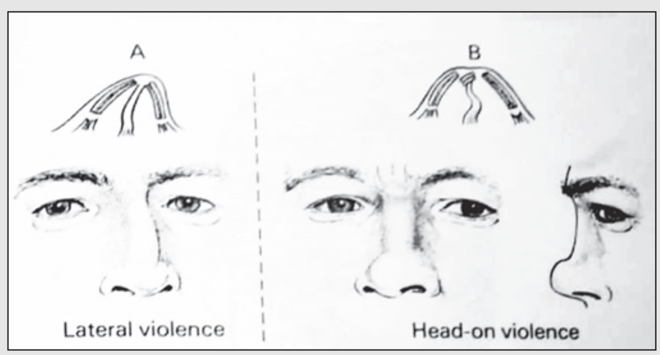

Fig. 18

Patterns of nasal fracture.
A) Pattern from lateral violence; B) pattern from head-on violence

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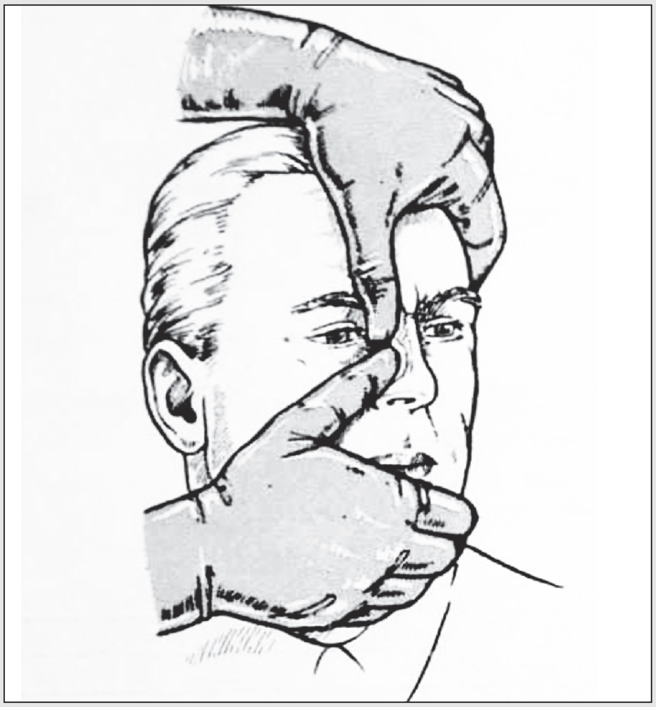

Fig. 19

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Manipulation from inside using Walsham's nasal forceps is sometimes required (Figs. 20-21). With the particular forceps for the side of the nose being manipulated, the slim blade is inserted into the nostril, and the broader blade outside. The blades are closed over the nasal bone. The bone is then mobilized with a rocking movement of the forceps, first laterally and then medially, to disimpact it. The mobilized bones are manipulated with the fingers to mold them into a symmetrical position.

The septum should be inspected and, if necessary, reduced into a central position using Walsham's septal forceps as shown in Figs. 22-23. In practice, reduction of the nasal bones frequently reduces the septal displacement simultaneously.

Collapse

This displacement is the result of head-on violence. It is essential from the point of view of treatment to recognize that the nose cannot collapse without either buckling of the septum or fracture. Straightening or reconstitution of the septum automatically corrects the nasal collapse.

Walsham's septal forceps are most effective for this purpose (Figs. 22-23). The blades of the tightly closed forceps are so made that they remain apart, leaving a gap corresponding to the thickness of the septum. With a blade inserted into each nostril along the nasal floor the forceps are "closed" and swung up towards the nasal bridge. As they move upwards, the blades straighten the septum. Any associated broadening of the nasal bones can be reduced by finger pressure if necessary after mobilization with Walsham's nasal forceps.

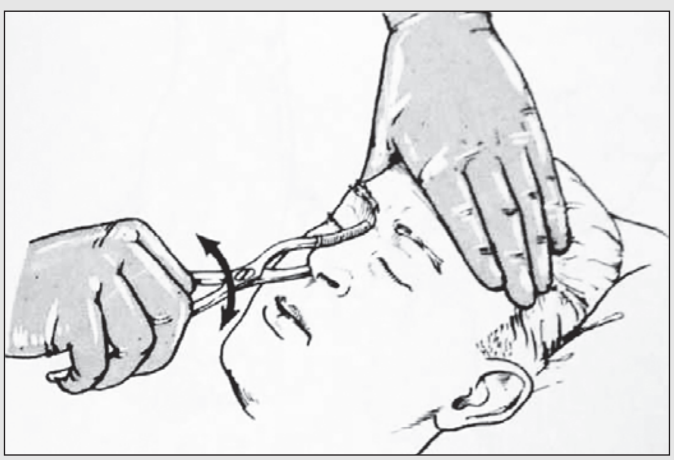

Fig. 20

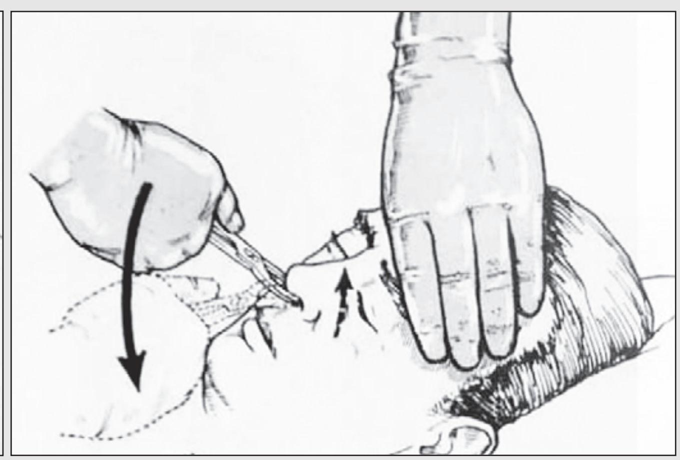

Fig. 21

Method of manipulating a nasal fracture using Walsham's nasal forceps. Note the use of rubber tubing to protect the skin from undue local pressure.

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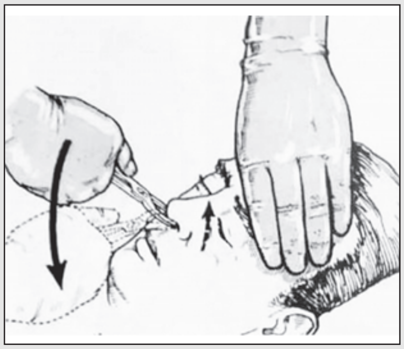

Fig. 22 **Fig. 23**

Nasal Septum Reduction with the Walsham's nasal forceps.

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Septal Hematoma
In a nasal injury, the state of the septum should be examined for hematoma, which if present, must be evacuated by incising the mucosa.

Packing and Immobilization
The nostrils are packed with tulle gras, Vaseline® gauze, Merocel®, or similar non-adherent nasal packing to provide support for the septum in its reduced position. This also helps to prevent the occurrence or recurrence of hematoma. It also provides some counter-pressure for the plaster of Paris immobilizing the nasal bones and prevents them from collapsing inwards. It can be removed in 24 hours.

A plaster of Paris splint molded to the nose (Fig. 24) is left in place for a week.

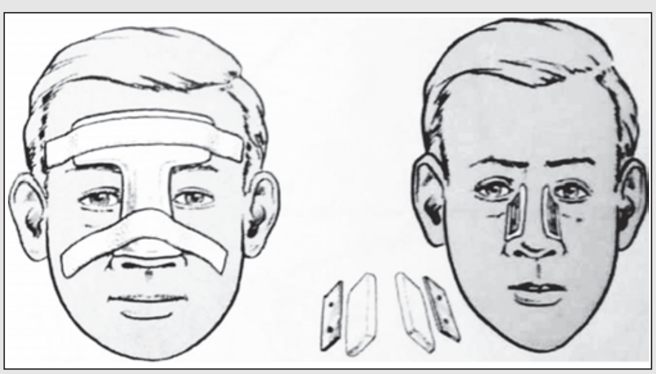

Fig. 24

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VII. Skull Fractures

The **skull** is divided into the cranium, which contains the brain, and the facial bones. The **cranium** is made up of eight bones: two parietal and two temporal bones, and one frontal, one occipital, one ethmoid, and one sphenoid bone. The superior rounded portion of the cranium is the **vault**. In the adult, this bone consists of firm inner and outer tables with cancellous bone, or diploe, lying between them. The **base of the skull** forms the floor of the cranial cavity and separates the brain from other facial structures. The five bones that make up the skull base are the ethmoid, sphenoid, occipital, paired frontal, and paired parietal bones. The skull base can be subdivided into three regions: anterior, middle, and posterior cranial fossae.

Fractures of the cranium are referred to as "skull fractures".

Classification of Skull Fracture
Fractures are described by:

- The pattern of the fracture (linear, stellate/radiating or comminuted).
- The term "depressed" is used to describe an inward displacement of a portion of the vault.
- The name of the bone involved.
- The term 'basilar" is used for fractures traversing the base of the skull.
- "Compound fracture" describes a scalp laceration in continuity with the fracture–an open fracture.

A fracture can, therefore, be a comminuted, depressed, compound fracture of the parietal bone.

Mechanisms of Brain Injury
The most critical aspect of head trauma is what happens to the brain.

The immediate brain damage that results from head trauma is dependent upon the force applied to the head, the size of the area of its application, and whether the head is fixed or freely movable. The damage can be caused directly by the injuring object, the effects of force transmitted through the skull to the brain, a portion of the skull lacerating the brain, and/or the effects of acceleration and deceleration (indirect forces) of the head on the brain confined by the semi-rigid dura and rigid skull. The resulting neurologic dysfunction relates to the area of the brain involved and the degree of damage caused by the direct or the indirect forces. Delayed brain damage is mainly caused by the reactions of the tissues within the skull.

A force applied to the skull may have a local effect of a laceration of the scalp, a fracture of the skull, laceration and contusion of the brain, or it may have a more generalized effect caused by the energy transmitted through a semisolid substance when the brain is driven against the inner portion of the skull and edges of the dura—the stretching and tearing effect of the resulting internal movement of tissue, and the loss of function by the compressive effect of the torque or stress applied to the upper portion of the midbrain with rotational movement of the brain. These mechanisms result in the clinical conditions of cerebral concussion, cerebral contusion, and cerebral laceration. They, along with the effect of alteration in total function of the nervous system, the alterations in cerebral circulation, the changes in respiration and vasomotor control, and the reaction of the nervous system tissue to injury, are the main reasons for the clinical syndromes seen in the head injured patient.

Treatment of Skull Fractures
Most skull fractures require no treatment e.g. closed linear fractures without any depression, intra- or extra-cranial hematoma.

Compound fractures must be treated. Compound fractures of the vault vary in severity, from severe crushes, with the escape of cerebral substance, to relatively insignificant compound fissured fractures. High-speed motorcycle accidents produce the worst examples of severe frontal crushes, and many are rapidly fatal. Severe cases that survive exhibit serious disability, such as hemiplegia or mental deterioration from loss of cerebral substance. The incidence of these injuries has been reduced by the wearing of crash helmets. When the velocity of impact is low, large compound depressions can occur with less diffuse cerebral injury, particularly when produced by blows from the side—in which the midline septum of the falx will limit the associated brain displacement.

Treatment of Compound Fractures: The replacement of large, loose skull fragments in the area of a compound fracture depends upon the degree of contamination, the integrity of the dura, and the area of the skull involved. If there is any doubt, it is best to remove all fragments of a compound fracture. The resultant bony defect can be closed secondarily making use of plate and screws, wires, SuperGlue®, or, if available, bone cement can be used and shaped into the defect and screwed or wired in position (caution must be taken to keep the brain protected from the heating reaction as the cement sets; it should be shaped in the actual bony defect and then removed while the chemical hardening process takes place). All compound skull fractures need prophylactic antibiotics. Staphylococcus aureus should be covered (e.g. Augmentin—amoxicillin and clavulanate) irrespective of whether the dura is lacerated or intact.

- As a general rule, it is best to elevate all **depressed fractures**, but a decision should depend on the size of the depressed segment, the depth of depression, the area of the skull depressed, and the ability to be certain that the dura has not been torn. In the following situations, elevation is required:
  - Any fragment which has been depressed more than a centimeter.
  - A fragment overlying the speech or motor area.
  - Most small fragments that appear sharp on x-ray usually should be elevated, since they may tear the dura and cause damage to the brain.
  - Special caution should be exercised when the depression overlies a venous sinus e.g. the sagittal sinus. Elevation might tear the sinus or cause a clotted tear to bleed anew.
  - Bleeding can be controlled by pressure for several minutes and with Surgicel®, Gelfoam® or Thrombin®-soaked Gelfoam® if these are available.
  - Dural tears should be repaired with 4-0 or 5-0 Neurolon® or Vicryl® on a small taper needle.

- **Closed depressed fractures of the vault** are rare. The treatment of a closed depressed fracture depends on the extent and site of the depression. Operation is not indicated if the fracture is small, provided that there are no sharp spicules of bone that have penetrated the dura and the fracture does not overlie an important cerebral area. Surgical intervention is required if the fracture lies over the speech or motor areas, or if x-rays suggest that spicules may have penetrated the dura. In such cases, scarring may cause adhesions between the brain and membranes, with the risk of subsequent epilepsy.

Operative Treatment: Trephine, burr holes adjacent to the fracture, and elevate the depressed bone should be all that is needed in most cases.

- The **combination of a depressed and compound fracture** will always require elevation to be certain that contamination has not been driven through the dura into the subarachnoid space or the brain. The scalp is relatively non- elastic, and an injury sufficient to fracture and depress the bone is almost certain to lacerate the scalp. Hematomas in the scalp sometimes simulate depressed fractures. Clotted blood in the margin of a hematoma may, on palpation, resemble the edge of a fractured zone, but the edge of the clot can sometimes be indented. Often X-ray is required to distinguish the two conditions.

- **Clinical Features:** An irregular lacerated wound of the scalp is often associated with a boggy sub-galeal swelling produced by blood escaping from the fracture line, which is partly exposed in the depth of the wound. A normal suture line should never be mistaken for a fissured fracture. A suture line is irregular and free from oozing blood. All scalp wounds should be explored adequately in order to discover and exclude a fracture. In compound depressed fractures, the fracture lines extend far laterally beyond the limits of the surface wound; this must be taken into consideration in planning the requisite exploration.

Operative Treatment: Operation should be undertaken as soon as possible to avoid infection, unless the patient's condition is so precarious that delay is advisable. If delay is advisable, then antibiotics should be given in full doses. The field of operation is infiltrated with 1:100,000 adrenalin in saline or 1% Lidocaine with adrenalin (1:100,000) to diminish scalp bleeding. Small compound fissure fractures may be exposed by extending the primary scalp wound after excision of its edges. Extensive depressions are exposed by forming a large horseshoe scalp flap around the margins of the fracture site. These flaps are the basic neurosurgical flaps based on one of the major scalp arteries.

Smaller depressions: A burr hole is formed beside the fracture to permit unlocking of the fractured particles. Bone that has been contaminated but intact is not opened. Foreign material/foreign bodies and damaged brain tissue are removed by irrigation and careful suction, and the dura is then sutured. Clean portions of bone may now be molded into place and then wound is sutured and antibiotic treatment commenced. SuperGlue® will hold small pieces of bone together. As mentioned below, large bony fragments should be reduced and wired or plated together.

Extensive depressions: To merely trephine and elevate the depressed bone is quite inadequate in

Fig. 25

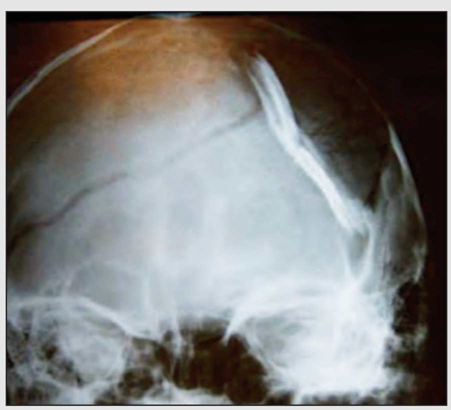


Fig. 26

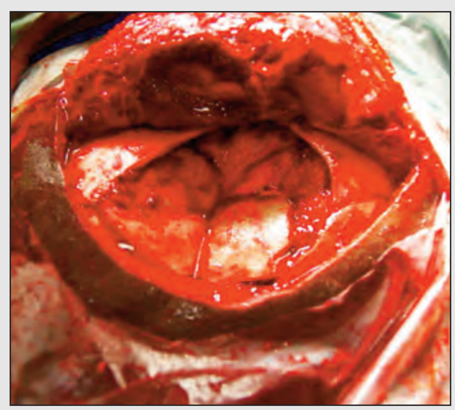


Fig. 27

Open and significantly depressed skull fracture with dural laceration.
Horseshoe-curved incision will give good exposure. A burr hole was needed adjacent to the fracture to enable the elevation of fragments and evacuation of hematoma. Dura repaired. Bone fragments were plated together with small plates. Where these are not available, wires or even sutures may be used.

this case, as a proper examination of the brain and membranes will not possible. An osteoplastic flap that includes the fracture is raised. The depressed bone is either molded into position or removed with suitable forceps. This osteoplastic flap is best made with a craniotome, though most hospitals may not have this. Several burr holes may be made, a Gigli saw passed between holes, and a flap raised. The dura is examined, penetrating spicules are removed, and the dura is then opened. Pulped brain is carefully removed by gentle suction at the site of penetration. Adhesions are separated. Hemostasis is secured, and the dura is carefully sutured. A pericranial or galeal graft may be used if dura is missing. The bone flap is then replaced and fixed with wires, plates, or, if necessary, sutures.

- **Head Wounds due to Missiles.** The outcome depends on the explosive impact of the missile in the cranium. This is the most common cause of fatality, due to the relation of the wound track to the great vessels and the ventricles. Through-and-through tracks, from side to side or front to back may be survivable. Patients with non-fatal injuries can be transported to a suitable hospital. Projection of the swollen brain through the dura at the site of entry or exit forms a hernia cerebri, which seals off the subarachnoid space during transport. A pressure dressing is applied.

  Operative treatment, if possible in your hospital, consists of the excision of the surface wound with suction, cleansing, and removal of foreign material from the track. The dura is closed by suture or grafting at entry and exit points. Antibiotics are always used. Mannitol® and steroids may be indicated.

- **Penetrating wounds** produced by sticks are always to be regarded very seriously. Although scissors or pokers may enter the roof of the orbit when a child falls, they can be successfully withdrawn. A stick that goes in through the orbital roof, or backward behind the orbit into the temporal lobe, cannot be withdrawn intact. The portions that are left behind may, from the previous contact with the ground, become infected with gas gangrene or tetanus, with probable fatal infection.

- **Fractures of the base of the skull** are usually produced by compression of the sphere and extension of fissures radiating from the vault. The complex fracture lines thus produced are accounted for by deflection of the fissure from the buttresses of the petrous bones, the basi-sphenoid, and the sphenoid wings, which can only be crossed respectively at the weak points formed by the cavities of the middle ear, the sphenoidal air sinus, and the sphenoidal fissure. Elsewhere, the fracture lines tend to wander into the foramina for the exit of cranial nerves. The fractures become compound at the middle ear, accessory air sinuses, and the cribriform plates, but the ominous reputation of fractures of the base is derived from the severe brain injury accompanying the fracture rather than from the risk of sepsis, which has been greatly reduced by modern methods of treatment.

  Treatment of a fractured base is that of the associated brain injury. The patient is propped up to lower pressure and diminish the escape of cerebrospinal fluid. Antibiotics are administered. If the discharge persists undiminished for ten days, fascial repair of the dural gap is required. The skull is X-rayed to see if an intracranial aerocele (pocket or cyst filled with air) has developed in association with cerebrospinal rhinorrhea. Air collections may be observed, either in the substance of the frontal lobe or in the subarachnoid space, occasionally filling the ventricle. Sepsis does not occur at first, because the upper respiratory air cells are sterile, but later, septic granulation tissue forms outside the dura. The moment the discharge of cerebrospinal fluid stops, meningitis arises from this source; thus, early repair is necessary.

- **Fractures of the skull that traverse one or more of the paranasal sinuses, the mastoid air cells, or the middle ear** are compound skull injuries that are not as obvious as a penetrating injury. The presence of cerebrospinal fluid drainage from the nose or ear is an indication that this type of open head injury has occurred. It signifies a rupture of the protective meningeal coverings of the brain and requires observation and prophylactic antibiotics to be certain that infection of the subarachnoid space or brain does not occur. The post-traumatic cerebrospinal fluid fistula of the ear almost always heals within a few days, but healing of rhinorrhea may be more difficult. It is important in both injuries that the patient remains under medical supervision until such drainage ceases. Usually, if either otorrhea or rhinorrhea continues for more than 10 to 14 days, surgical repair of the dural tear is necessary.

Antibiotic therapy in Skull Fractures

Staphylococcus should be covered with all compound fractures. In anterior base fractures, it is important to also cover Streptococcus. In general, 24-hour cover is adequate. In severely contaminated wounds or gunshot wounds, five days of coverage is needed, and guided according to wound cultures as available.

Anti-Convulsive Drugs in Skull Fractures

There is no standard regimen. But, it is recommended that Epanutin® or Epilim® (Dilantin®) is given if the dura is violated (not for skull base or posterior fossa fractures). The recommendation varies from a loading dose and a week's treatment up to one month's treatment. This is to prevent early-onset epilepsy, but will not prevent late-onset epilepsy. In severe brain damage, gunshot wound or severe penetrating wounds, long-term anti-convulsive therapy is recommended. If the patient has had a convulsion, the standard period of treatment is two years.

Chapter 8
Cutaneous Lesions

Paul Lim

Malignant Neoplasms

Marjolin Ulcer
(see also Chapter 2 on Chronic wounds)

Marjolin ulcers are malignant neoplasms that develop in chronic wounds. It was originally described as a squamous cell carcinoma developing in a chronic unstable burn scar. However, the eponym is used to describe any malignant neoplasm arising in a chronic wound. These can arise in cutaneous sinuses associated with chronic osteomyelitis. They also arise in pressure sores. Squamous cell carcinoma is the type most commonly found and is typically a very aggressive form with patients often presenting with metastatic disease. For this reason, closing chronic wounds is not simply for improving quality of life but may have impact on quantity of life, as well, by preventing lethal Marjolin ulcers.

Prior to definitive closure, biopsy should be performed in wounds of greater than ten years' duration or with suspicious qualities such as exuberant or nodular granulation tissue, increased pain, foul odor, new bleeding, etc. If the biopsy is positive for malignancy, then a search for metastatic disease should be aggressively pursued to guide appropriate treatment.

Treatment: Wide local excision of the primary tumor should be performed to obtain negative margins (2 cm margins). Sufficient deep margins may require resection of muscle and/or bone with flap coverage. Deep fascia must always be taken with the resected specimen. Extremity amputation may be necessary for complete resection and potential cure. If there is clinically suspicious palpable lymphadenopathy in the associated nodal basin, then a lymph node dissection should be performed. Radiation therapy is indicated for nodes positive for malignancy.

Acral Lentiginous Melanoma—Subungual
This is a subtype of melanoma found on the sole of the foot, palm of the hand, or beneath the finger nail or toe nail. Subungual ("beneath the nail") melanomas have a worse prognosis than other cutaneous melanomas. Signs and symptoms include dark nail matrix pigmentation, pain, swelling, nail deformity, ulceration, bleeding. They are commonly misdiagnosed as fungal infections or other inflammatory conditions leading to delay in diagnosis and treatment.

Treatment: Biopsy, metastatic workup and treatment of regional lymph nodes as described in chapter 38 on Hand Tumors should be followed. For the primary tumor of the hand, instead of basing resection on radial margins, amputation through the joint just proximal to the lesion should be done. For the thumb, if the distal phalanx has been amputated, then the first web space should be deepened at a later stage with a 4 flap Z-plasty to improve grip and function. (See chapter 12 on Burn Reconstruction). For the foot, resection should be done through the metatarsophalangeal joint with a plantar flap for closure if possible. Regional lymph node dissection should be carried out if there is questionable adenopathy.

Kaposi's Sarcoma
Any facial lesion that is difficult to diagnose should be biopsied. The appearance of the lesion in Fig. 1 was not diagnostic. On biopsy it was found to be Kaposi sarcoma in a patient that did not know he

Fig. 1

had AIDS. When Kaposi sarcoma is associated with AIDS, the patient should be placed on highly active anti-retroviral therapy (HAART).

Vascular Anomalies

Hemangioma

Hemangiomas are vascular neoplasms and are the most common vascular anomaly of infancy. Cutaneous hemangiomas are typically not seen at birth but become visible in the early neonatal period as erythematous macules or telangiectasia surrounded by a pale halo. Most occur in the head and neck area but can be found in any other region.

Natural History

- Proliferative phase: Lesions rapidly grow, usually reaching their maximum size by 9-12 months of age, but this phase may end earlier or later (Fig. 2).

- Involutional phase: Usually begins at 12-18 months of age with complete involution occurring in approximately 10% of lesions per year such that up to 90% have involuted by 9 years of age (Fig. 3). Even with "complete" involution, there may be a residual deformity as the hemangioma is replaced with fibrofatty stroma.

Diagnosis: Most cutaneous hemangiomas can be diagnosed by history and physical examination. Doppler ultrasound may be able to distinguish hemangioma versus vascular malformation. For vascular lesions, an MRI is typically used to evaluate characteristics of vascular malformations for treatment planning, but an MRI can also be used to diagnose a vascular anomaly.

Complications

- **Ulceration**. It is the most common complication of hemangiomas and usually occurs with lesions in the perineal region (Figs. 4, 5). Typical local wound care should be instituted, such as topical antibiotic ointment. Pulsed-dye laser treatment effectively heals ulceration but is generally not available in developing countries.

- **Bleeding**. It usually responds to direct pressure. Surgical excision may need to be done if bleeding persists.

- **Visual obstruction**. Deprivation amblyopia of infancy and/or astigmatism due to pressure on the cornea are potential complications of eyelid hemangiomas. These should be treated urgently and aggressively to avoid these ocular complications.

- **Upper airway obstruction**. Subglottic hemangioma is a rare cause of upper airway obstruction in children, but warrants close

Fig. 2
Superficial hemangioma in proliferative phase.

Fig. 3
Young girl with a hemangioma of the upper lip which did not involute substantially.

Ulceration secondary to involution or secondary to local medicine applied to the wound, "Native Medicine." History was not helpful.

Fig. 4

Fig. 5

Ulcerated hemangioma on left gluteal region.

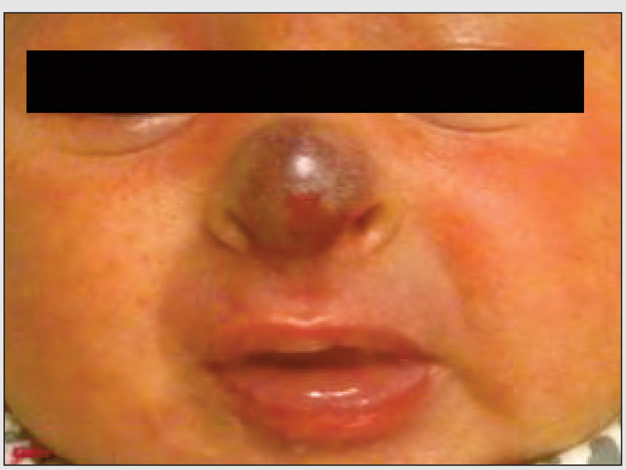


Fig. 6

Nasal tip hemangioma in a one-month old child.

observation. Most have associated "beard area" or cutaneous neck hemangiomas. Aggressive treatment is needed if any signs of airway compromise occur. Tracheostomy may be necessary while pharmacologic treatment of the hemangioma is initiated.

- **Auditory canal obstruction**. Parotid hemangiomas can obstruct the external auditory canal so should be treated to avoid conductive hearing loss.

- **Tethered spinal cord**. Cutaneous hemangiomas overlying the lumbosacral spine or the midline gluteal region are associated with tethered spinal cords which may lead to lower body paresis. MRI of the spine is indicated with these hemangiomas.

- **Nasal tip lesion**. Large hemangiomas can cause significant, permanent nasal alar cartilage deformities (Fig. 6). This is not a significant functional deformity in the classic medical sense; however, it can significantly impair social integration depending on the degree of deformity. Pharmacologic treatment during the proliferative phase may cause complete regression. If not, surgical treatment at approximately one year of age is performed (assuming safe anesthesia and a surgeon experienced with open rhinoplasty operations).

Treatment

- **Observation**. Observation is typically warranted initially with uncomplicated hemangiomas, as most will involute. When the child has self-awareness and is socializing more (4-5 years old), then intervention may be considered for psychosocial reasons if the lesion persists.

- **Systemic beta-blocker**. Oral propranolol is a novel treatment for complicated hemangiomas in the proliferative phase. The first reports of its efficacy were published in 2008. There are risks of bradycardia, hypotension, and/or hypoglycemia—particularly for neonates—so patients are closely monitored on initiation of therapy (inpatient monitoring for neonates). It appears to be more effective than the more traditional systemic corticosteroid treatment, and certainly has fewer side effects. It has effectively replaced corticosteroids at the author's institution as the medical treatment for hemangiomas.

Treatment guidelines for propranolol:

- Baseline blood pressure, temperature, pulse and respiratory rate; height and weight.
- For neonates (< 1 month old): 24-hour inpatient monitoring for initiation of treatment, including continuous cardiac monitoring and frequent BP measurements.
- For infants (> 1 month old): 4 hour monitoring in outpatient clinic including VS every hour.
- Propranolol 0.83 mg/kg dose orally every 8 hours (2.5 mg/kg/day) for initial dosing, adjust to keep at 2-3 mg/kg/day as patients gain weight.
- If the commercially prepared oral solution is not available, a solution may be prepared using the pill form at 4mg/ml
- Parents must be instructed on how to dose it in suspension form, as the crushed pill rapidly settles, giving potentially hazardous variable dosing.
- Return to clinic every two weeks to weigh patient, check vital signs and adjust dosing.
- Typical treatment course is 4-5 months.
- Taper medication after 4-5 months by decreasing dose size in half and discontinuing after 1 month.

- **Topical beta-blocker.** Ophthalmic timolol applied topically has been reported recently for the treatment of complicated hemangiomas in the proliferative phase. These have been very small in number—anecdotal case reports. The idea is very appealing as there would be virtually no risk of systemic side effects. 1-2 drops on the lesion, gently massaged in by a parent's finger, done twice per day is the usual protocol. If there is no effect by 10 weeks of treatment, then an alternative treatment should be used. If signs of involution or non-proliferation occur by 10 weeks, then continue treatment until the patient is 10-12 months old.

- **Systemic steroids**. Traditionally, the mainstay of pharmacologic treatment of hemangiomas was corticosteroids. If oral propranolol is not available, prednisone is still a reasonable alternative. Short-term, typically transient, side effects: Cushingoid facies, adrenal suppression, personality changes, gastric irritation, fungal infections, hypertension, weight gain, and diminished height.

  Treatment guidelines:

  - Prednisone 2-3 mg/kg/day for a 2-week trial
  - If evidence of regression or stabilization, continue for 2 more weeks, then taper over several months with completion of treatment by 1 year of age.

- **Intralesional steroids**. This has been successfully used to stop progression and promote involution in complicated hemangiomas, but the author **does not recommend its use** for this text (in areas where most of us work) because of the relatively high risk-benefit ratio, as it usually requires general anesthesia (especially for eyelid lesions) and can cause devastating complications such as blindness (particulate embolization and occlusion of the retinal artery when injecting eye lid lesions). **Propranolol or systemic corticosteroids are better alternatives**.

- **Surgical excision**. Relative indications for surgical excision include lesions that will likely have a deforming residual scar, cause psychosocial impairment, bleed, ulcerate, or may result in

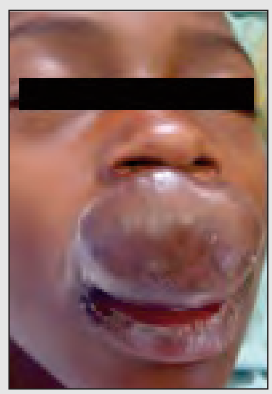


Fig. 7

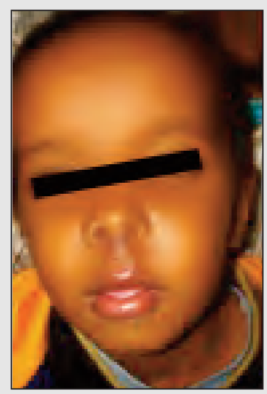


Fig. 8

Large residual hemangioma.

Lip aesthetic resection done while preserving the philtrum columns and Cupid's bow. Segments of lip were removed from lateral to each philtrum column, with reconstruction of new philtral columns on each side. The mid-line skin between the philtral columns was preserved. As much mucosa as possible was saved laterally. Lateral orbicularis muscle was approximated in the midline. The post-operative picture was taken over a year after surgery.

Fig. 9

Fig. 10

Fig. 11

Residual hemangioma—Complete resection not possible.

Patient scheduled to return for evaluation and likely removal of more muscle and Karapandzic procedure and possible Abbé flap. The hemangioma in this case involved most of the muscle of the lip. Cheek advancement flaps were used with a Burow's triangle on the patient's left side. Patient will need secondary surgery.

Fig. 12

Fig. 13

Fig. 14

Fig. 15

(L to R) Pre-op; Intra-op; End of surgery; Two months postop.

Large residual hemangioma in a 10 year old girl required a large resection of all involved tissue, bilateral Burow's triangle excision, partial Karapandzic flap on right side and Abbé-Estlander flap on left.

airway or visual obstruction. Failure of non-surgical treatment or lack of suspected regression and involution may indicate need for surgical excision, especially if the lesion is in a conspicuous or easily damaged location. For small lesions, a circular excision with a single intradermal purse-string closure is a strategy that can be employed to minimize scar length and size. This can be the definitive treatment or can later be excised and closed with a linear scar if that would improve cosmesis. Larger residual hemangioma excisions may require flap reconstruction.

Vascular Malformations

They are present at birth, grow proportionately with the child, and do not regress or involute. Indeed, they may expand with hormonal changes such as with puberty or pregnancy. Clinical signs include firm lesions that are compressible and nontender. High-flow lesions (arterial malformations, arteriovenous malformations, and arteriovenous fistulas) may have bruits, palpable pulses, and/or thrills. Low-flow lesions include capillary, lymphatic, venous malformations.

Ultrasound with Doppler may be useful for diagnostic purposes of superficial lesions. Other sophisticated diagnostic techniques will likely not be available. Surgery should not be contemplated for extensive arterial or venous lesions unless advanced imaging devices are available.

Capillary Malformation
(Port-Wine Stain or Nevus Flammeus)

These are flat, cutaneous lesions often found on the face and neck, present at birth with a pink to purple color that become more “cobblestoned” in appearance with age. These do not typically cause any functional problems (except appearance) but are associated with other disorders:

- Facial lesions: glaucoma, retinal arteriovenous malformations
- Occipital lesions: meningoencephaloceles
- Midline lumbar lesions: spinal dysraphism, lipomeningocele, tethered spinal cord

Treatment: If lasers are not available, then no treatment is usually warranted except for addressing associated disorders.

Lymphatic Malformations

Lymphatic malformations are low-flow, distended lymphatic channels, are present at birth, and become more prominent with age. These are not neoplasms though they are often erroneously referred to as “lymphangiomas.” When in the neck region or axilla they have been commonly and traditionally referred to as “cystic hygroma.”

Presentation

They may appear as cool, soft, smooth, translucent masses located beneath normal or bluish-colored skin. They are single or multi-cystic either separate or interconnected often associated with hypertrophy of soft tissue and bone.

Location

The most common sites are the neck, axilla, and chest. In the neck, they can unexpectedly enlarge with infection and cause airway obstruction.

Natural History

As with other vascular malformations, these **do not** involute spontaneously. They can change in size over time with the presence or resolution of infection or with the opening of lymphatic venous anastomoses. This is distinguished from hemangiomas, which follow a typical, consistent pattern of proliferation and involution.

Fig. 16 **Fig. 17**

Large lymphangioma or Cystic Hygroma which extended into chest and up along cranial nerve and caused airway obstruction.

(L to R) Before and after surgery

Fig. 18

Some lesions are deep in the cheek and are difficult to remove safely.

Complications

- **Infection**, often by beta-streptococcus, is a common complication requiring antibiotic treatment. Transient enlargement may indicate infection.
- **Bleeding** may occur into the malformed lymphatic channels.
- **Cervicofacial lesions** may cause abnormal speech, airway compromise, and mandibular body overgrowth. Complete resection is challenging as these complications need to be managed along with the additional risk of cranial nerve damage with resection.

Treatment

- **Observation**. Resolution occurs in a small percentage without intervention, often by age 5 years, presumably from changes in lymphatic and venous connections or from repeated episodes of inflammation and subsequent scarring. Expectant management is reasonable for the first few years of age unless complications occur. Compression garments can be used to control swelling in extremities. Complete or staged excisions can be performed successfully.

- **Surgery**. As mentioned above, surgical resection is a challenging procedure for a number of reasons. The surgery, especially in the neck, requires patience and a thorough knowledge of anatomy. Large neck masses may take many hours to completely remove. If not removed completely, these will recur. Furthermore, the multicystic masses are extremely thin, making the boundaries difficult to appreciate without magnification and good lighting. This surgery is very tedious. A head and neck anatomy atlas should be made available in the OR and referenced frequently. Not only do these masses wrap around the cranial nerves in the upper neck, but they also may extend into the upper chest; in rare circumstances, a thoracotomy may be necessary for complete resection. **It is also important that the surgeon have a capable assistant**. These masses always extend out further and deeper than what the physical examination would indicate. When masses extend to the opposite side or from axilla to neck or vice-versa, these excisions can be staged with careful labeling of where the excision stopped. The editor prefers to do these in one stage, but these should be scheduled as the first and only case of the day. The danger is getting into a hurry and leaving residual tissue behind. These will recur (See Chapter 9). These lymphatic lesions may be microcystic or macrocystic. The lesions with the larger cystic areas are easier to excise without leaving the small, microcystic areas behind.

Venous Malformations

These are low-flow lesions, present at birth as a faint blue patch or soft mass. Symptoms which may occur include pain and swelling with dependent positioning, exertion, or from thrombosis. Bleeding and symptoms from compression of adjacent structures may also occur.

Treatment

Complete surgical resection is typically not recommended as cutaneous venous malformations often have underlying skeletal involvement requiring very debilitating operations to completely resect them (for instance, extremity amputation). If asymptomatic, no treatment should be done. Compressive garments are used for symptomatic swelling and aspirin for thrombosis prophylaxis. Percutaneous sclerotherapy has been used successfully to treat lesions but should be done under fluoroscopic or Doppler ultrasound guidance to reduce tissue necrosis risk and systemic effects. Compartmentalization of these by large sutures has been recommended. After the lesion is compartmentalized, a sclerosing agent is injected. Image-guided embolization can also be used for treatment if available.

Arteriovenous Malformations
(See also chapter 37 Hand Tumors)

Arteriovenous malformations (AVMs) are high-flow lesions composed of direct vascular connections between arteries and veins. They are present at birth but may not be apparent until they increase with size with hormonal changes such as during puberty or pregnancy. Symptoms may include pain, redness, swelling, hyperhidrosis, ulceration, bleeding. Signs include bruits, thrills, cutaneous blush, increased warmth and hypertrichosis—excessive hair growth. Large AVMs may cause congestive heart failure or massive hemorrhage. Most head and neck lesions are in the mid-face, making surgical resection very problematic.

Imaging will not be possible in most district hospitals. Ultrasound with color flow Doppler imaging can be used diagnostically in the absence of

MRI availability. MRI, if available, provides the most information for both confirming the diagnosis and planning treatment. Angiography may also be helpful for treatment planning.

Treatment

These **should not be attempted** except where diagnostic, radiological and surgical personnel and equipment are available. Most of us will not have access to the following procedures. Refer these cases if possible.

Options include complete excision of lesion and feeding vessels, combined embolization before surgical excision, or complete embolization of lesion. Embolization alone can also be used for palliative treatment. If done preoperatively to reduce anticipated blood loss, the resection should be done within 24-48 hours of the embolization to avoid rapid expansion from collaterals. Proximal ligation of feeding vessels should not be done as a definitive treatment modality, as it would create a more difficult problem from collateral circulation recruitment of the lesion. Even in the best of circumstances (having embolization equipment and expertise available), AVMs are very difficult lesions to surgically resect due to significant blood loss and incomplete resection with multiple recurrences. They may also be complicated by the need for extensive soft tissue reconstructions.

Chapter 9
Head and Neck Tumors

Peter M. Nthumba

Malignant Neoplasms
Lesions of any size in the head and neck may have a significant effect on cosmesis, speech, respiration, and alimentation, and they can significantly impact a patient's quality of life.

Head and neck cancers include squamous cell carcinoma (SCC), basal cell carcinoma (BCC), and malignant melanoma, among others. Adenoid cystic carcinoma of salivary glands is a tumor with poor prognosis because of its mode of spread, and early lung metastasis.

Wide excision of lesions is a challenge in this region, as these margins would encroach on important structures. Prevention of local recurrence is a significant challenge. Frequent recurrence and regional nodal metastases lead to a poor prognosis, especially with aggressive tumors.

Radiotherapy and chemotherapy are showing improved outcomes as primary treatment modalities, with results comparable to surgical resections. These are modalities that will continue to be largely inaccessible to many in the sub- Saharan region, and surgery, therefore, remains the main treatment modality for the majority of patients.

Plastic surgeons are generally not involved in the treatment of thyroid, parathyroid or laryngeal cancers, and these will not be discussed in this chapter. Plastic surgeons will be involved in the management of salivary gland tumors, especially of the parotid gland, because of the defect that is left following resection of a malignancy and management of the facial nerve that may be involved in resection.

Physical Examination
Studies have suggested that even in the West, patients with head and neck cancer make more than 10 hospital/physician visits prior to the initial diagnosis of a cancer. In Sub-Saharan Africa, patients frequently present with huge or extensive tumors, with a history of having presented to healthcare facilities or physicians at some point in the past. While early diagnosis of malignancy improves outcomes, failure to recognize a malignancy will lead to increased morbidity and mortality associated with a late presentation.

A careful systematic history and physical examination will reveal head and neck pathology.

Scalp—look for nodules, ulcers, pigmented lesions, etc.

Cranial nerves form an important part of head and neck examination; occult malignancies may cause nerve palsies that make it easy for the physician to locate them. Facial nerve palsy in the background of a parotid mass makes it more likely to be a malignancy, rather than a benign tumor.

Oral cavity—halitosis, bad breath, will usually be present in patients with an upper aero-digestive malignancy. Bi-manual palpation of the oral cavity may reveal an indurated area that would be the seat of a lesion.

Neck—palpation reveals the presence of any enlarged nodes or other masses. Palpate for thrills and auscultate for bruits.

N.B.: up to 5% of patients with head and neck cancer have a synchronous squamous cell carcinoma of the head and neck, esophagus or lungs. Where available, endoscopy should be performed (esophagoscopy, direct laryngoscopy, and bronchoscopy) in patients with a known head and neck cancer. The tonsils, base of tongue and piriform sinuses form the most common sites for occult primary tumors.

Biopsy
Biopsies form a core part of the management of head and neck tumors, as they determine the operation needed, the extent of resection, and the need for neck dissection. As a rule, biopsies should be performed away from any necrotic or infected areas. They should include some adjacent normal tissue.

Fine needle aspirate (FNA)—although dependent on the physician's accuracy and the pathologist's experience in cytopathology, this is an excellent initial modality for many head and neck tumors. FNA in good hands has a false negative rate of less than 7%.

Punch biopsy—useful for mucosal lesions.

Core and ***open biopsies*** are invasive, and most authors recommend a resection soon after, or even immediately. These give more tissue, and, thus, the diagnosis is more definite, allowing for appropriate treatment.

Squamous cell carcinomas (SCC) are the most common head and neck cancers. Histologic grade (degree of differentiation) has been used to prognosticate in the past. Perineural spread, lymphatic invasion, and tumor spread beyond the lymph node capsule have been found to more consistently predict prognosis.

Tumors of the Head and Neck Region

Because of its anatomy, the head and neck region has a diversity of tumors, both benign and malignant. A number of these tumors are rare. Head and neck cancer is more common in males than in females, and occurs in older age groups.

Head and neck primary cutaneous malignancies constitute 20% of all skin malignancies in the African population; 27% of all primary skin squamous cell carcinomas occur in this region. In the USA, head and neck cancers consist of 2-3% of all cancers and about 50% of patients have metastatic

Fig. 1

Late-presentation untreatable squamous cell carcinoma.

region are squamous cell carcinomas.\antibiotic ointment. Pulsed-dye laser treatment effectively heals ulceration but is generally not available in developing countries.

Treatment Options

Surgical treatment of head and neck cancer should be offered to patients with:

1. Curative intent.
2. Significant palliative benefit.

The absence of supportive/adjuvant therapy should not form the basis for precluding surgical treatment for patients who would otherwise benefit from such care. Radiation therapy and chemotherapy remain difficult to access in most parts of Sub-Saharan Africa; most facilities have to refer their patients to a central national site. This puts a strain on resources, and there are long waiting times between intervention and treatment, often leading to recurrences.

Lymphatic Drainage

The lymphatic drainage of the head and neck is predictable. The knowledge of patterns of drainage will help the clinician determine the primary tumor, in most instances, when a tumor first presents as a neck nodal metastasis.

Neck nodes have been grouped together in levels (I to VI):

I—Ia: Submental; Ib: Submandibular.

II—IIa: Upper jugular (anterior to XI cranial nerve); IIb: lower jugular (posterior to XI cranial nerve).

III: Middle jugular nodes.

IV—IVa: Lower jugular (clavicular); IVb: Lower jugular (sternal).

V—Va: Posterior triangle (below XI cranial nerve); Vb: Posterior triangle (transverse cervical).

VI: Central neck nodes.

Level I

Marginal Mandibular Nerve

Avoid the marginal mandibular nerve—found 1cm anterior and inferior to the angle of the mandible. Locate the mandibular notch: identify the submandibular gland and the facial vein passing over

Fig. 2

Fig. 3

Lymph node metastasis with unknown primary: wide resection, bilateral lymph node dissection and closure with rotation of large deltopectoral flap.

it. The nerve is deep to the platysma muscle, but superficial to the facial vein. Identify the facial vein and ligate it. Dissect deep to the vein, raising it with fascia over the gland. The nerve will be safely out of harm's way.

Hypoglossal Nerve

Appears deep to the internal jugular vein and internal carotid artery, turns 90° and passes between these two structures.

Level II

Spinal Accessory Nerve

Found deep to internal carotid artery in 70% of patients; in 30% is superficial to the internal carotid artery.

Level III

Phrenic Nerve

Posterolateral to carotid sheath, within prevertebral fascia, on anterior scalene muscle

The Scalp

Primary carcinomas of the scalp are common; 30% of all primary cutaneous malignancies occur in the scalp. Because of the robust vascularity of the scalp region, this is also a common site for cutaneous metastasis of tumors from other parts the body.

Small lesions should be excised using elliptical incisions, parallel to skin lines. In order to define skin lines on the face and scalp, ask the patient to grimace; this will enhance the skin lines, ensuring an esthetic scar.

Skin grafts are best applied on those areas of the face/scalp that have the least motion: the parotid area, the temporal region, and laterally, on the bridge of the nose. The best donor sites for full-thickness grafts for facial defects are the retroauricular skin and the supraclavicular fossa skin. Primary closure or closure with the use of local flaps, either random or axial in design, are based on the rich anastomoses between the branches of the external carotid artery and sturdy subdermal plexus.

Marjolin's ulcer in unhealed post-burn wounds is

Fig. 4

Scalp squamous cell carcinoma

Fig. 5

Fig. 6

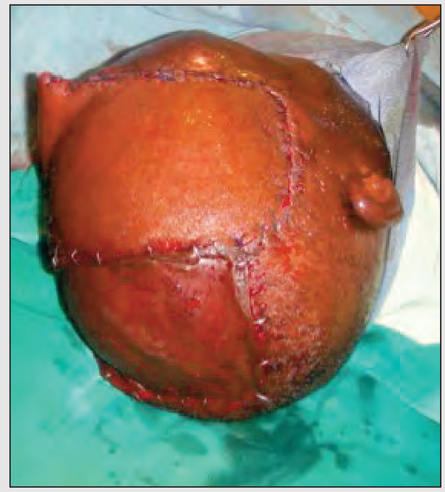


Fig. 7

Rapidly growing Marjolin's ulcer in post burn scar in older patient. (L-R) At the time of biopsy; at time of surgery two weeks later, showing rapid growth; and showing the reconstruction with the rotation of a large scalp flap. A STSG was used for the donor site. Tumor went down to galea but not to periosteum. The galea was removed with the tumor.

commonly seen.

Conjunctiva

The conjunctiva is the mucous membrane that covers the anterior portion of the globe; the lining epithelium is both stratified squamous and columnar.

Tumors may arise from either the epithelium or stroma. While small benign- appearing tumors may be managed by serial examination, larger tumors should be managed by either excisional or incisional biopsies. While many modalities of therapy exist, the main ones accessible to the majority of Sub-Saharan African patients will be surgery and radiotherapy. Surgery may involve orbital exenteration, and general surgeons should be familiar with the steps of this operation. Topical chemotherapy may also be effective for small tumors. A slit-lamp examination is an important screening tool, but may not be available outside major medical centers.

Fig. 8

Fig. 9

14-year old girl with unhealed burn wound of 12 years. Six months later she has a large Marjolin's ulcer and bilateral neck metastasis.

Common malignancies include squamous cell carcinoma, malignant melanoma and sebaceous gland carcinoma. Benign tumors include limbal dermoids, papilloma, and pyogenic granulomas. The

Fig. 10

Lower lid conjunctival tumor.

circumscribed nevus is the most common melanocytic tumor of the conjunctiva, with a less than 1% risk of malignant transformation into malignant melanoma.

Major Salivary Gland Tumors

The major salivary glands include the parotid, submandibular, and sublingual glands. The proportion of tumors arising in these glands is 100:10:1 respectively. While most salivary gland tumors arise from the parotid gland, 80% are benign. Of all the tumors of the submandibular, sublingual and minor salivary glands, 40%, 60%, and 80%, respectively, are malignant.

Radiation exposure is a risk factor for the development of salivary gland tumors, especially mucoepidermoid tumors.

While fine needle aspiration with cytology is useful for diagnosis, many surgeons consider that the presence of salivary gland enlargement is sufficient reason for resection.

Pleomorphic adenoma, a benign mixed tumor, is the most common salivary gland tumor, usually occurring in the parotid gland. A superficial parotidectomy is sufficient treatment, with a recurrence rate of less than 1%.

Mucoepidermoid carcinoma is the most common malignant tumor of the parotid gland. **Adenoid cystic carcinoma** is an aggressive tumor with an affinity for perineural invasion, and early lung metastases. It is the second most common malignant tumor of the parotid gland, and the most common in the submandibular and sublingual glands.

Fig. 11

Recurrent parotid tumor.

N.B.: Bilateral parotidomegaly should be investigated to rule out systemic conditions, such as HIV /AIDS, lymphoma, or inflammatory conditions.

Parotidectomy requires a good understanding of the anatomy of the facial nerve, to avoid facial nerve injury. While a superficial parotidectomy is sufficient for most benign tumors, a total parotidectomy must be performed for malignant tumors that involve the deep lobe as well. Facial nerve injury is then a real possibility, and must be discussed with the patient/guardian. If recognized, the transected facial nerve should be repaired with the finest suture available and if necessary, a nerve graft.

Although CT scans and MRI scans have different indications as investigative modalities, where available, they provide useful information that aids in the planning of surgery. They help differentiate between cystic and solid lesions and may suggest malignancy.

In performing a submandibulectomy, the surgeon must keep in mind the proximity of the marginal mandibular nerve, coursing on the surface of the gland, just above the facial vessels.

(**Editors' Note**: Major surgical textbooks have excellent descriptions of this procedure and show the techniques to identify the facial nerve. Also, one can find complete descriptions on YouTube.)

Oral Tumors

Pyogenic Granulomas

Can be confused for malignant lesions; these develop most often on the lips and gingivae, but can be found anywhere in the oral cavity. They usually develop in response to local irritation, trauma and/or hormonal changes, although the actual cause remains unknown. Mucosal and cutaneous lesions are probably etiologically different. These lesions may vary in size from a few millimeters to several centimeters. Their most common mode of presentation is bleeding. Surgical excision is often sufficient as recurrence is extremely rare.

Squamous Cell Carcinoma

This is the most common malignancy in the oral

Fig. 12

Pyogenic granuloma.

cavity. Squamous cell carcinoma (SCC) in the oral cavity may present with induration or an ulcer. Gingival lesions may present with loosening teeth or as a non-healing ulcer after a tooth extraction. Late presentation in Sub-Saharan Africa is common as a result of misinformation, poverty, and illiteracy. Most patients will attribute an ulcer to some past event, and will wait for resolution for a long time, before presenting to the doctor (Fig. 21). Wide excision with or without neck dissection is the main mode of management. Where radiotherapy is accessible, surgery may be followed by radiotherapy of the neck. As noted previously, radiotherapy alone is equivalent to surgery for many lesions, without the attendant morbidity of surgical therapy.

Achieving adequate tumor resection in our environment may be more important than cosmesis; surgical reconstruction can be achieved upon referring the patient to centers where the expertise is available. **The prognosis after tumor resection is not impacted at all by a waiting period prior to reconstruction. Referring a patient for resection and reconstruction, on the other hand, may worsen the patient's prognosis because of the waiting time for treatment. So, early excision followed by reconstruction at a center may give better cure rates and better long-term cosmesis.**

N.B.: Skin grafts **will not** take on bare tendons, cartilage or bone. The **exception** is the thin/flat bones of the skull/facial skeleton such as the orbit and squamous temporal bones on which skin grafts **will** take on bare bone without periosteum.

Oral Tumors

Lymph Node Metastases without a Primary Tumor

Some patients present with positive nodes without an identifiable primary tumor. Unless the primary is identifiable, these patients have a poor prognosis. Triple endoscopy (direct laryngoscopy, bronchoscopy, and esophagoscopy) may help in finding the primary. Where available, a CT scan or MRI may aid in identifying the primary tumor.

Cystic Hygroma

Though the name implies tumor ("-oma"), cystic hygromas are not true tumors but are lymphatic malformations. They most often present in the

Fig. 13

Fig. 14

Fig. 15

Leukoplakia or early SCC can be treated by a lip peel. (L-R) Excision of lesion and mucosal advancement.



Fig. 16 **Fig. 17** **Fig. 18**

Lip SCC with wide resection and reconstruction with Karapandzic flaps.



Fig. 19 **Fig. 20** **Fig. 21**

(L-R) Squamous cell carcinoma of mouth, palate, and extensive palate



Fig. 22 **Fig. 23** **Fig. 24**

Large macrocystic hygroma in newborn, wide excision with preservation of facial nerve, and immediate postoperative photo.

neonatal or early infancy period, and obstructed labor may be the first indication that there is a mass. They may be seen in adulthood but usually there will be a history of a mass dating back to childhood.

Surgical excision can be challenging in the infant with an extensive lesion that is intricately related to the facial nerve. Avoidance of facial nerve injury is critical. Macrocystic lesions (made up of large cysts which are more easily identifiable) have a much better prognosis whether managed surgically or medically. Microcystic cystic hygromas are very difficult to treat as it is difficult to identify all the small cysts for complete removal.

While watchful waiting may be used for a few lesions, medical management involves the use of sclerosants. Of the sclerosants used, absolute alcohol or tetracycline/doxycycline (10mg/ml solution) are the most readily available in Sub-Saharan Africa.

N.B.: Although aspiration has been frowned upon in the past, some workers have reported successes with this technique.

Further Reading

Other chapters in this book include other head and neck tumors and the reader is referred to these chapters:

Chapter 2: Chronic Wounds and Ulcers
Chapter 8: Cutaneous Lesions
Chapter 10: Jaw Tumors
Chapter 13: Nasoencephalocele
Chapter 16: Noma
Chapter 21: Neurofibromatosis

Chapter 10

Jaw Tumors

Peter M. Nthumba and Tertius H. J. Venter

Introduction

Tooth development begins at 37 days of intrauterine (IU) life with the formation of a continuous horseshoe-band of thickened epithelium in the location of upper and lower jaws, the dental lamina. Each dental lamina develops ten centers of proliferation from which tooth buds grow.

Tooth buds for the permanent teeth that have deciduous predecessors appear at ten weeks, from deep continuations of the dental laminae, while the rest appear at different times. These laminae mature into enamel organs, one for each primary and permanent tooth. Cells of the enamel organ differentiate into *ameloblasts* and synthesize *enamel*.

The ameloblasts stimulate the dental papillary cells to differentiate into odontoblasts, which later synthesize dentin.

History

In the history of jaw tumors, one may elicit any of the following:

Pain, loose teeth, recent occlusal problems, delayed tooth eruption, swellings, dysesthesias, or intraoral bleeding. There is often a history of a recent tooth extraction, with a resultant non-healing ulcer. Paresthesias, trismus, and malocclusion may indicate a malignant process if recent in onset. In the Sub-Saharan African patient, this may just be the result of a neglected benign lesion.

The onset and course of the growth rate of the mass are important. For example, the recent history of rapid growth after a long history suggests a malignant degeneration. The overall appearance of the patient should be considered. Cachectic patients often have malignancies, whereas big jaw tumor patients are often not very emaciated at all.

General Head and Neck Examination

Carefully examine the affected part of the jaw and overlying dentition, noting ulceration, the degree of jaw involvement, and any nodal involvement. Palpation will differentiate soft tissue masses from bony lesions.

Investigations

Radiologic examination of the mass is the investigation of choice in the evaluation of jaw related cysts and tumors. The type of examination is determined by the availability of facilities, and the ability of the patient to pay for the test. The standard useful films are right and left lateral oblique view of the mandible and a PA of the skull.

- An Orthopantomogram (OPG)/Panorex will often confirm clinical suspicions and even allow the formulation of differential diagnoses. This, however, requires specialized equipment that may

Table 1

Type	Classification	Tumor(s)
Benign	Odontogenic Cyst	Dentigerous Cyst, Odontogenic Keratocyst
Benign	Epithelial Odontogenic Tumor	Ameloblastoma
Benign	Other Jaw Lesions	Fibrous Dysplasia
Malignant	Osteoclastic Tumors	Squamous Cell Carcinoma
Malignant	Osteoclastic/Osteoblastic Tumors	Osteosarcoma

The classification of jaw tumors is quite complex and is significantly abbreviated here, to cover the commonly seen lesions.

not be universally available. Skull radiographs may be more universally available while chest radiographs are useful where malignancy is suspected.

- Where available and affordable, CT Scans are excellent for delineation of jaw tumors. They help narrow down the differentials and are useful for planning the extent of the surgical excision and reconstruction.

As a general rule, well-demarcated lesions outlined by sclerotic borders suggest a benign process. Aggressive tumors have a tendency to show up as ill-defined lytic lesions. With larger more aggressive lesions, the CT scan may more clearly identify bony erosion and/or invasion into adjacent soft tissues.

Large tumors do not necessarily mean malignant lesions. They do, however, make both the resection and reconstruction more difficult.

helpful to diagnose inflammatory or secondarily infected lesions.

The term, 'jaw tumors,' is an expansive and all-inclusive term. It includes a large number of different tumors, both benign and malignant. This chapter will only deal with tumors that patients present with, with relative frequency, in the context of Sub-Saharan Africa.

Dentigerous Cysts

Dentigerous cysts may constitute up to 24% of all developmental cysts. They are commonly located in the mandibular 3rd molars, maxillary canines, and maxillary 3rd molars.

They occur most commonly in the second to the fourth decades and are largely asymptomatic. Large cysts can cause the displacement or resorption of adjacent teeth. They may also cause malocclusion, pain, and even interfere with respiration.

Fig. 1

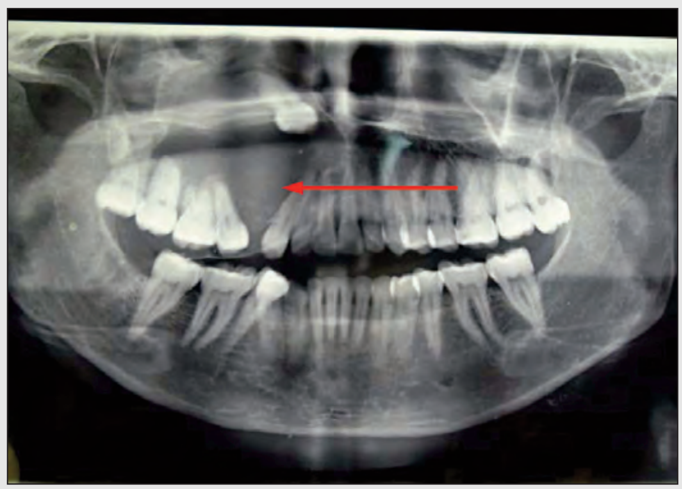


Fig. 2

Dentigerous Cyst (cystic area at end of red arrow in Fig. 2).

- Where possible, the tissue is obtained for histologic identification of the lesion. The biopsy may be done under local anesthesia, or it may require a general anesthetic, depending on the ease of accessibility and the safety of the airway.

- As far as possible, trans-oral biopsies are preferred. It is important for the biopsy scar site to fall within the anticipated tissue to be excised. Fine needle aspiration is excellent for ruling out vascular lesions prior to open biopsy and may be

Ameloblastomas

Ameloblastomas are the most common odontogenic tumors. They are benign, but locally aggressive tumors, with the potential to grow to enormous sizes, resulting in severe bony and facial deformities.

Ameloblastomas may originate from any epithelium within the jaws that is involved with the formation of enamel. Although ameloblastomas may arise from the lining of a dentigerous cyst, they more often arise independently of impacted teeth.

Fig. 3

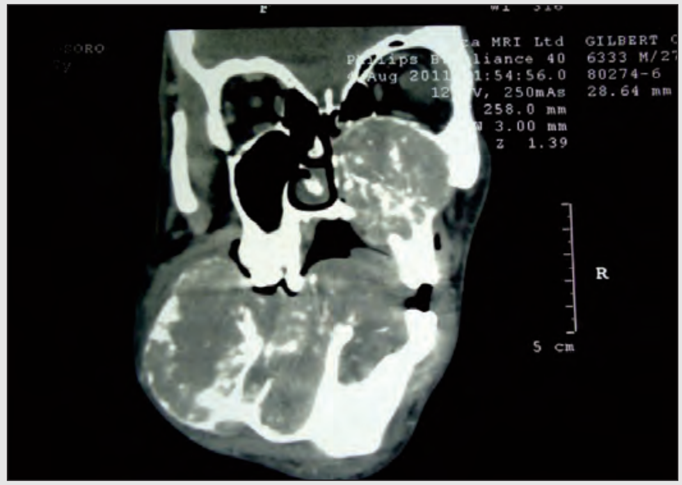


Fig. 4

Ameloblastoma

In Western series, these tumors have no gender predilection and occur in adults, with a mean age 40 years.

Radiographs may reveal well-circumscribed, expansile soap-bubble radiolucency (either unilocular or multilocular) with clearly demarcated borders. The lesions may be unilocular or multilocular. Unilocular lesions are indistinguishable from an odontogenic cyst, hence the need for a biopsy because of the differences in the management of the two lesions.

Clinicopathologic subtypes include:

- Multilocular and multicystic/solid intraosseous
- Uni-cystic intraosseous
- Peripheral/extraosseous

These constitute 86%, 13%, and 1%, respectively, of ameloblastomas. The solid (multicystic) subtype is the most aggressive of the three, requiring more aggressive treatment. Recurrence rates of 50 to 90% have been reported when curettage was the means of treatment.

Clinical presentation:
Ameloblastomas are slow-growing, locally invasive odontogenic tumors of the jaws with a high rate of recurrence when improperly treated.

Ameloblastomas frequently grow to enormous sizes, especially in the patient population in Sub-Saharan Africa. The mandible is more frequently involved than the maxilla.

Ameloblastomas have a small risk of metastasis,

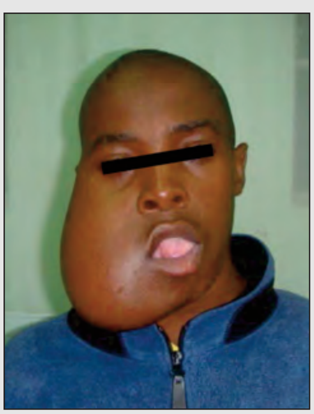


Fig. 5

Fig. 6

Fig. 7

Fig. 8

Ameloblastoma and two years post-op (Note cystic appearance on pre-op x-ray).

Fig. 9

Fig. 10

Ameloblastoma of mandible and maxilla. Mandible had been previously curetted. Mandible/maxilla reconstructed with titanium condylar plates.

usually to the lungs: ameloblastomas that behave in this manner have been called metastatic ameloblastomas. Histologically, these are indistinguishable from other ameloblastomas. Ameloblastic carcinomas have, on the other hand, microscopic characteristics of malignant tumors.

Early symptoms are often absent, while late symptoms may include a painless swelling, loose teeth, malocclusion, fistula formation or nasal obstruction. Maxillary tumors may extend into the antrum, and after that grow into the nasal cavity, ethmoid sinuses, and skull base. Once the tumor grows outside the limits of the mouth, the mucosa is no longer moist, and it dries and may ulcerate. This gives the impression of malignancy.

Anesthesia is a challenge in these cases. Often the surgery is relatively easy; the difficult part of the operation is securing a good airway for the case. In many locations, this will not be possible, and the patient must be referred to a large center. A tracheostomy may always be done when the intubation is difficult or impossible, but the postop care of the tracheostomy may be difficult (see Chapter 5). In the small masses, an oral endotracheal tube may be inserted. Sometimes it may be possible to insert a nasotracheal tube. In ideal situations, a fiber-optic bronchoscope is available, and it is used to safely intubate the patient through the nose.

It is to be hoped that after the mass is removed, the patient will not require intubation, but with the large masses, it may not be wise to remove a tube for the first 12 hours. Suction and attentive nursing care must be available in these cases. One of the authors frequently uses one dose of an intravenous steroid (such as Solu-Medrol®) before starting large head and neck cases, with the expectation that this will reduce swelling. Several doses may also be given in the first 24 hours. There are other ingenious ways to intubate such a patient, but the above methods are the safest. It is to be emphasized again that the surgical resection is the

Fig. 11

Fig. 12

(L-R) Ameloblastic carcinoma; Osteosarcoma—synchronous mandible and maxilla.

easiest part of the care of this patient. Anesthesia and postoperative care are most important.

Some use a GlideScope® to help with intubation, but this can only be used for oral endotracheal intubation. This is a laryngoscope attached to a small monitor that may be watched while one attempts intubation. This allows for better visualization during intubation. A GlideScope® is costly ($20,000 USD) but would help less-experienced anesthesia personnel with intubation. Cost and inability to nasally intubate make the GlideScope undesirable.

One may Google “GlideScope” for further information and YouTube demonstrations of the GlideScope® technique.

Surgery:
The incision for mandibular resections is a submandibular incision with a midline split of the lower lip. The incision can extend to the angles of the mandible. In ameloblastomas, much of the expanded mucosa may be saved, and closure is relatively easy. Xylocaine® 0.5% with adrenaline (epinephrine) is used to infiltrate the skin and mucosa before the incision to help reduce the bleeding. Care must be taken to place the incision below the mandibular branch of the facial nerve and elevate the skin below the platysma muscle. The facial vein can be identified, ligated, and elevated with the skin flap to help protect the nerve.

The treatment of choice is resection of the involved mandible or maxilla, with surgical margins of 2.0 cm or 1.5 cm, respectively, of the mandible or maxilla. Extension of the tumor into surrounding soft tissues requires an additional wide resection of the soft tissue. Postoperative follow-up is recommended, to monitor for recurrence and plan treatment accordingly.

Reconstructive challenges after resection of parts of the mandible or maxilla:

- Small bone defects of **4 cm or less** may be reconstructed with a steel/titanium plate and a bone graft from the iliac crest, rib or best calvarium.

- Defects **larger than 6 cm** should ideally be reconstructed using vascularized bone—either as a pedicled flap (as a pectoralis flap with a rib) or as a free flap with fibula or scapula. While the former requires some training with a good understanding of the anatomy and vascular patterns around the ribs or scapula, the latter requires specialized equipment, ideally an operating microscope, and microvascular surgical training.

- In most cases with large tumors and defects, reconstruction using a plate of stainless steel or titanium will be an acceptable option and all that is possible. These patients will do well if they adhere to a strict “no-chew” diet. Some body, ramus, angle, and condylar defects can be ignored. Although these result in cosmetically unacceptable defects, the patients will be functional with the mandible loss and even with an “Andy Gump” deformity.

- Where the entire hemimandible including the condyle may need to be removed, and one does not have microsurgery capabilities, then one may reconstruct the defect with a condylar plate which


Fig. 13


Fig. 14


Fig. 15

Resection of ameloblastoma, titanium plate reconstruction, final result. The plate was attached to both angles. Note: bilateral flaps from midline to angle in submandibular plane.

Fig. 16

Fig. 17

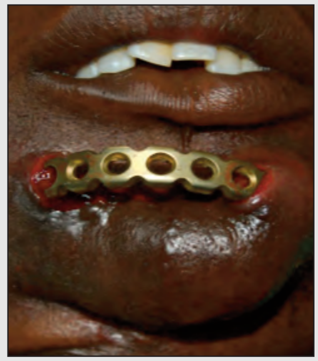


Fig. 18

Fig. 19

Resection of ameloblastoma with titanium plate reconstruction without bone graft (Fig. 16 and 17). Extrusion after one year requiring further reconstruction with deltopectoral flap.

extends up into the TMJ. If such a plate is unavailable, a titanium plate can be used to reconstruct the ramus, angle, and body and a large non-absorbable suture can be used to suspend the plate from the zygomatic arch. At least three and preferably four screws must be placed into the mandible on the opposite side. The disadvantages of plate reconstructive include hardware failure and exposure/extrusion (see Figs. 16-19).

- When one does not have microvascular capability, plate reconstruction can first be done as described above. Then a few months later (after 3 months), tightly packed iliac crest cancellous bone grafts can be placed along the entire length of the plate. This is done via an external approach, not entering the oral cavity, and will permit bone reconstitution within the defect over time, with minimum risks of bone graft infection.
- Titanium mesh trays are available but very expensive. Cancellous bone may be packed in these trays and a new mandible reconstructed.
- Hardware failure or exposure necessitates removal and/or soft tissue coverage. Vascularized bone would be preferable, but the realities of practice in some environments would only permit the use of a flap to cover the exposed hardware/bone. Most likely, the extrusion of a metal plate will occur in the anterior midline. Flaps used are the deltopectoral, pectoralis major, or supraclavicular perforator flap (see Figs. 16-19 below, and chapter 27 on Flaps).

Fibrous Dysplasia

Fibrous dysplasia (FD) is a benign tumor in which normal bone is replaced by fibrous connective tissue

Fig. 20

Fig. 21

Fig. 22

Fibrous Dysplasia in young girl (Fig. 20) and boy (Fig. 21). X-rays of boy in Fig. 22.

resulting from a defect in osteoblast differentiation and maturation. Fibrous dysplasia may affect a single bone (monostotic type) or multiple bones (polyostotic). Fibrous dysplasia may also occur as part of the McCune-Albright syndrome, consisting of polyostotic fibrous dysplasia, café-au-lait spots and an endocrinopathy (hyperthyroidism or precocious puberty in females).

Monostotic FD is the most common type; 70-80% is found in the long bones or ribs. The head and neck region is involved in 25% of cases. Polyostotic FD is less common, found in 15% of all FD; 50% of the cases involve the head and neck region.

Clinical presentation:
Fibrous dysplasia in the jaws presents as a painless mass, most commonly in the maxilla. The lesion usually does not cross the midline and is generally limited to the bone involved, hence causing asymmetry. The antrum is often obliterated, and the orbital floor may be involved, leading to the displacement of the eye.

Fig. 23

Fibrous dysplasia in maxilla: required near total maxillectomy and bone grafts.

Radiologically, FD may be radiolucent, or reveal a mixture of radiolucency and radio-opacity, with a 'ground-glass' appearance. The border of the tumor is ill-defined, merging with normal bone; when well-defined, it is difficult even on microscopy, to differentiate it from ossifying fibroma.

FD usually presents in childhood or early adolescence, during the period of greatest skeletal growth. FD may have exacerbations, may occur during pregnancy and with oral contraceptive use, and usually stops growing with the cessation of growth in late adolescence, although there are exceptions to this.

FD has no sex predilection.

FD may also occur in the skull. Massive cranial involvement may lead to a lion-like facies, "leontiasis ossea" or bilateral maxillary involvement called "cherubism."

Treatment
Treatment is determined by the following variables:

- The age of the patient.
- The rate of tumor growth.
- The location and extent of the lesion.
- Degree of cosmetic deformity.
- The resulting functional impairment.

There are three approaches to the treatment of FD:

Fig. 24

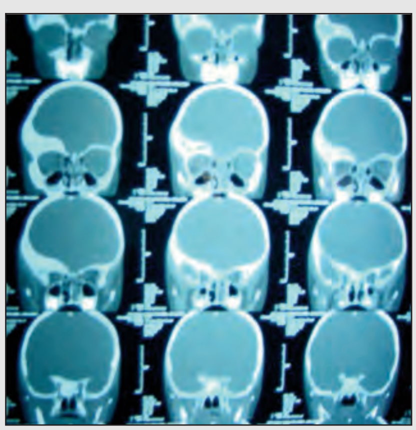


Fig. 25

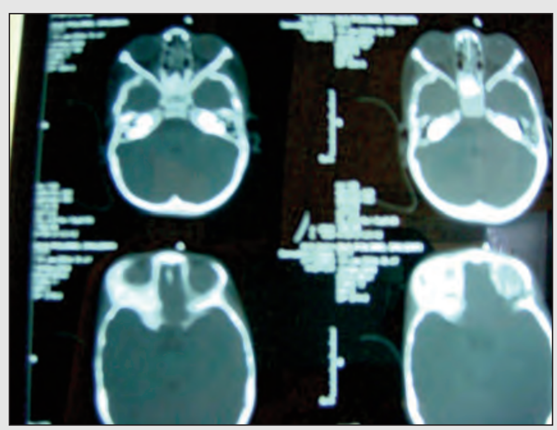


Fig. 26

Fibrous dysplasia in the skull and orbital roof: If symptomatic, it will require the expertise of a neurosurgeon and plastic surgeon working together.

- **Observation**, if the patient is still growing and the mass is not causing any functional difficulties.
- **Conservative** surgery, with sculpturing and contouring (surgical debulking) the lesion to as normal a shape and size as possible with preservation of alveolar ridge and teeth
- **Radical surgical excision and reconstruction**. Surgical intervention is aimed at correcting or preventing functional deficits, and the restoration of as near-normal facial cosmesis as possible. Radical excision is most appropriate for extensive mandibular involvement where tumor debulking is impractical, and reconstruction a viable option.

Surgical debulking involves significant blood loss. Bone wax is a very handy hemostatic agent, as the bleeding is frequently unresponsive to cauterization. The administration of calcitonin preoperatively has been reported to reduce operative bleeding, as well as aid in bone remodeling. Pamidronate has also been used to treat pain and pathological fractures from lesions in long bones.

Where possible, treatment should be deferred for as long as possible, especially until skeletal maturity. Children with FD require long-term follow-up. When the patient is near the end of physical growth, debulking with preservation of teeth may be carried out. Younger patients with large masses may also undergo surgical debulking with preservation of teeth,but close followup is necessary, and second stages will likely be necessary.

There is a small risk (less than 1%) of malignant transformation into osteogenic sarcoma, and therefore, accelerated growth or aggressive lesions will require early surgical intervention with en bloc resection and reconstruction. Radiation therapy has been reported to cause malignant transformation of FD and is therefore contraindicated.

Surgical Technique

Many cases of FD are in the maxilla and require a hemimaxillectomy. The maxilla is approached through a Weber-Ferguson incision (For more information, Google "Weber-Ferguson Incision") which extends through the upper lip, around the nose and just below the lower eyelid. If possible, the inferior orbital rim is left, with a small portion of the maxilla as well as zygoma. In very large tumors, the entire inferior orbital rim must be taken. Care is taken to preserve the suspensory ligaments of the orbit. If necessary, the rim can be reconstructed with calvarium.

Cementoblastoma

Cementoblastoma is another uncommon benign jaw tumor that usually occurs in people under the age of 25, often involving the molars or premolars. It forms an irregular or round mass attached to the root of a tooth. On x-ray, it is a well-defined radiopaque mass. Usually, it is small, but when consultation is delayed, it may grow quite large. It is very similar in appearance to ossifying fibroma and osteoblastoma. Resection is the only treatment and reconstruction is similar to the reconstruction for ameloblastoma.

Fig. 27

Fig. 28

Cementoblastoma, pre and post-operative.

Osteogenic sarcoma

This malignant tumor of bone is the most common primary malignancy of bone (apart from myeloma). Only 5–10% of these tumors occur in head and neck, primarily in the jaws. They usually present as painless swelling in the jaws, although pain and paresthesias may result from nerve involvement or compression. Osteosarcoma of the jaws may present at any age, but peaks in the fourth decade.

Some reports suggest a slight male predilection, with mandible predominance. Jaw osteosarcomas are less likely to metastasize, but unfortunately, the prognosis has not improved with the use of chemotherapy, as with osteosarcomas of long bones. The main cause of death in jaw osteosarcomas is a local recurrence.

Radiologically, these tumors may exhibit the classic 'sunburst' appearance, best seen on CT images. Lesions may otherwise exhibit ill-defined bone edges, with radiolucency or a combination of a radiolucent and radiopaque pattern.

Burkitt's Lymphoma

This is not a surgical disease, but is included in this text for the sake of completeness. This tumor may present as a jaw tumor, and lack of familiarity with the pathology may lead to unnecessary surgical intervention. It may present as any of the three variants; the endemic, sporadic and immunodeficiency (HIV) associated types. The endemic and immunodeficiency-associated variants are relevant to the surgeon working in Sub-Saharan Africa.

Fig. 29

Burkitt's lymphosarcoma is treated medically.

A fine needle aspirate is sufficient to provide a diagnosis, while chemotherapy is often rapidly effective in controlling and decreasing the size of the tumor. A cure may be possible if the tumor is caught early.

Rhabdomyosarcoma

Rhabdomyosarcoma is the most common soft tissue sarcoma in children under 15 years of age, except in some parts of Africa where Burkitt's lymphoma is more common. A biopsy must be taken to make an accurate diagnosis. Whereas ameloblastoma can be both a benign and malignant odontogenic tumor, Burkitt's and rhabdomyosarcoma are nonodontogenic malignant tumors. Burkitt's can be treated by high doses of chemotherapy, so it is important to get an accurate tissue diagnosis.

Squamous Cell Carcinoma

Squamous cell carcinoma is the most common malignancy of the oral cavity. It has a higher prevalence in certain regions because of cultural practices e.g. betel nut chewing, inverse smoking, etc. It afflicts more males than females, and is most frequently found in the tongue and floor of mouth, but can arise in any part of the oral cavity. It may metastasize to regional lymph nodes, leading to a poor prognosis.

A number of cases are recognized after a tooth extraction because of a non-healing ulcer.

In radiographs, bone radiolucency, with a 'moth-eaten' appearance adjacent to the soft tissue mass, is indicative of bone involvement. **Most squamous cell**

Fig. 30

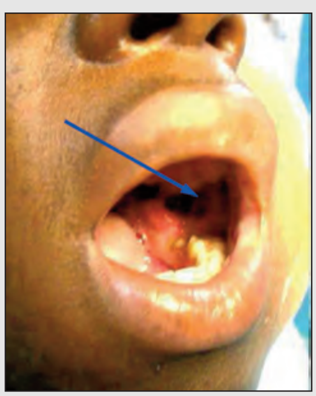


Fig. 31

Fig. 32

Fig. 33

Rhabdomyosarcoma of mandible in 16-year-old boy: Note oral ulceration in Fig. 31 (blue arrow) with destruction of the posterior mandible, angle, and ramus (Fig. 33, green arrow). This was a rapidly growing mass over a nine month period.

carcinomas found in jaws have invaded from lesions of the oral cavity, but primary intraosseous carcinoma may arise within the jaw presumably from residues of odontogenic epithelium. Squamous cell carcinoma has also been reported occurring as a Marjolin's ulcer in an orocutaneous ulcer in a large mandibular ameloblastoma.

Surgical resection with adequate margins may be sufficient treatment for early lesions. Late lesions amenable to surgical therapy will need wide excision and neck node dissection, with or without


Fig. 34

Fig. 35

Fig. 36

Fig. 37

A titanium plate is used, and the bone graft is anchored to the plate before the anastomosis is performed between the peroneal blood vessels and the major vessels in the neck (Courtesy Peter M. Nthumba).


Fig. 38

Fig. 39

Fig. 40

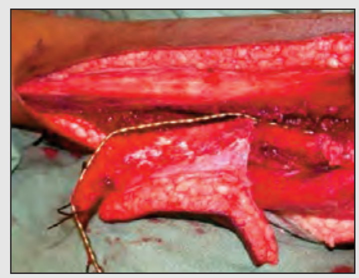



Fig. 41

Another microvascular case with fibula reconstruction (Courtesy of David Chang).


Fig. 42

Fig. 43

Fig. 44

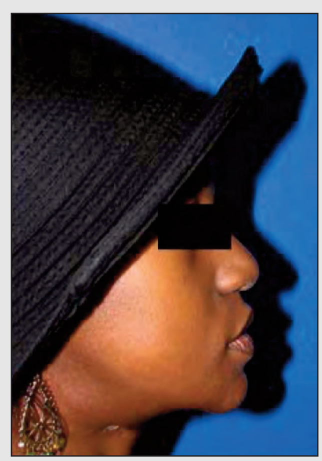



Fig. 45

Fibula reconstruction (post-operative, same case as Figs. 38-41).

radiotherapy. Surgical excision is the most durable form of treatment available for most patients in Sub-Saharan Africa, as radiotherapy may not be as easily accessible. For lesions that are not amenable to surgery, radiotherapy (if available in a timely fashion) may downgrade a tumor, and make surgery feasible. Various flaps may be used to reconstruct defects including deltopectoral and pectoralis myo/osteocutaneous flaps.

Microvascular Reconstruction

In the rare case where microvascular reconstruction is possible, the cases seen in Figs. 34-37 and Figs. 38-45 are examples of what can be done with a fibula bone graft.

This is tedious surgery, requiring microvascular instruments, loupes, a microscope, and someone skilled in microvascular surgery. Also, since these cases are long, good anesthesia and a postop ICU are necessary.

Surgery of the jaws requires histopathology in most cases. Ameloblastoma may be obvious with a cystic mandibular lesion in a young adult. Otherwise, it is best to have a pathological report before beginning extensive surgery. On the other hand, some may be in remote areas where you will have to proceed based on your experience.

Chapter 11

Acute Burns

Assessment and Management

Derick A. Mendonca

Epidemiology

Burns are a common form of trauma. Some burns occur as genuine accidents, but most are caused by carelessness or inattention, pre-existing medical conditions, or they may follow alcohol or drug abuse. In some cultures, burn injuries may be the result of acid attacks, liquid paraffin, petroleum products and other inflammables.

Patients with epilepsy are at a higher risk of burns, following a seizure. Leprosy patients are also at a higher risk of cutaneous burns, especially over their insensate palms or soles.

In both adults and children, the most common place to be burned is in the home. The most dangerous places in the home are the kitchen and the bathroom, as most scalds in children and the elderly occur in these two rooms.

In developing countries, flame burns account for most of the burn injuries in adults; in children, scald burns are the most common cause[1]. This is often due to explosion of kerosene stoves or gas cylinder explosions while cooking. Outdoor cooking or warming is also common source of flame burns in developing countries. Scalds in adults and children are most commonly due to hot oil, hot milk or water.

Data from Southern India[1] show that 45% of burns tend to be accidental in nature, while 25% are suicidal and 8% homicidal. Of the homicidal burns, 5% were acid burns following personal rivalry or romantic jealousy. In Africa, 1 in every 5 burn victim will die. 59% of all burn injuries are from scalds, while 33% are caused by flame injuries.[5]

Emergency Examination and Treatment

Rapid assessment and treatment of a patient with burns can be life-saving. The history should alert the doctor to the possibility of co-existing injuries:

- Road traffic accident, especially with ejection or high speed.
- Blast or explosion.
- Electrical and lightning injuries.
- Jump or fall while escaping a fire

First aid consists of stopping the burning process, and cooling the burn wound.

In flame burns, the flame should be extinguished by the patient rolling on the ground, either actively or

Fig. 1

Severe burns in a young man with epilepsy

Fig. 2

16 year old boy with leprosy.

passively. Hot, charred clothing should then be removed as quickly as possible. In a scald, the clothing soaked with fluid acts as a reservoir of heat, so removal of clothing will stop the burning process; additionally, all jewelry should be removed.

The burn surface should be cooled with cold running water. The ideal temperature is 15°C for at least 20 minutes. Ice or iced water should **not** be used. The extreme cold causes vasoconstriction and has been shown to deepen the risk of tissue injury[2].

Primary Survey: ABCs

A: Airway maintenance with cervical spine control. Check the airway for foreign material and open the airway with chin lift/jaw thrust. Keep movement of the cervical spine to a minimum. Always provide supplemental oxygen.

B: Breathing and ventilation. Expose the chest and ensure chest expansion is adequate. Ventilate via a bag mask or intubate, if necessary.

- **Beware**: Carbon monoxide poisoning may give a cherry pink skin color to skin and mucous membranes of a non-breathing patient.
- **Beware**: Circumferential chest burns: ask yourself: is escharotomy required?

C: Circulation with hemorrhage control. Stop bleeding with direct pressure. Check the pulse, blood pressure, oxygen saturation and capillary return on the fingers. Circumferential burns on limbs need an escharotomy. In the case of doubt, perform an escharotomy.

D: Disability, neurological status. Establish the level of consciousness

A: **Alert**.
V: Responds to **Vocal** stimuli.
P: Responds to **Painful** stimuli.
U: **Unresponsive**.

E: Exposure with environmental control. Remove all clothing and jewelry. Keep the patient warm with blankets/sheets.

F: Fluid resuscitation proportional to burn size.

- Indications for fluid resuscitation: Adults: Burn area >15% and Children: Burn area >10%.

- Insert 2 large bore, peripheral IV lines, preferably through unburned tissue. Obtain blood for hemoglobin level, Urea/creatinine and electrolytes, and blood for cross matching, where available.

- The author uses the Parkland formula for fluid resuscitation, and prefers to use Ringer's lactate or Hartmann's solution because of its isotonic properties. Normal saline is the next alternative.

- Parkland formula[2]: 4 ml Hartmann solution/kg body weight/% burned second and third degree (partial and full thickness) + maintenance fluids for children.

- Half the calculated fluid is given in the first 8 hours (calculate fluids from Burn Time Zero to the time of presentation—this must be given judiciously if the time left is limited), the rest is given over the next 16 hours.

- For example, a 40 year old man weighing 60 kilograms sustained 30% total surface burn injuries 3 hours prior to presentation. His calculated fluid requirement is as follows: 4 x 60 x 30 = 7200 ml; give 3600 (8-3) hours, then 3600 over the next 12 hours i.e. 720 ml/hr for 5 hours and then 225ml/hr for the next 16 hours.

- Maintenance fluids for children [2]: 4% glucose with $\frac{1}{4}$ or $\frac{1}{5}$ normal saline.
  - First 10 kg: 100ml/kg/24 hours. 10-20 kg: 50ml/kg/24 hours.
  - Every 1 kg above 20 kg: 20 ml/kg/24 hours.
  - In addition: maintenance fluids for 24 hours.
  - For example: a 28 kg. child would require 1660 cc. plus maintenance fluids.

- The area burnt is estimated using the rule of nines (See Fig. 4).

- Monitor the adequacy of fluid resuscitation by aiming for a urine output of at least 1ml/kg/hour; maintain urine output at this level,

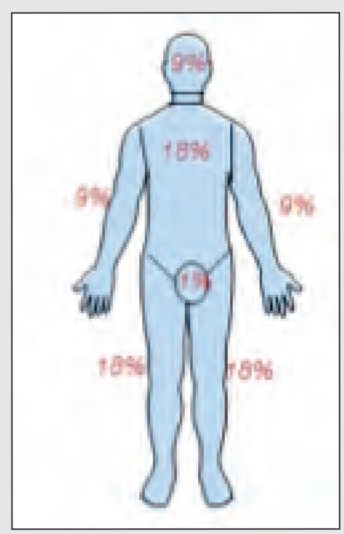


Fig. 4
Rule of Nines body surface area estimation.

but monitor to avoid fluid overload. Keep a close watch on the pulse, blood pressure, respiratory rate, pulse oximetry or arterial blood gases, if available.

- Pain relief: major burns hurt. Give morphine slowly and cautiously.

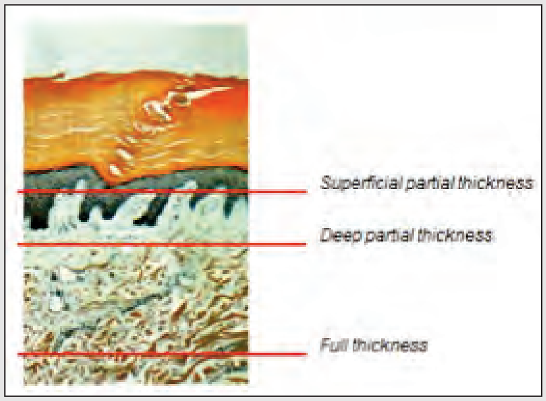


Fig. 3
Cross section of skin and burn depth.

Secondary Survey

This is a comprehensive head to toe examination, detecting associated injuries, fractures, chest/abdomen/pelvic injuries. For a quick history, use **AMPLE: A**—Allergies, **M**—Medications, **P**—past illnesses, **L**—last meal, **E**—events of injury

Burn Wound Assessment and Management

The two important determinants of the seriousness of the burn injury are the area and depth of burn. The greater the surface area of the body injured, the greater the mortality rate. In many developing countries, any deep burn >40% is life threatening.

The **Rule of Nines** divides the body surface into multiples of nine percent, with the exception of the perineum which is 1%. A method of estimating a small burn is to use the palmar surface of the patient's hand, which approximates to 1% body surface area.

The rule of nines is relatively accurate in adults, but maybe inaccurate in small children. The child has a proportionately larger shoulder and head than an adult. The Lund and Browder chart (Fig. 5) more accurately calculates the fluid requirements of pediatric burn patients.

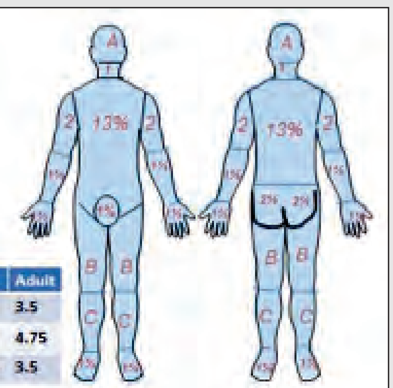
Estimation of depth: The skin consists of two parts: the epidermis and dermis. Depending on the depth of tissue damage, burns may be classified as either superficial or deep. In practice, most burns are a mixture of areas of different depth. See Figs. 6 to 9.

- **Epidermal burns/first-degree burns:** The common causes of such burns are sunburns and minor flash injuries from explosions. These burns are red in color with no blistering, are quite painful and heal within 7 days leaving no scars (Fig.6).

Superficial partial thickness burns: The hallmark of this type of burn is the blister. The overlying epidermis over the blister is dead, and de-roofing along with release of blister fluid is recommended. These burns are extremely painful as the nerve endings are exposed. Partial thickness burns heal by epithelialization within 14 days leaving only a color mismatch, especially in Indian and African patients (Fig.7). This is temporary.

(**Editor's note**: If the patient presents early, and has not been exposed to any traditional therapies, cleaning the burns, and leaving the blisters is safe. The blistered skin provides an excellent dressing, protects the patient from the severe pain experienced following blister de-roofing, and protects the patient from losing protein-rich fluid from the burn surface. In a few days, neo-epithelium covers the burn and the blister will slough off (Fig. 6b). If a blister stays in place for 10-14 days, then it should be opened and debrided.)

- **Deep partial thickness burns**: The hallmark of these burns is the fixed capillary staining, resulting from the burnt dermal vascular plexus.



Age	0	1	5	10	15	Adult
A	9.5	8.5	6.5	5.5	4.5	3.5
B	2.75	3.25	4	4.5	4.5	4.75
C	2.5	2.5	2.75	3	3.25	3.5

Fig. 5
Lund and Browder chart.

These burns have reduced sensation and may take longer than 3 weeks to heal (Fig. 8).

- **Full thickness burn**: Full thickness burns destroy both layers of skin: epidermis and dermis. They have a dense, white, charred appearance. The sensory nerves in the dermis are destroyed making it insensate. The leathery appearance is called eschar (Fig. 9).

  (**Editor's note**: These color descriptions are primarily what is seen in light-colored skin. Dark-skinned individuals will have different color presentations, but full thickness burns appear the same.)

Escharotomy

Escharotomy is the release of the burn wound surgically by incising the burned skin down to the subcutaneous fat. The burnt skin loses its ability to expand and causes a restrictive effect, hence requiring an escharotomy. As indicated above, full thickness burns are not painful and one should not wait for anesthesia to perform escharotomies.

The indications for escharotomy are:

- Circumferential full thickness burns on the extremities: may lead to compartment-like syndrome.
- Circumferential full thickness burns on the chest/neck: restrict chest expansion.
  - Chest: the incisions need to be made longitudinally along the anterior axillary lines to the costal margins bilaterally, and then connected by a cross incision convex upwards across the upper part of the abdomen (See Fig. 10).
  - Extremities: in the upper limb, the incisions are made in the mid lateral lines bilaterally. In the upper limb, the incision should go in

Fig. 6a

Fig. 6b

First degree burns—note blisters. The patient has applied herbs on burn prior to hospitalization. Note evidence of early re-epithelialization at 4 days after admission.

Fig. 7

Fig. 8

Fig. 9

(L to R) Superficial partial thickness burn; superficial and deep partial thickness burns; full thickness burn.

front of the medial epicondyle avoiding damage to the ulnar nerve. In the lower limb, the medial incision passes behind the medial malleolus (Fig. 10).

The equipment needed is a scalpel to cut through the burnt skin. Reaching of subcutaneous fat is the endpoint, marked by a sudden "give". Hemostasis can be obtained with vessel ties or diathermy. Once the areas are released, check for distal pulsation and capillary refill. Light non-compressive dressings like gauze and pads are applied into the wounds.

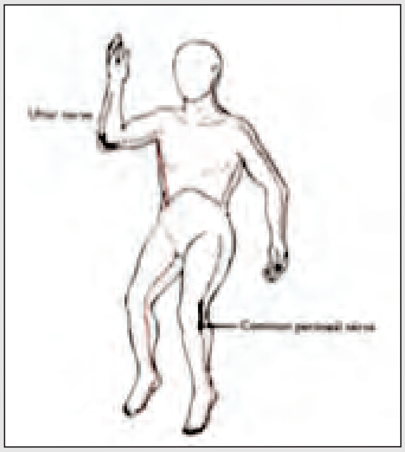


Fig. 10

Markings for escharotomies. Be aware of the ulnar and common peroneal nerves

Inhalation Injury

Inhalation injury is most commonly associated with burns of the head and neck. This is a potentially fatal injury. A history of burns in an enclosed space, such as a house or vehicle increases the likelihood of an associated inhalation injury. The following clinical signs are suggestive of inhalation injury, following burns:

- Burns to mouth, nose and pharynx.
- Singed nasal hairs.
- Productive cough with carbonaceous sputum.
- Change of voice, hoarse cough.
- Flaring of alar nasi.
- Inspiratory stridor.
- Tracheal tug.
- Indrawing of supraclavicular fossae.

During initial assessment, it is important that all patients with burns be given humidified oxygen by non-rebreathing mask with reservoir at 8 liters per minute. If increasing airway obstruction/edema is suspected, the airway must be secured by endotracheal intubation.

Delay may make intubation impossible due to airway edema. Stridor and respiratory distress are definite indications for intubation. Further management of the intubated patient is done by bronchial toilet to clear secretions. Intensive care support is essential for the management of these patients, and transfer to an appropriate facility adequately staffed with critical care specialists is necessary.

Electrical Injuries

Electrical injuries are divided into low voltage, high voltage and lightning strikes. Low voltage is anything below 1000 volts, usually involving domestic

Table 1

Depth	Color	Blisters	Cap Refill	Sensation	Healing
Epidermal (First Degree)	Red	No	Present	Painful (++)	1 week, no scarring
Superficial Partial Thickness (Second Degree)	Pale Pink	Small	Present	Painful (+++)	10 days, minimal scarring
Deep Partial Thickness	Blotchy Red	+/-	Present	Painful (+)	21 days, moderate scarring
Full Thickness (Third Degree)	White/Black	No	Absent	Absent	Severe scarring

This table shows the signs of different burn depths. A fourth level (4th degree) is burn depth beyond the skin, extending to muscle/bone.

accidents. High voltage includes anything above 1000 volts, commonly encountered in high tension transmission cables. Tissue damage results from the generation of heat, which is a function of resistance of tissue, duration of contact and intensity of the current. Arcing burns, flash burns and contact burns are other burn injury mechanisms in electrical injury patients.

High voltage electrical injuries are a special sub-group of patients, with multisystem involvement. Primary and secondary survey should be performed as per the ATLS protocol. In addition, these patients have a higher risk for dysrhythmias, compartment syndrome and myoglobinuria.

An ECG should be done on all patients with electrical injury. The peripheral circulation should be assessed for skin color, edema, worsening pain, pulses and sensation. A high index of suspicion should be maintained for compartment syndrome, and if suspected a fasciotomy should be performed. In severe cases, the distal limb may be charred or severely crushed. In such situations, an early decision for amputation should be contemplated. (A fasciotomy is through the muscle fascia not the superficial fascia as in a thermal burn. It usually requires anesthesia.)

Electrical injuries cause extensive muscle damage, resulting in myoglobinuria. Serial monitoring of CK-MB indicative of muscle damage can be performed if available. The emphasis should be on aggressive fluid resuscitation, aiming for a high urine output (2-3 ml/kg/hr), in order to prevent renal failure. A return to normal urine color is an indication of satisfactory clearing of toxins.

Fig. 11

Inhalation injury.

Chemical Burns

Commonly used chemicals causing burns are:

- **Alkalis**: sodium, potassium, ammonium, lithium, barium and calcium hydroxide (washing powder, drain cleansers, paint removers)
- **Acids**: picric, tannic, sulfasalicylic, acetic, formic, hydrochloric, hydrofluoric

The essential difference between thermal and chemical burns is the length of time which tissue destruction continues since the chemical agent causes progressive tissue damage until it is inactivated by a neutralizing agent or dilution with water.

Acids produce coagulative necrosis, while alkalis produce liquefactive necrosis. Constant water flow is the most important treatment of most chemical burns. Chemical injuries to the eye require copious irrigation and then referral to an ophthalmologist.

Burn Management after the First 24 Hours

Fluid Balance

During the second 24 hours, the fluid requirements are less than in the first 24 hours. If the urine output is adequate, the author reduces the fluid requirements to maintenance fluids (dextrose/saline). Excessive fluid can cause pulmonary edema and precipitate cardiac abnormalities.

Oral Intake

Oral intake is started as soon as the patient is able to. Patients with severe burns need a high protein diet. The patient is encouraged to eat 2-3 eggs per day, along with meat. Vegetarians are encouraged to eat pulses (beans, lentils, etc.). Eating of fresh fruits and vegetables is also encouraged. Multivitamin supplements may have to be added if nutritional intake is poor. In major burns, naso-gastric feeding at night may have to be considered if oral intake is poor.

Wound Care

The wound should be assessed for burn progression and depth. If a burn is superficial, the author applies a moisturizing cream and no dressings are required. In case of partial thickness burns, blisters are deroofed completely. This is best accomplished with a wiping action using wet gauze. All loose skin is wiped away, leaving behind raw dermis. The overlying epidermis is dead, and it is essential to wipe it all away, preventing future risk of infection. Simple non adherent dressings like paraffin gauze are applied topically. The author also uses a topical antibiotic like Neosporin® (Polymyxin) to create a moist environment. If the dressings are relatively dry, they do not need to be changed every day. Wound inspection can then be done every 48-72 hours.

(**Editors' note**: Honey may also be used on superficial partial thickness burns and left on for 2-3 days between dressing changes. This is raw honey and not the honey purchased in a store. It is antibacterial, keeps the wound moist, absorbs fluid and exudate, and is deodorizing.)

Deep partial thickness and full thickness burns need special care. Silver sulfadiazine cream (SSD) is the mainstay of initial treatment. If SSD is not available, honey dressings can be used.

At every dressing change, the loose slough is debrided and cut. These burns are unlikely to heal within 3 weeks, hence an early decision to debridement and split skin grafting should be made. This decision is made at the end of the first week, by which time full thickness burn areas are well demarcated. Beyond this time, waiting and watching only increases the risk of infection and systemic sepsis.

Burn excision and skin grafting should therefore be performed early in the care of these patients so as to decrease the cost of care, and the associated morbidity and mortality.

Fig. 12

Dark urine (myoglobinuria) in electrical burns

Fig. 13

Acid burns—note pattern of skin involvement

Tangential debridement is done using a Watson knife (skin graft) knife. Infiltration solutions have been consistently shown to reduce blood loss and prevent large volume transfusions[2]. A Weck blade on a Goulian handle works well also (See Chapter 12 on Burn Reconstruction).

The author infiltrates the donor area and the burn tissue with a Klein's solution to reduce blood loss (1 liter normal saline, 1ml 1:1000 adrenaline, 20 ml 0.25% Sensorcaine®/ Marcaine® [bupivacaine] for pain relief). Following infiltration, the burned tissue is sliced in a sequential manner using the Watson knife or Weck blade (see diagram). All non-viable tissue is excised, till healthy punctate bleeding from deep dermis or bright yellow fat is seen. This technique is useful in preserving normal tissue. One should keep debriding until good quality healthy tissue is reached. This may take some experience, as relying on tissue bleeding, for example, can be a misleading sign with the whole region being inflamed. After all the areas are debrided, meticulous hemostasis is obtained. Adrenaline soaked sponges are used to wrap large areas. Split skin graft is then harvested, meshed and then applied to the defect and secured with sutures or staples. The author uses paraffin gauze and topical Neosporin®, along with fluffed gauze and cotton wool as a pack over the grafts. A Plaster of Paris splint should be used on extremities for the first 5-7 days till the first graft check.

(**Editor's note**: The larger the

burn and the deeper the burn, the more urgency there is to debride the wound and get it covered with good skin or skin substitute. Generally speaking, full thickness burns >40% will not live in remote hospitals in remote areas. Burns >40% require an ICU/ Burn Unit and doctors who are interested in burn care.

When the burns are <40% full thickness or deep partial thickness and surgeons have time to care for these burns, excision and grafting should be started near the end of the first week. The techniques described by the author above are excellent. Just as described, the burned areas should be infiltrated before excision and the wounds covered with gauze sponges soaked in dilute Adrenaline solution after excision. Sterile conditions with sterile sheets must be provided, along with mosquito nets, showers, and good physical therapy. In addition, blood and blood products must be available especially with tangential excision as described above. One should only tangentially excise 10% or less. It is important to cover the excised wound with autograft if available. In developed countries, homograft (cadaver) skin is available along with heterograft (pig skin) and other biological dressings as Biobrane, Integra, etc. Ideally the hands and upper extremities are grafted early. The editors graft the neck and face last as these areas have better blood supply and frequently deep partial thickness burns will heal by 3 weeks. After the wounds are skin grafted the editor use the paraffin or Vaseline gauze with wet gauze or cotton to help keep the wound moist for better healing.

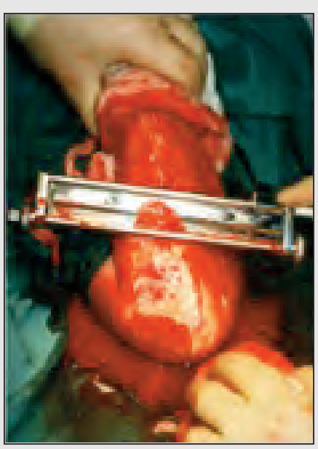


Fig. 14a

Fig. 14b

Tangential burn excision and grafting. Excision with Humby/Watson knife or Weck blade.

It is difficult not to try to save a patient with 50-60% deep burns. No one wants to give up on a patient since often with a severe burn the patient is alert and orientated when admitted. In resource-poor areas without the supplies mentioned above, including a blood bank, and in order to save the patient, the patient should be transferred to a burn center if available. On occasion a healthy patient with a 50% partial thickness burn will survive with good care.)

Historically, hydrotherapy has been used in the treatment of burn injuries. Analgesia, joint mobilization, and wound cleaning are the reported benefits of hydrotherapy. The challenge for burn caregivers is the maintenance of sterile bathtubs and other equipment used. Further, microbes that may be otherwise harmless to the individual with intact skin, may invade the skin of the patient with burns. The challenges of maintaining sterile conditions for such equipment in Low and Middle Income Countries cannot be overstated. For this reason the editors suggest using showers for daily cleansing of the burn wound and not tubs.

Analgesia: Incremental doses of intravenous narcotics may be necessary for large burns. Analgesics should be administered at least half an hour before a major dressing change. Analgesia should be taken seriously since for many patients, the dressing change is a major source of anxiety and fear.

Infection control: All equipment should be kept separate for the burn patient. Hand washing between patients is the most effective means of preventing cross infection. In developing countries, contamination of wounds is a big risk; however, antibiotics are not indicated in the absence of an infection. Routine administration of "prophylactic" antibiotics is associated with increased incidence of yeast colonization of the gastrointestinal tract, and the rapid emergence of resistant gram-negative organisms. In addition, antibiotics have not been shown to decrease the incidence of gram-positive wound burn cellulitis.

Topical antiseptics (silver sulfadiazine) provide adequate protection, and antibiotics are only used for regional or systemic infection.

Physiotherapy: It is important to maintain all joints in an appropriate position. The position of comfort is the position of a contracture and patients quickly develop a contracture. The positions of the joints recommended at rest:

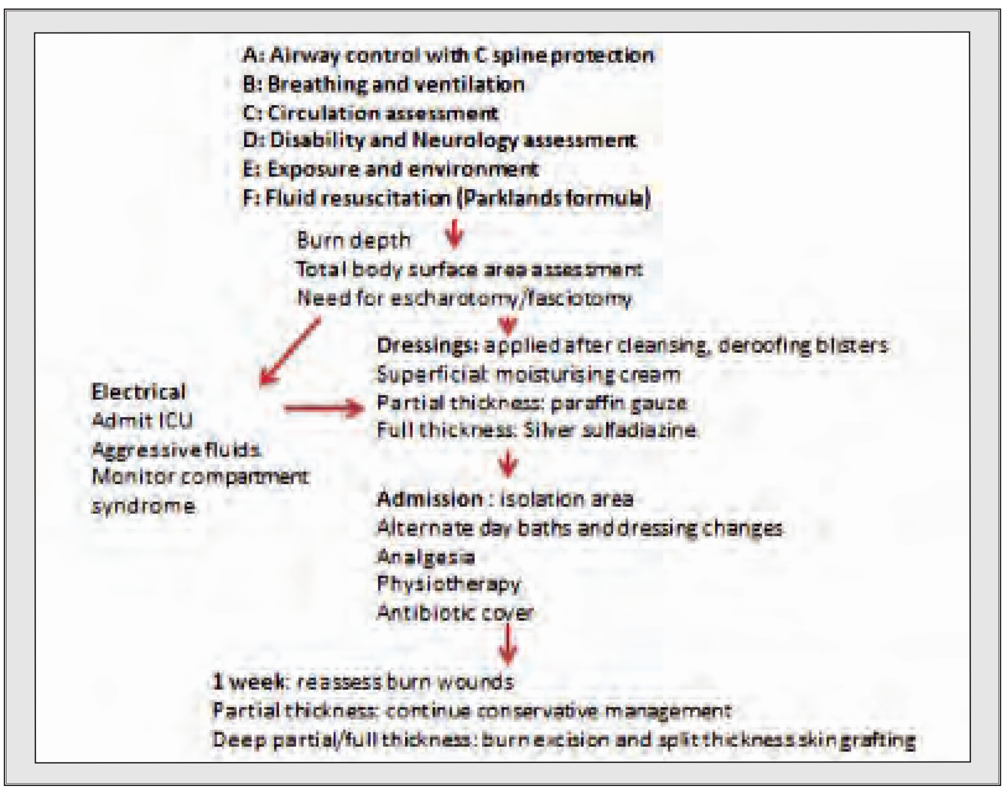
- Neck: extension.
- Axilla: abduction.
- Elbows: extension.
- Wrists: neutral.
- Metacarpophalangeal joints: flexion.
- Interphalangeal joints: extension.
- Knees: extension.
- Ankles: 90 degrees dorsiflexion.

Appropriate splints should be used to maintain these positions. The arm can be suspended on an IV pole to abduct the axilla.

Early ambulation is a priority. The attenders of the patient should be asked to put all joints through a passive range of motion 3-4 times a day. Those patients with respiratory burns should have supervised breathing or coughing exercises to ensure adequate pulmonary expansion.
Patients should be strongly encouraged to continuously move their joints to prevent joint contractures.

Long Term Scar Management
The healing of the burn wound is not the end! Scars should be moisturized and massaged regularly 2-3 times a day. If moisturization is not done, scars get dry and hard, for lack of sweat and sebaceous glands. Coconut Oil is a common agent used for moisturization and control of itching. Locally available moisturizing creams are good enough for massaging and moisturization, and this activity should be done for at least 6-9 months. The patient's family should be encouraged to get involved with physiotherapy and scar care.
Patients should be educated about the possibility of hypertrophic scars and keloids. Regular mobilization and movement of all joints help in the prevention of a joint contracture (See Chapter 44 on the use of pressure garments to prevent and treat scar formation).

At right is an algorithm for the management of severe burns.



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Chapter 12
Burn Reconstruction

Einar Eriksen, with Louis L. Carter, Jr.

Editor's Comments: Special Introduction

Burn deformities exist around the world, and especially in Africa, where there is often inadequate acute burn care. This is due to a lack of resources—dermatomes, meshers, physical therapy, and, most importantly, nurses and doctors interested in burn care. Most of this chapter is written Dr. Einar Eriksen from Addis Ababa, Ethiopia. Dr. Eriksen has worked at the Korean Hospital (Myungsung Christian Medical Center) there for the last four years, and he has been working with burns in Ethiopia for over 15 years. His results are remarkable. The keys to Dr. Eriksen's outstanding results are:

1. His singular interest in burn reconstruction.
2. Complete excision of burn scars with full-thickness grafting of deep burns of the face, hand and over joints.
3. He has his own ward, operating room and well-trained staff.
4. Long term follow-up in a nearby rehab facility where patients and their caretakers can stay several months if necessary.
5. Excellent equipment and supplies, including the availability of staplers to anchor large grafts in place, which saves time.
6. Outside funding for his surgery and follow-up care (through his own foundation).

His techniques may be more technologically appropriate for Africa than other methods, though they still require considerable resources. Certainly all general surgeons know how to skin graft, but not all surgeons possess Dr. Eriksen's skills in full-thickness skin grafting. Also, few have the funds, equipment, time, and quality of nursing care to obtain his results. Most general surgeons do not know how to use flaps in burn reconstruction, though some know how to do some flaps for wounds, especially lower leg reconstruction. Flaps will be included and described in this chapter in a **blue print**. Flaps do not require lengthy hospital stays and usually eliminate large grafts, especially large full-thickness skin grafts (FTSG). FTSGs will not heal as well as a well-performed flap, but these flaps almost double the size of the area needing reconstruction, since the flap donor site often requires grafting.

This chapter will give the reader a chance to pick the right operation for their patient, taking into account their skills, facilities and supplies, the patient's funds, and whether or not the patient and caregiver can stay until the wounds are completely healed.

While Dr. Eriksen's methods are the "ideal," the editors realize that many of his techniques may not be practical for the general surgeon in the district hospital. The use of flaps may also be beyond the experience of many general surgeons.

Again the **blue print** in this chapter are editorial comments by the editors, and provide different views and techniques.

Aspects of Acute Burn Treatment (See also chapter 11)

1. **General**: Thermal injuries are one of the most common causes for emergency admission to hospital facilities across the African continent. Often the main cause is an unprotected fireplace or ground level cooking. Females and children are often affected. Burn survivors frequently develop various contractures and deformities which impose a heavy burden on the families and their society.

2. **Principles for improved burn care:** Successful treatment of burn patients starts with physicians and nurses with an interest in the care of the burn victim. A multidisciplinary approach where doctors, nurses, and therapists work as a team is imperative for the successful outcome of burn treatment.

3. **Diagnosis of acute burns:** A basic understanding of how to diagnose the depth and extent of thermal injuries will guide the health professional in providing the best possible treatment for his patient.

   The risk of future scarring and contracture development is closely linked to the depth and location of the burn. Proper assessment of the depth will guide the surgeon to decide whether or not skin grafting is necessary.

The depth of a burn is traditionally classified into 3 different levels:

- **First-degree burn**: The superficial part of the skin, the epidermis, is affected with mild erythema, pain and discomfort. There is no blister formation. This burn has no clinical importance. Sunburn is the most common cause of first-degree burn.
- **Second-degree burn**: This burn may be classified as superficial partial thickness or deep partial thickness, depending on how deep the injury penetrates into the dermis of the skin. The main sign and symptom of a second-degree burn is blister formation and pain. The more superficial the burn is, the more pain the patient will experience. As the burn gets deeper into the dermis, there is less pain.
- **Third-degree burn**: The whole thickness of the skin is destroyed, and often even underlying structures like subcutaneous tissue, fascia, tendons, and bony structures. The patient does not feel any pain with this burn. This is also known as a full-thickness burn.

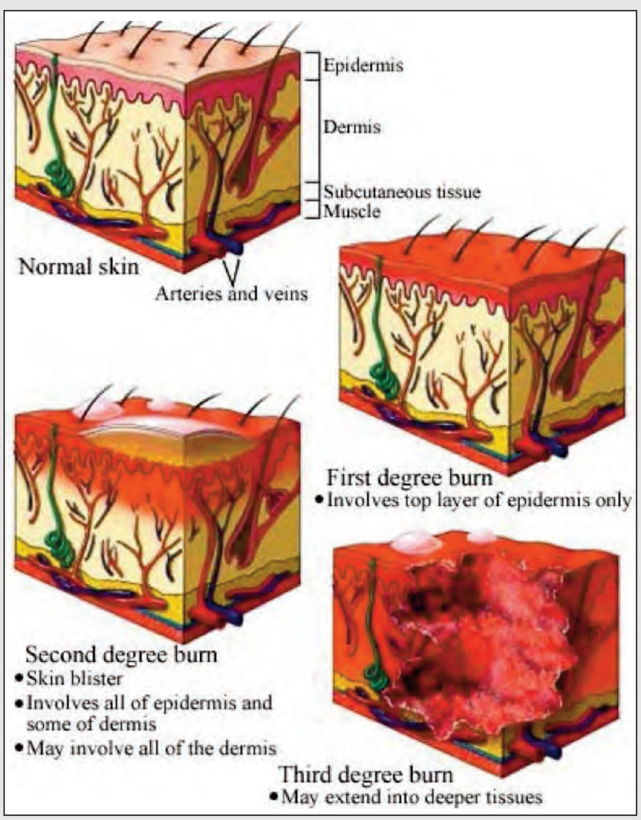

Diagram 1

Superficial wounds tend to heal quicker and will seldom leave a significant scar behind. A second-degree burn usually heals within 2-3 weeks. If a wound has not healed properly within 3 weeks, the wound is classified as a third-degree or full-thickness burn wound. This wound will eventually heal in most instances, but with scar tissue.

One should refer to other textbooks (as well as chapter 11) for more details regarding diagnosis and assessment of burn wounds and acute treatment.

4 **Scar development—the tragedy for the neglected burn patient:** The horrible consequences of neglected burn care are due to scarring and, in particular, involving:

- The face.
- Joint-related areas.
- Hands and feet.
- Groin, perineum, or genitals.
- Neck and axilla.

Injuries in these areas should make the burn team aware of the possibility of contracture development if wound healing is not completed within 3 weeks.

The best way of preventing unnecessary scarring and contracture development is to perform skin graft procedures within 3-4 weeks of the initial injury, ideally in the first two weeks. If it is definite that the patient has a full thickness burn, early excision and grafting in the first few days after the injury is advised, if the patient is stable. Scar and contracture development occur quickly if the wound is left to heal by secondary intention.

Even if burn wounds are treated with early skin grafts, significant hypertrophic scarring and contractures may still occur and require additional surgery. Wounds left to scar in by secondary intention without early skin grafting, however, will always result in contractures if they are over or near joints.

****Still, early skin grafting is the most important undertaking a surgeon can do to prevent a burn victim from developing disfiguring contractures and deformities.**

Development of disfigurements and deformities is more pronounced among children, compared to adults, due to their ongoing growth. For this important reason, children are in need of a close follow-up after initial burn treatment and skin grafting. Scars do not grow, and in the growing child, contractures will become more pronounced with age.

5 **Skin graft procedures during the acute stage:** The depth of an acute burn may be difficult to assess during the first couple of days.

In case of a small (1-2%) and obvious 3rd degree burn, primary excision, and skin graft during the first 2-4 days should be considered the treatment of choice.

In general, there are many advantages in waiting to perform skin graft procedures until 14 days following the injury. Most second-degree burns have healed by the end of the second week. The surgeon should consider grafting wounds that have not healed by three weeks. When there is an isolated deep partial thickness or full thickness upper extremity burn, then an experienced burn surgeon should consider early excision and grafting within the first two weeks. This should only be undertaken if the patient is stable, and blood products are available. Tourniquets, if available, should be used on the extremities to minimize blood loss during excision. This will give the best functional result.

The use of skin graft meshers enhances graft take considerably and allows for the ability to cover larger areas of wounds. Skin grafts applied to joint areas should **not** be meshed. **Joints should be covered with sheet grafts (unmeshed grafts) to enhance the functional as well as the aesthetic result**. (Refer to chapter 11 and appropriate textbooks for further details regarding acute burn surgery.)

This advice is for victims with less than 40% total body surface area (TBSA) burn. Patients with larger burns have a significantly higher mortality. The ideal treatment in the West, with early excision and grafting, is not applicable for Sub-Saharan Africa where there are few burn specialists and burn centers with nurses, sufficient blood and supplies to care for victims who are severely burned.

Techniques Used in Reconstructive Surgery

Basic Principles

After post-burn contracture release, the resultant wound may vary in size and depth. Rarely, a wound can be covered and closed with adjacent normal skin:

1 Z-plasty: Only applicable in linear scars with normal surrounding skin.

2 Rotation flaps: May be a good solution to cover

Fig. 1

Fig. 2

FTSG vs. STSG: primary contracture is significant in a FTSG because it contains more dermis, but later contracture is less.

joint areas, such as the axilla.

3 Flaps are ideal when tendons and joints/bony structures are exposed. Without vascularized tissue covering these structures, flap coverage is **mandatory**.

4 For the majority of burn scars, a “simple” skin graft will give a satisfactory result.

5 **Split thickness skin grafts (STSG):**
- Common donor sites are the thighs, legs, flanks, and upper arms.
- Avoid harvesting skin grafts from forearms if possible, as this leads poor aesthetic appearance.
- Also, avoid harvesting from the posterior aspects of lower limbs and trunk (see donor wound care below).
- STSGs may vary in thickness, from thin superficial grafts to thicker grafts (~8 to 20 1000ths/inch).
- It is the degree of the dermal component of the graft that determines the result of the skin graft procedure. The thicker the dermal component, the better appearance and functional result (the thicker graft should contract less).
- On the other hand, the thinner the dermal component of the STSG, the sooner the donor wound is going to heal, but scar formation at the recipient site may create a new contracture.
- The donor wound left by a medium, “standard” STSG will heal within 14 days and typically does not leave a noticeable scar.
- The donor wound from a deep STSG may take up three weeks to heal.
- STSGs are frequently meshed (meshers = meshing machines) to cover larger areas.
- Full thickness grafts are not meshed by a machine but are often meshed by hand with a scalpel (“pie crusting”) to allow blood and serous fluid to escape into the overlying dressing.
- Full thickness skin grafts require defatting of the undersurface of the dermis to enhance graft take.
- Sheet grafts are more functionally and cosmetically appealing, compared to mesh grafts.

6 **Full thickness skin grafts (FTSG):**
- A FTSG consists of the whole layer of skin—epidermis plus the entire dermal layer.
- Full thickness grafts are technically more challenging to harvest. Meticulous hemostasis of the recipient wound is mandatory. Hematoma formation underneath the graft will inhibit graft take.
- FTSGs are preferred to STSGs when reconstructing facial defects and special joint areas:
  - Eyelids, lips, and cheek.
  - Anterior neck and axilla.
  - Volar aspect of the wrist, hand & finger joints.
- Smaller grafts may be harvested from the posterior aspect of the ear, supraclavicular area, the medial side of the upper arm and groin area. These donor wounds are usually easily closed.
- Hair follicles in grafts harvested from the

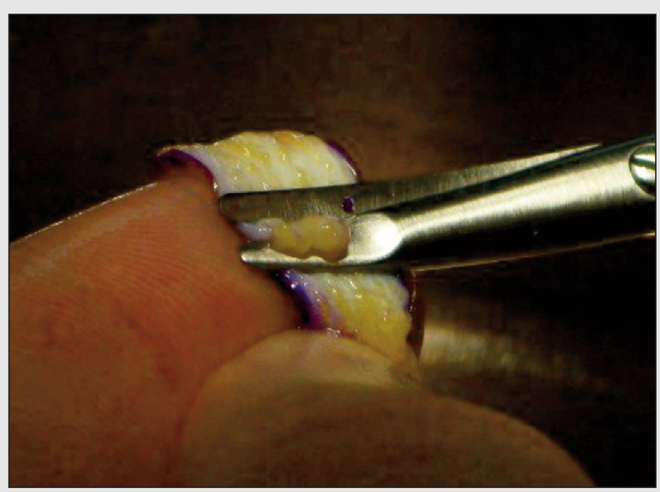

Fig. 3
Defatting FTSG with sharp, curved scissors.

Fig. 4

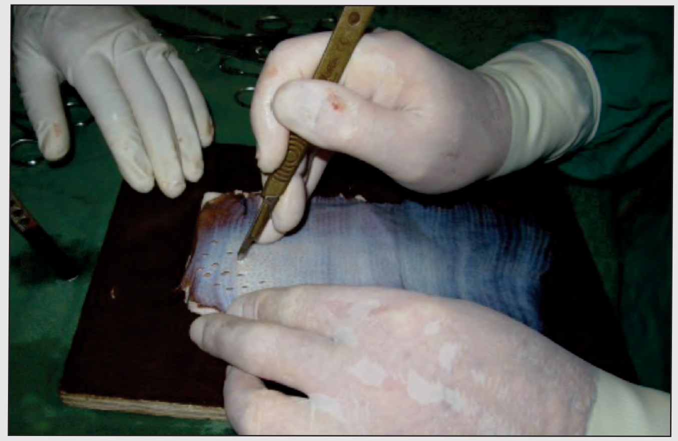

Fig. 5

4) Humby/Watson knife; 5) Manual meshing.

groin will lead to hair growth, an issue that needs to be taken into consideration when planning the surgery. Defatting and depilating the graft into the dermis is important to minimize hair growth within the graft. Also, grafts should be taken from the lateral groin where there is less hair.

- When **large FTSGs are required, the grafts may be harvested from the medial side of the upper arm, groin area, flank, and abdomen, or from the thigh.**
- Large FTSGs from the medial aspect of the upper arm or thigh will likely need to be closed with a meshed STSG.
- When harvesting FTSG from the thigh, the manual dermatome (Watson/Humby knife) can provide a wide graft.
- When harvesting FTSG from the abdomen or flank, a scalpel is used to remove the graft.

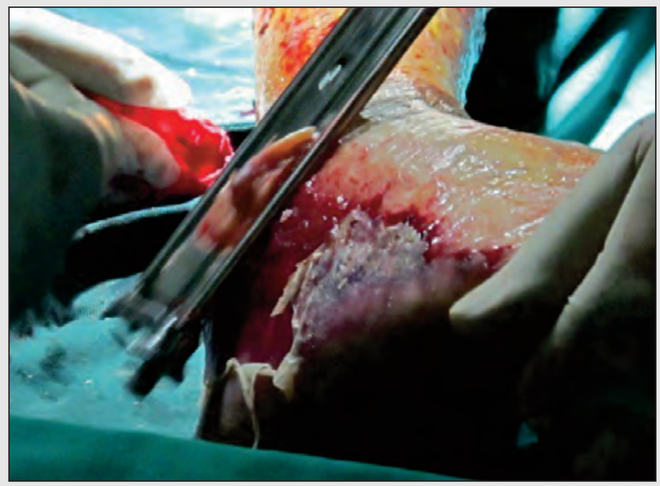

Fig. 6

Humby/Watson knife and blades used for excisional debridement as well as harvesting the skin grafts.

Basic Equipment

Dermatomes may be electric or manual (Watson/Humby knife). Although an electric dermatome is a great tool when dealing with extensive burns, the author advises burn surgeons to learn to use manual dermatomes. There are several reasons for this:

1 Manual dermatomes are inexpensive and may last for years when handled with care.
2 Blades can be re-sterilized several times, providing they are handled with care.
3 Manual dermatomes can harvest wider grafts than electric dermatomes, an important point when dealing with reconstructive surgery.
4 Regular electric power supply may be an issue in many places.
5 Maintenance and repair of electric dermatomes may also be an issue.
6 Electric dermatomes are expensive and hard to find.

Meshers or mesh machines are mandatory in order to succeed with burn surgery, be it acute burn surgery or post burn reconstruction. The graft take is enhanced considerably, and larger areas can be covered with grafts when using a mesher.

Skin staplers are highly recommended when dealing

Fig. 7

Fig. 8

7) Brennan mesher; 8) Meshed 3:1 when covering donor site, but usually meshed 1:2 for grafting.

with acute or chronic burn patients. Use of skin staplers reduces the operating time considerably. Securing skin grafts with ordinary skin sutures is very time consuming and probably more expensive, when considering increased operating time.

- Skin staplers are particularly recommended when operating on acute burns. Skin staplers are also very useful in many reconstructive procedures.
- After debridement of a burn scar, a graft can be immediately applied with a stapler. The immediate application of a graft will help minimize bleeding due to the hemostatic properties of the fresh graft. Then pressure should be immediately applied to the recipient site for 5 minutes for further control of the bleeding.

Tourniquets are highly recommended whenever surgery on the limbs is undertaken. If a tourniquet apparatus is not available, an esmarch can be used, if available. (When using an esmarch, the extremity should be exsanguinated and the esmarch wrapped around the proximal part of the extremity twice and then the end tucked into the previous wrap.) The tourniquet reduces blood loss significantly and also allows the surgeon to do the dissection properly and distinguish between injured tissue and healthy tissue in acute burns.

Indication for application of tourniquet:

- Contracture release in upper and lower extremities.
- Excision of chronic, fibrotic hyper-granulated wounds.
- Tangential excision of deep partial and 3rd

Fig. 9

Staplers save time and money.

Fig. 10

Esmarch is useful as a tourniquet; especially in children when a small tourniquet may not be available.

degree burns

A Diathermy machine/electrocautery machine is needed to obtain meticulous hemostasis before applying a skin graft to the recipient wound area. This cannot be overemphasized. This is of particular importance in dealing with FTSGs/sheet grafts that are not meshed.

- Diathermy machines may not be available. Hospital administrations should make all efforts to provide this vital piece of equipment.
- Adrenaline 1:1000 can be diluted and used topically to control bleeding. Usually 2 ml. are added to 100-200 ml of saline.

Application of Skin Grafts

- As mentioned above, surgeons should be familiar with the use of a **manual dermatome**.
- The thickness of the graft is determined by observing the gap between the roller of the dermatome and the blade.
- When the gap permits a scalpel or razor blade to slide gently in between the roller and the blade of the dermatome, a medium thickness STSG will be harvested—approximately 0.015 inch in thickness
- The gap needs to be adjusted a bit to widen the space between the roller and dermatome blade to get a thicker STSG or even full thickness graft.
- To obtain a thick graft, open the space in order to be able to "twist" the scalpel blade a bit between the roller bar and the blade. On the Humby, there are marks indicating the thickness. When the opening is set between marks 2 and 3, I am usually pleased with the thickness. It depends on the way the handle is used, angle to the skin, force applied to the skin, whether the blade is new or used, from where on the body you harvest, and whether the patient is a child or an adult.
- **(Editor's note**: The Humby knife has 7 marks or notches along the side to measure the thickness of the graft. At the first mark the knife is closed. The distance between each mark is 0.25 mm, or approximately 0.010 inches. When opened all the way, the thickness is 1.50 mm or 0.060 inches. This is the average thickness of adult thigh skin. As Dr. Eriksen stated above, he only opens the Humby to mark 2 to 3 (never past 4) and takes his grafts. When he desires a full-thickness graft, he uses a sharper angle and more pressure. When he desires a split thickness graft, he reduces the angle and pressure. Often after taking a full-thickness graft, Dr. Eriksen continues to harvest the split thickness graft during the same cut by adjusting the angle and pressure. This is used to graft the full- thickness donor site after meshing the split skin. The thickness of the skin varies with age. The harvest of such grafts will take the surgeon considerable practice. Most surgeons have difficulty using the Humby knife. "I can harvest thick and thin graft in the same cut just by adjusting the angle of the Humby." (Personal communication from Dr. Eriksen)
- It appears obvious that **this procedure needs experience**. Again the following points all determine the thickness of the graft:
  - The patient's age—child or older adult?
  - Consider that thickness of the skin varies from one place of the body to another.
  - The angle between the dermatome and the skin surface.
  - The pressure applied on the dermatome.
- **With experience, the surgeon will adjust his cut to obtain the desired thickness.**
- When the graft has been harvested, one can easily assess the depth of the cut/the thickness of the graft:
- The thicker the graft, the more elastic is the graft; the deeper is the donor wound, and the more likely the graft will contract primarily.
- The pattern of the bleeding points in the donor wound will also give a good indication of the depth: Tiny numerous bleeding points indicate a superficial cut, whereas larger and spread out bleeding points indicate a deeper cut.
- If subcutaneous tissue and tiny small blood vessels are visible, the cut is close to a full thickness depth.
- When a full thickness cut is observed, the wound should ideally be covered with a mesh graft for quick healing to prevent prolonged healing time and hospital stay.
- Joint areas should preferably be covered with thick STSG sheet grafts or full thickness grafts after **hand meshing** the graft in few areas to permit serous

fluid and blood to escape into the overlying dressing.

- Other less important surfaces may be covered with a mesh graft, and this will allow coverage of larger areas.

- If a mesher is **not** available, split thickness grafts may still be meshed by hand with a number of small cuts thereby allowing expansion of the graft.

- **FTSGs** can either be harvested with an ordinary surgical blade or with a Humby knife. Make sure all fat tissue is trimmed with a sharp scissor. FTSG will not heal properly if fat tissue is left on the graft. Trimming off a thin layer from the undersurface of the dermis enhances graft take.

- Large and wide FTSGs can be harvested with a Humby knife from the anterior or lateral side of the thigh.

- Before grafting the recipient area, meticulous hemostasis needs to be obtained. This is particularly important when using **FTSG**. Small collections of blood underneath the grafts—"tenting it up"—will inhibit graft acceptance.

- FTSGs are applied to the recipient wound surface and sutured to the surrounding skin edge with fine 5-0 or 6-0 skin sutures or small staples.

- When applying meshed STSG to larger areas, the need to obtain complete hemostasis is not as important because the meshed skin will allow proper drainage into the overlying dressing. However, bleeding vessels need to be controlled as "tenting of the graft" is still possible.

- The application of proper bandage and dressing material is of great importance. Properly applied dressings will prevent hematoma formation and ensure the graft does not move. This principle is applied to grafts wherever they are applied. A "shear" injury to the graft from sliding around is one of the leading causes of graft failure.

- One way of securing FTSG to the face and neck, is to use tie-over sutures to hold the dressing in place—a bolster dressing. If, however, the dressing is applied properly with an elastic bandage holding the dressing in place, there may not be a need to apply tie-over sutures.

- The surgeon is responsible for follow-up on all patients. The author advises the surgeon to do the first dressing change and allow the burn nurses to do the follow up dressings.

- The right timing for post-op dressing changes may vary:
  - Clean wounds with a sheet graft—check wound (do not remove dressing completely) at 1-2 days to check for hematoma.
  - Clean wounds after reconstructive surgery: First dressing change after 5-6 days if the graft has been meshed and bleeding well controlled.
  - Unclean wounds /chronic hypertrophic granulation wounds: First dressing change after 1 – 3 days.

Care for Donor Wounds

Neglecting care for donor wounds may prolong hospital stay considerably! Make all efforts to prevent donor wounds from becoming infected.

Infected split thickness donor wounds may sometimes require a skin graft after debridement for the donor wound to heal properly.

- If possible, avoid harvesting skin grafts from the posterior aspect of the lower limbs and trunk. Donor wounds from these areas may easily become secondarily infected.

- A simple and inexpensive dressing for donor wounds is Vaseline® gauze (non-adherent gauze) covered with several layers of dry surgical gauze followed with a crepe bandage or gauze roll bandage.

- Make sure bedclothes and blankets do not touch the wound. This is important in order to keep the donor wound dressing dry, and the best way of preventing donor site infection especially on posterior donor sites.

- Check the donor site dressing every day. If the dressing becomes wet—a sign of possible infection—the wet part of the dressing needs to be changed without delay.

- To prevent donor wound infection, a complete dressing change on the 2nd or 3rd post-op day may be a good investment.

Fig. 11

Fig. 12

Bilateral chronic wounds. The patient required several weeks of nutrition and multiple debridements before wounds were ready for grafting.

(**Editors' note:** There are different ways to handle donor wounds. This method described above is excellent for the large donor sites. For smaller ones from the anterior or lateral thigh, the editor takes off the gauze down to the Vaseline the day after surgery and leaves the wound open. In hot climates, this allows for the wound to dry and not become wet and infected.)

Chronic Burn Wounds: A Challenge

(Many patients present with chronic wounds with or without a contracture or deformity. The patients might have waited for months or sometimes even years before seeking help. Many of these patients, children as well as adults, show evidence of malnutrition and often have chronic skin lesions like scabies. These patients are difficult to treat. Before even considering surgical excision and grafting procedures, the patients may need additional nutritional support. Measures need to be taken to address chronic anemia, and blood transfusions may be necessary.

Sooner or later though, surgery has to be planned. The author has adopted the following routine in these cases:

- Nutritional support from the day of admission.
- Routine work-up and treatment (scabies, parasites, HIV, etc.).
- Daily wound care with antibiotic cream (Silver Sulfadiazine).
- Physiotherapy.
- Tangential excision of chronic wounds **under a tourniquet** and with preoperative antibiotics.
- Continue daily wound care.
- Apply meshed skin grafts 2-4 days following wound excision if wounds are clean. A repeat tangential excision may be necessary.
- Post-op dressing change every day or every other day until healing of grafts.

Chronic wounds may consist of a thick fibrous tissue that needs to be excised before any graft is applied. Skin grafts will be rejected in most instances if applied to fibrotic tissue. **The thickness of this fibrous tissue may exceed 1 cm or more. The only way to secure graft take is to undertake a complete excision of the fibrotic wound. Dissection needs to be performed in the layer or plane between the fibrotic tissue and healthy tissue.** One should see good **punctate bleeding** in the subcutaneous tissue. Skin grafts heal readily on healthy vascularized tissue like fat, fascia or even paratenon.

Keep in mind that chronic burn wounds, if left

Fig. 13

Fig. 14

Chronic wound that turned into Marjolin's Ulcer, requiring amputation.

Fig. 15

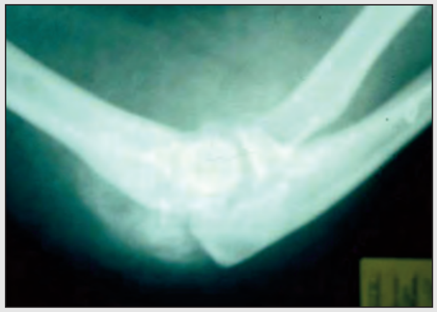

Fig. 16

Fig. 17

15-16) Heterotopic Bone (HO). 17) Marjolin's Ulcer.

untreated for years, may degenerate into a spinocellular carcinoma (squamous cell carcinoma—Marjolin's Ulcer)

Differential Diagnosis of Burn Contractures

Joint contractures are not always caused by burns. One must be aware of the other causes:

- Snake Bites—this is often a deeper injury that involves soft tissue and muscles as well as skin.
- Heterotopic Bone Formation (HO)—need x-rays; especially common at elbow and often without a deep burn. Sometimes occurs at the elbow without an elbow burn but with a burn elsewhere.
- Trauma around joints with bone and/or joint injury Septic arthritis with scarring of joint capsule.
- Pterygium is a congenital flexion contracture at either elbow or popliteal fossa. This is not a surgical condition.
- Marjolin's Ulcer—squamous cell carcinoma in burn that is usually >10 years old

Reconstructive Procedures

(Unless one excises the entire burn scar as Dr. Eriksen does, one should not release burn scar contracture during the active phase of wound healing when the scar is still immature and highly vascular. It is best if the burn scar matures and becomes soft and supple before surgery is attempted. This often takes at least one year after the scar is mature. Surgery before this time causes additional trauma and possibly additional contraction since the scar is highly vascular. Skin grafts, especially FTSG, may not heal as well with significant bleeding from the scarred tissue.

During the immature wound healing phase, additional physical and occupational therapy will be beneficial.

There are exceptions to waiting until the wound is mature: scars that continue to break down and leave open wounds, scars/contractures that interfere with eyesight, eating, and required activities of daily living (ADLs), and scars that will lead to severe joint contractures and progressive, significant tendon deformities if left for additional months.)

Eyelids

1 Thermal injuries to the upper part of the face/forehead will frequently affect the eyelids.

2 Second-degree facial burns usually heal completely within about 2 weeks.

3 Wounds of the eyelids that have not healed properly within 3 weeks may easily contract and retract the eyelids.

4 Early reconstruction of retracted eyelids is of paramount importance in order to protect the cornea and restore normal eyelid function.

5 Technique:
- General anesthesia is preferred.
- Inject Lidocaine with adrenaline in the scar tissue/incision area to minimize bleeding. Allow 5-7 minutes for hemostasis.
- Make an incision about 2-3 mm from the lid margin. Gently dissect the scar tissue from the underlying normal eyelid tissue. Bleeding points should be controlled with cautery.
- Make sure the contracture is completely released into healthy tissue.
- Both upper and lower eyelids should be repaired together if affected.

- Full thickness grafts harvested from either behind the auricle or from the supraclavicular region are commonly used for the best color match.
- All fat tissue of the graft needs to be trimmed.
- Hand mesh the graft with a scalpel blade in order for serous fluid and blood to escape into the overlying gauze dressing.
- Apply the full thickness graft by stitching the graft to the edge of the wound using 4-0 or 5-0 skin sutures.
- Make sure there is no bleeding from the wound before applying the graft. Small bleeding vessels need to be arrested.
- Tarsorrhaphy is advised before applying the dressing. The dressing should consist of Vaseline® gauze, wet gauze, then dry gauze before securing the dressing with a gentle elastic bandage. **(Editor:** A stent dressing can be applied with wet cotton balls and tie-over sutures. Place wet cotton balls over the Vaseline® gauze.)
- Remove tarsorrhaphy and stitches within 10 days. If the eyelid contractures are acute or severe, one should consider leaving the tarsorrhaphy sutures in for two weeks and even longer.Continue to apply dressing support to both eyelids for another 2 weeks.

6 Representative cases are shown in Figs. 18-31.

Fig. 18

Fig. 19

Fig. 20

The above patient required release of contractures, excision of surrounding scar, and reconstruction with FTSG from the supraclavicular area with an excellent result.

Fig. 21

Fig. 22

Fig. 23

Fig. 24

This patient waited 20 years for surgery. Some vision remained in her left eye. Release with FTSG from supraclavicular areas was done for all four eyelids in two operations. FTSG from the thigh was used for the lip. The donor sites were covered with split thickness skin grafts, meshed 3:1.




Fig. 25 **Fig. 26** **Fig. 27** **Fig. 28**

Facial burn in an epileptic patient that required wide excision and FTSG from medial side of upper arm. Donor area was covered with meshed STSG.



Fig. 29 **Fig. 30** **Fig. 31**

Same patient with recurrence of ectropion—repeat release and FTSG.

Nose

Deformities of the nose range from alar rim defects to complete loss of the nose. There may be severe scarring of the nose, damage to the nasal cartilages, and various degrees of nasal collapse. Unfortunately, the surrounding skin is often burned and not available for reconstruction. If possible a nasolabial flap or variation is used for rim defects. Complete nasal reconstruction requires mucosal replacement, a cartilage framework and skin covering. Often the best results are from a forehead flap if the forehead skin can be used. The framework requires cartilage from the concha of one or both ears, a split calvarial graft or a split rib for the dorsal strut.

Mucosa can be replaced with nasolabial flaps, even if previously burned, or a midline forehead flap (which is turned down over the cartilage framework), or a conventional forehead flap which has been previously lined with skin grafts. If the midline forehead flap is turned over for the lining, then the nasal skin is reconstructed with lateral forehead flap based on a superficial temporal artery.

The mid-line forehead skin does not have to be used if it is scarred. If necessary, pedicled radial forearm flaps may be used (Tagliacozzi).

Lips

1 Post burn lip defects are reconstructed using the same technique as eyelid reconstructions.
2 FTSGs are preferred, and are harvested from the same places as for eyelids.
3 The dressing can be strapped against the mandible and the maxilla reducing the risk of hematoma formation.

Fig. 32

Fig. 33

Fig. 34

Fig. 35

Fig. 36

Fig. 37

Fig. 38

A young boy after injuries sustained during an epileptic seizure: Complete wide excision of scarred areas, with skin grafts to chin, lips, cheek, forehead, eyelids, and side of partially destroyed nose. Ready now for nasal reconstruction with forehead flap as next stage.

4 There is usually no need to apply tie-over sutures

Cheek, Forehead, and Scalp

1 Facial burns often involve various parts of the face. Cheeks, eyelids, forehead, and scalp are frequently affected simultaneously.

2 The surgeon may concentrate on dealing with one anatomical part at a time, like doing the eyelids before proceeding to the rest.

3 If the surgeon becomes familiar with a good harvest technique, he should consider grafting all these areas during the same operation.

4 This will require good pre-operative planning.
- Blood transfusion might be needed.

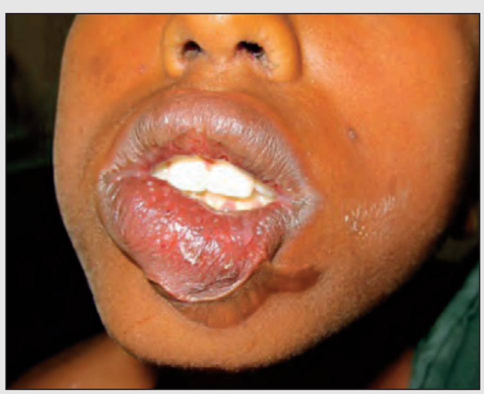

Fig. 39

Fig. 40

Lower lip contracture with FTSG.

- Diathermy/electrocautery equipment.
- **The Editor uses dilute adrenalin solution: 2-3 ml. of 1:1000 adrenalin (Cardiac adrenaline) in 100-200 ml saline.** Gauze is soaked in this solution and applied to the bleeding wound for 5 minutes. Cautery is used to control persistent bleeding.
- Small skin staplers will make the operation more efficient if large areas are grafted.
- Good manpower assistance.

5 Scalp and forehead may often be covered with a thick STSG.

6 If possible, plan to graft the cheek with a FTSG as this will give a better cosmetic result and will have a less tendency to contract.

7 A thick STSG can also be applied to the cheek if necessary.

8 Apply the grafts to the forehead and cheek as sheet grafts. The scalp can be covered with meshed grafts.

9 It is recommended to harvest and prepare the skin grafts **before** starting to deal with the recipient site. This will make the surgical procedure more efficient and will certainly reduce the bleeding.

Fig. 41

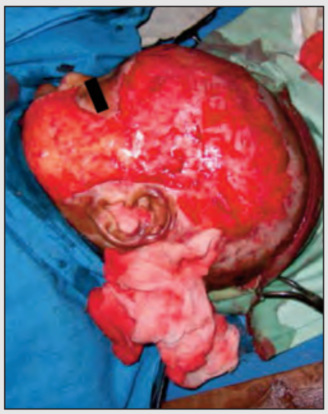

Fig. 42

Fig. 43

Fig. 44

The child below presented 4 weeks after being burned in open fireplace. Once burns are debrided the left eyelid returned to its normal location. Cheek and forehead grafted with full thickness sheet grafts and scalp with meshed split thickness grafts.

Fig. 45

Fig. 46

Fig. 47

4 week old face and neck burn—thick STSG.

10 If a localized defect is planned for reconstruction with a full thickness graft:

- One may decide to excise the wound first,
- Secure adequate hemostasis with adrenalin/diathermy, and
- Then harvest a template of the defect from the donor site.

11 Remember, reconstruction of the cheek is best covered with a FTSG, if possible (see Figs. 37-38 and 43).

12 The donor defect (medial side of the upper arm) is covered with a meshed STSG from the thigh.

13 If the wound is extensive, involving cheek, forehead, and scalp, start with the cheek, move to the forehead, and graft the debrided areas sequentially in order to reduce the bleeding.

14 Make sure all fibrotic and old granulation tissues have been debrided and removed properly before applying the graft.

15 A good assistant and well-trained scrub nurses are mandatory to minimize the degree of bleeding.

- **Skin grafts have a remarkable hemostatic effect on a clean bleeding wound surface.**
- **Apply the prepared skin graft to the wound surface as soon as the wound has been debrided to reduce bleeding (see #9 above).**

16 Skin staplers reduce the operating time considerably and should be used if possible on the larger wounds.

17 Once the cheek and forehead have been grafted, move to the scalp with the application of meshed

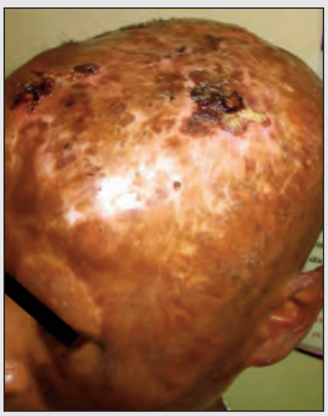

Fig. 48

Fig. 49

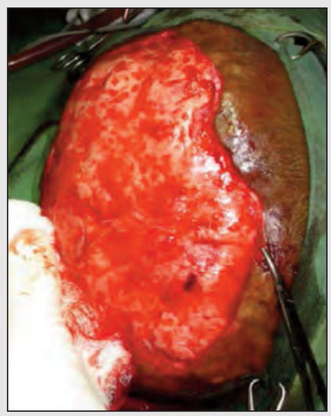

Fig. 50

Fig. 51

Fig. 52

Fig. 53

Fig. 54

15 year old with deep scalp burn at age 2 years—scar broke down multiple times and reverse radial forearm flap used to give good cover over skull. Radial forearm flap was released at 16 days. Excellent donor site result on left forearm (Tagliacozzi technique).

grafts after the wounds are well debrided.

18 Dressing procedure:
- Vaseline® gauze.
- Wet gauze or cotton balls.
- Dry gauze.
- Elastic bandage/stent.

19 Follow up:
- Plan the first dressing change within 2-3 days if the wounds were chronic.
- Otherwise, the first dressing change may be carried out 4-5 days after the operation (as long as some meshing was done).

A special case is seen in the 15 year old boy shown in Figs. 48-54 who had flame burn when he was 2 years of age: the scar suppressed skull growth, and scar broke down many times.

When microsurgery is not available, a pedicle radial forearm flap can be used.

Scalp Reconstruction: Another approach

Certainly the use of the radial forearm flap shown in Figs. 48-54 is an excellent method of achieving good tissue over the skull defects while one waits for skull reconstruction. Also many will not have tissue expanders as discussed below.

Because of excellent blood supply, even deep full-thickness scalp burns usually heal primarily without the need for grafting if they are carefully cared for.

Alopecia is the most common residual scalp deformity. Where the area of alopecia is small, surrounding hair may be combed over the defect. Sometimes these areas may be excised and closed primarily. At other times serial closure may be carried out in 2-3 stages. Many small defects can be closed by local flaps—rotation, rhomboid, advancement, etc. When a local flap is used, all the surrounding tissue must be freed up to allow the flap and the donor area to be closed. The dissection should be carried out at the subgaleal level. Frequently the galea needs to be scored parallel, and also perpendicular, to the defect. Cuts should be 1 cm. apart and should go into the subcutaneous tissue while attempting to preserve larger vessels. Orticochea described multiple scalp flaps that not only closed the defect but also permitted the scalp donor areas to close. One may find Orticochea flaps in major texts, and these flaps always include scoring of the galea. Large rotation flaps can be used, but these may leave open areas that need skin grafting. This will just transfer the area of alopecia. The larger flaps are always based on one of the main arteries to the scalp—supraorbital, anterior temporal, occipital, etc.

A relatively new method of scalp closure is with **scalp expansion**. See Chapter27. This is an excellent method for closing scalp defects and areas of alopecia, but it takes several weeks for adequate expansion. **If tissue expanders are available, one or more are used to expand the skin adjacent to the defect over several weeks.** Expansion may be necessary a second time. Expanders are available in different shapes and sizes; the most common are rectangular and crescent shapes. Expanders can be expanded to twice the recommended size if one has

Fig. 55

Fig. 56

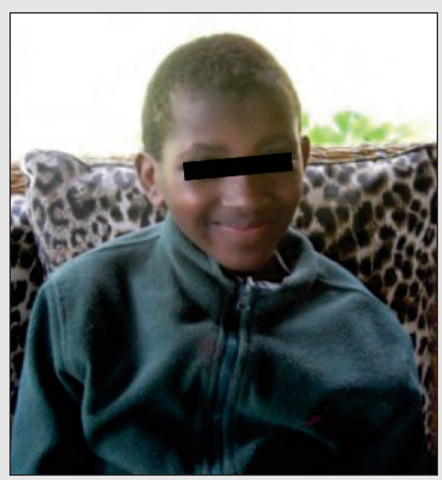

Fig. 57

Scalp defect (congenital nevus) reconstructed with expanded scalp flaps.

Fig. 58

Fig. 59

Fig. 60

Fig. 61

Larger scalp post-burn defect closed with expanded skin with excellent results.

limited numbers and sizes. The best method to insert the expander is at the edge of the defect and perpendicular to it—not along the edge of the defect or parallel to it. Urethral sounds are used to create the pocket beneath the galea for the expander. The skin is closed with non-absorbable suture and these sutures are usually left in until the expanders are removed. The "port" is placed over a bony prominence, as over the mastoid, so it can be easily felt. Some leave the port hanging just out through the skin and the injections can be done with ease and without complications. About 20-50 ml is initially placed in the expander at surgery. Expansion is begun 7-14 days later. The amount injected every 2-3 days depends on the size of the expander. The surgeon usually aims at injecting just enough so that the patient feels some tightness/discomfort. In expanders with a 300-400 ml volume, one may inject 20-30 mL each time. In most cases injection does not require anesthesia since a #23 needle is used for the injection. The defect can be measured and compared to the amount of expanded skin to determine when it is time to remove the expanders and advance the flaps. A week or two of extra expansion will make closure much easier.

Expanders can hold different volumes, but most can accept twice the stated volume for the expander. There will be the usual silicone induced pocket after expansion but this can be left alone. One can drain the pocket(s), but most of the time the closure is tight and no drainage is necessary. The galea of the expanded flap(s) may also be scored at 1 cm intervals. It is important to understand that the number of hair follicles remaining after a burn will never increase, so expansion will lead to thinning of the scalp hair. (Keeping the patient in the hospital if he/she lives far away can be costly. One regimen is to bring the patient into the hospital every Friday afternoon for injection and then inject again on

Fig. 62

Fig. 63

Fig. 64

Outer table burred down to bleeding inner table which was grafted.

Fig. 65

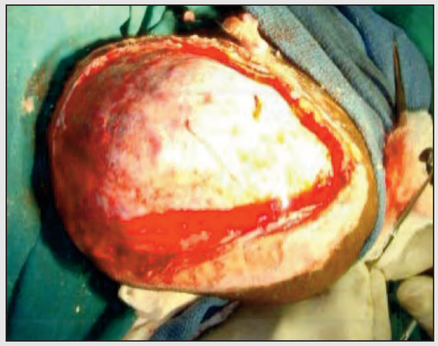

Fig. 66

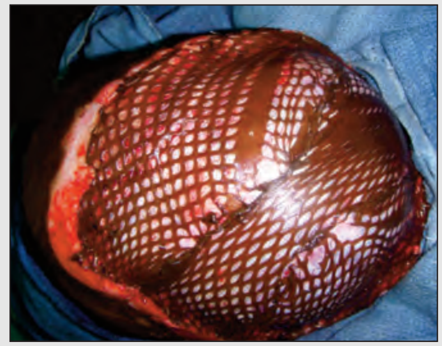

Fig. 67

Entire skull burned when child was placed close to fire to keep warm. Attempt was made to save inner table, but in a young child, the skull is very thin. The graft is on the dura, and child will need protection until old enough for reconstruction. A radial forearm flap would be an excellent choice for better protection—see Fig. 48-54.

Fig. 68

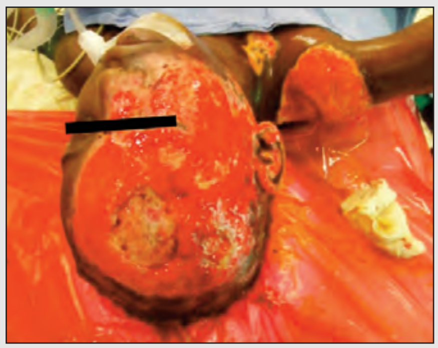

Fig. 69

Fig. 70

Deep scalp burn with necrotic skull—white arrow, requiring skin graft on dura. Later, good surrounding skin can be expanded, and the skull covered with the expanded flap. Then skull reconstruction can be carried out with either bone graft (from split skull, rib, or iliac crest), allograft bone, or with cranioplast if available.

Monday morning before discharge.)

Skull: Partial and Full-thickness Loss

Burns of the scalp are common especially in children. Newborns are often left close to the fire in order to keep the child warm, and older children fall into fires during a seizure–often their first sign of epilepsy. In both of these cases the burn will likely be very deep because of thin skin in children and a comatose condition after a seizure. Some burns in children can even destroy the skull and full-thickness skull must be removed and skin graft or a flap placed directly on dura. In others the burn is just down to the outer table and once this is removed, a graft or flap may be placed on bleeding inner table.

In most small children, the skull is very thin and a deep scalp burn may destroy both tables of the skull. When there is widespread destruction of the skull and the entire skull must be removed, this is a life threatening condition for the child. Usually the dura is well vascularized, and split thickness skin grafts can be placed directly on the dura with a good take (See Figs. 65-67). Meningitis is always a fear in these cases. Later brain injury is a concern as only the skin graft separates the brain from the outside. Some sort of "helmet" must be worn. This could be something as simple as plaster of paris "cap" worn over a cloth cap. The plaster can be fitted around the cap for protection. Smaller defects can more easily be cared for.

If the outer table appears viable but the pericranium is missing, then one may either use a burr to remove the outer table to the bleeding inner table or one may make drill holes a few cm apart in the skull and down into the diploe between the tables. This is

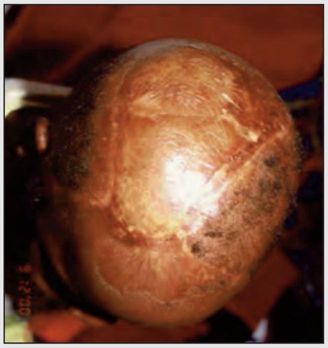

Fig. 71

Fig. 72

Fig. 73

Fig. 74

Patient burned as an infant, with skin graft placed on dura. Expanders inserted on each side were completely expanded twice, with later titanium plate skull reconstruction. Fig. 74 is after reconstruction with plate. Six years later, cranioplasty with methylmethacrylate was performed. Note that number of hair follicles never increased.

Fig. 75

Fig. 76

Fig. 77

Fig. 78

Entire forearm skin was taken based on retrograde flow through radial artery. Flap was divided at 20 days. This case demonstrates that the entire scalp may be covered with this flap.

only necessary when there is no surrounding skin to use for skull coverage. If a flap is readily available, then burring or drilling the skull may be unnecessary. Drilling of multiple holes allows granulations to emerge through the holes and slowly cover the exposed skull. The skull must be kept moist during this time. This method takes considerable time.

Radial forearm flap may give exceptional coverage of the skull while waiting for bony reconstruction. The case shown in Figs. 75-78 is a Marjolin's ulcer in a 12 year old boy who was burned very early in childhood. After radical excision of the SCC leaving most of the brain exposed.

(**Editor's Note**: This is a wonderful result in a very severe Marjolin's ulcer in a very young man and demonstrates the reliability of the forearm flap. This type of aggressive SCC is also seen in albinos, who often delay surgical treatment for SCC.)

Neck Contractures

1 **Anterior and lateral neck contractures are among the most difficult post burn reconstructive procedures to perform.**
   - The scar tissue may involve a huge area of the neck.
   - The chin may be pulled inferiorly towards the sternum, making **intubation a huge challenge** for the anesthetist.
   - Most hospitals will not have access to fiber-optic intubation equipment.
   - If intubation seems to be difficult, a **preliminary release of the scar** under local anesthesia must be performed in order to have the patient intubated. Patients can be given ketamine and local anesthesia prior to

Fig. 79

Fig. 80

Fig. 81

The surgeon must anticipate that the anesthetist may not be able to intubate patients with severe neck contracture, and must be prepared to quickly prep, drape and release the contracture under local anesthesia and ketamine. Then the patient may be intubated in most cases. This is followed by re-prepping, draping, and skin grafting.

neck release. Usually the patient can then be intubated. One should prepare for a tracheostomy if it becomes necessary.

2 As with other contractures, all the scar tissue should be excised for the best result.

3 Many surgical techniques have been described to reconstruct neck contractures:
- Skin graft procedures: STSG or FTSG.
- Local flaps.
- Advancement flaps.
- Rotation flaps.
- Supraclavicular flaps.
- Use of expanders.
- Free flaps.

4 Expertise to perform free flaps is not readily available in most Sub-Saharan countries. The use of the expander technique (expanding the chest skin) is not feasible either. Free flaps usually require multiple defatting stages. (See chapter 29 on Perforator Flaps for supraclavicular perforator flap reconstruction).

5 As underlined above, the scar tissue in neck contractures may be extensive. The surgeon will always be surprised to realize that the wound defect created after removing all contracting scar tissue will be much larger than one might have expected prior to the operation.

6 Another important observation is the fact that there is quite often a healthy layer of subcutaneous tissue underneath the scar tissue.

7 In most instances, resurfacing the wound can be

Fig. 82

Fig. 83

Fig. 84

Fig. 85

Lateral neck contracture, released and FTSG from thigh used.

achieved by:

- Advancing local flaps.
- Applying full thickness grafts or thick split thickness skin grafts.
- A combination of the two.

8 **Meticulous hemostasis** is of greatest importance before applying the FTSG.

9 Once the size of the wound has been outlined, the FTSG will be harvested, either from the lateral side of the thigh, from the inside of the upper arm or from the flank/abdomen.

10 Using a Humby knife to harvest a FTSG is a good choice, as the graft will not have any subcutaneous tissue that needs to be trimmed.

11 A Humby knife can harvest a wide graft, which is a great advantage.

- When harvesting from upper arm or abdomen, the surgeon still has to spend considerable time to make sure the FTSG is free of any fat tissue.
- The graft has to be hand meshed before applying the graft to the neck.
- If the recipient wound is very big, which quite often will be the case, the surgeon might have to harvest 2 sizeable FTSGs.

Remember a FTSG will immediately contract due to the elasticity of the dermis. A FTSG has to be gently stretched across the wound surface to match the size of the graft at the donor site.

Fig. 86

Fig. 87

86) Lip and neck contracture. Recurrence after the previous release. 87) Required re-release.

Fig. 88

Fig. 89

Fig. 90

Fig. 91

Severe anterior neck contracture, wide release, donor site on inner arm with Humby knife, and post-op view (L-R).

Fig. 92

Fig. 93

Final result of patient in Figs. 88-91.

12 Avoid linear vertical suture lines by creating Z-lines between skin edges and the FTSGs.

13 A good thick dressing needs to be applied, and then supported by an elastic bandage. The author is not using tie-over sutures as a routine.

14 The patient needs to be positioned in his bed postoperatively with slight neck extension and is kept in bed for at least the first 4-5 post-op days.

15 When harvesting a FTSG from either the upper arm or thigh, the donor wound needs to be covered with a meshed STSG. This also applies to the abdomen and flank, if primary closure is not feasible.

(**Editor**: Lower Lip—One may use a non-absorbable suture to suspend the lower lip. This suture is placed just beneath the lip mucosa and along the vermillion border as a running horizontal suture, and is sutured deep in the muscle above the commissure at both ends. A stent dressing is applied for 5-7 days with horizontal tie-over sutures.

Fig. 94

Fig. 95

Fig. 96

Lateral neck and axillary contracture with local flaps and FTSG for neck and face.

Fig. 97

Fig. 98

Fig. 99

All neck contractures must be carefully evaluated, as this patient had a recurrence of the contracture after two releases. The main problem was with the deformed mandible. The figure on the right is after mandible reconstruction, with removal of bilateral first bicuspids, mandibular osteotomy with removal of wedge on each side, and maxillomandibular fixation by wiring or plating.

Neck—it is important to recreate the normal neck crease. If grafting the chin and neck together, three sheets are needed to provide a good contour: one sheet for the chin and two for the neck, with one sheet above the normal crease and one below. At the junction of the two neck sheets of skin, an absorbable suture (Monocryl®, if available) is used to suture the two sheets together with a deep bite to include soft tissue at the site of the normal crease. This helps to recreate the crease. The editor uses large stent dressings over each grafted area. The grafts are hand meshed with small holes. The wounds are inspected at day 5, and if there is no evidence of hematoma, the stents are left another 3-5 days. Once the stents are removed, a bulky dressing is re-applied, and a crepe/elastic dressing is wrapped around the dressing and neck for another week. Then a soft collar is used. The editor uses absorbable sutures to anchor the grafts in the neck. Staples may be used.

The use of a soft neck collar/splint, similar to the one used for cervical fractures is often used for 3 months and at night time for another 3-6 months. In addition, if available, Silastic sheeting may be used under the splint to soften the scar. The method of using a thick dressing without a splint works well, with careful nursing care.)

Additional cases or neck reconstruction are seen in Figs. 97-112 (Eriksen).

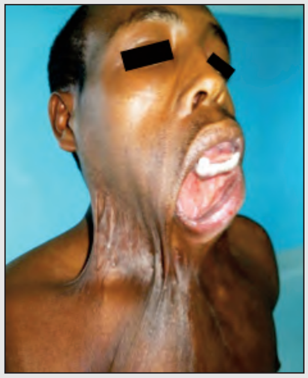

Fig. 100

Fig. 101

Fig. 102

A 19 year-old male who sustained a flame burn when he was 3. Over the following years, he developed an extensive anterior neck contracture.

Fig. 103

Fig. 104

Fig. 105

Another severe neck contracture. Note the large defect left after radical contracture release.

Fig. 106

Fig. 107

Fig. 108

A 8 year old boy sustained a flame burn to the left side of his face and neck four years before admission to hospital. The contracture was affecting the entire cheek, including the lower eyelid on the affected side. A radical contracture release created a huge wound that was covered with a full thickness graft taken with a Humby knife from the left lateral side of his thigh. The donor wound was covered with a thin meshed graft to avoid healing problems.

Fig. 109

Fig. 110

Fig. 111

Fig. 112

The patient sustained a horrible burn affecting his neck and his face when he was 2. A careful look at the face clearly shows how burn contractures can alter and affect the growth of the face in a child. The growth of the left side of the face has been affected to the extent that the left eye is projected below the right eye. The contracture has had a dramatic effect on the mandible where the lower teeth are projecting horizontally. The occlusion is also very much altered. The lower lip is fixed to the upper part of the sternum. The anterior neck was covered with a full thickness graft, and the chest has been covered with a split thickness graft. He will need mandibular osteotomies.

The main principle when dealing with an anterior neck contracture is to release all contracting forces that contribute to the deformity. In broad-based contractures, make sure the incision line is extended just beyond the mid-lateral line (mid-axis) on both sides of the neck to prevent post-operative linear scar contractures.

- The right level of dissection is beneath the scar. Make sure all scar tissue has been removed before grafts are applied.
- Meticulous hemostasis is mandatory to prevent hematoma formations underneath the graft.
- Full thickness sheet grafts in the anterior neck area is the best solution to prevent contractures in the future.
- Full thickness grafts are easily harvested by a manual dermatome, like a Humby knife, from the thighs (see above).
- Alternatively, grafts may be harvested from the flank/abdominal wall or from the medial aspect of the upper arm.

Breast Reconstruction

When the chest is burned in childhood, breast reconstruction is usually not addressed until breast development begins during puberty. Some recommend early excision of the scar with skin grafts or flap reconstruction in childhood, but often the surgeon will not see the patient until faced with a constricted scarred breast in adolescence. Early excision of the burned chest and grafting will limit breast contraction in adolescence, but still there will likely be the need for some reconstruction in adolescence in females. There are three areas of consideration: breast mound, areola and nipple. For the totally constricted breast without a mound, surgery is performed when there is evidence the mound is beginning to develop, or the contralateral normal breast has begun to develop. The incision is placed at the level where the inframammary crease is estimated to be and extends from the anterior axillary fold to the sternum.

Once the incision is made, tension is placed above and below while the scalpel is pushed against the scar. As the scar is released, the developing breast mound will be seen. The incision is carried down to the muscle fascia. At this point, there is usually a defect on the inferior side of the breast and on the chest wall with a crease in the area of the normal inframammary fold. The author has always used thick split thickness skin grafts to reconstruct the defect. Some may use a Latissimus dorsi flap, but this will be thick and will not give definition without secondary defatting procedures. The skin grafts are sutured into place in the same way as the panels for neck reconstruction, with a continuous suture placed between the sections of skin graft in the inframammary crease and with grasping of the underlying soft tissue. Stents are applied in the same

Fig. 113

Fig. 114

Fig. 115

Fig. 116

Breast contracture with axilla involved. Contractures released with grafting (2 sections of thick STSG for breast). Late result with nipple reconstruction using "skate flap" technique.

fashion as the neck—Vaseline® type gauze directly to the grafts, wet cotton balls in the crevices, wet gauze, dry gauze, and stent sutures for each graft. It is very important to gain complete hemostasis, and to leave small holes throughout the grafts as there will be considerable serous drainage. Elastic gauze is typically wrapped around the chest loosely to hold the stents in place. The stents can be removed at 7 days or less. Once the stents are removed, the wounds are still dressed with good definition of the inframammary creases, and elastic bandages wrapped around the chest until the skin grafts have completely taken and are dry.

When healing is complete, a bra can be worn to maintain the elevation of the breast tissue. The final result is often very acceptable with the upper panel extending from nipple level to the inframammary fold and the lower panel extending from the fold inferiorly along the chest wall but often hidden from view when by the breast mound when the patient is erect.

The areola is not easy to reconstruct. In the West, tattooing is performed with excellent results. In Africa, the breast is often discolored from the burn and scarring, and an areola reconstruction is not necessary. Where it is desired in lighter-skinned individuals with minimal surrounding burn, full thickness grafts can be taken from the inner thigh or even the labia and the donor areas can be closed primarily. The graft is held in place by a stent dressing for a week.

Finally, the nipple should be reconstructed from available local tissue. There are several methods described in major plastic texts. The editor has found the "skate flap" technique easy to use—see Fig. 116.

Breasts reconstructed in the above manner are aesthetically pleasing as the aesthetic units are reconstructed. When the burns are not as severe, and the contracture and constriction of the breast is less, then lesser procedures are performed, often with less acceptable results, but still satisfactory under a bra. In cases where the entire breast bud has been destroyed, then breast reconstruction with one of the well-known and acceptable methods—latissimus dorsi or an abdominal flap (TRAM), if the abdominal skin is not burned. Expanders and implants may often be used.

Frequently the breast deformity is associated with an axillary contracture, which is usually addressed at the same time as the case above.

Upper Limb

Shoulder & Axilla

Burns to the upper part of the body frequently affect the upper arm, shoulder, armpit, and anterior neck. Several patients will appear with contractures in all places. These patients will need several surgical procedures and weeks in hospital before the contractures are all dealt with.

Axillary contractures:

- Reconstructed with either a large thick STSG or FTSG. Either graft will provide good functional results.
- The best donor site is the lateral thigh, from where large grafts may be harvested using a Humby knife.
- Another good surgical option for coverage of the armpit is the use of a rotation flap from either the upper arm or the anterior axillary area.
- Axillary burns are kept abducted for 4-6 weeks,

and until all the grafts are mature.

Figs. 117-124 show patients treated with both options.

Axilla Reconstruction Using Flaps: The methods described below use flaps to cover the axillary defect after release. There is still a need to graft areas not covered by the flap, but once the surrounding grafts have healed, the patient can be discharged without the need of follow-up or splints.

The axis of motion of the axilla is from 0° when the arm is adducted at the side to 180° when the arm is fully abducted over the shoulder. A range of motion from 0° to 135° allows for most activities of daily living, most jobs, and for personal hygiene and care of our hair. Some may have good function but an unsightly web when abduction greater than 135° is attempted. The patient, often a female, may request corrective surgery, even though function is adequate.

If a linear contracture involves the anterior or posterior axillary fold, with normal skin on either side and **the contracture is less than 60°**, one or more Z- plasties may be performed. The angle of the Z-plasty flaps should be 45-60°. All limbs must be of equal length, and wide undermining of surrounding tissue is necessary. Limbs of 45° will give 50% increase in length and 60° will give a 75% increase based on the length of the limbs. All flaps should contain superficial fascia to enhance blood supply.

If there is **scarring on one side but not the other side** of the contracture in either the anterior or posterior fold—usually the scarring is anterior on the chest or posterior on the back with normal skin in the center of the axilla—a Y-V-plasty is an excellent


Fig. 117


Fig. 118


Fig. 119

Same patient as Fig. 94. Excision of chronic wound, rotation flap from upper arm for axilla, with FTSG to face, neck and axilla and STSG to chest wall.


Fig. 120


Fig. 121


Fig. 122


Fig. 123


Fig. 124

Another neck and axillary contracture. FTSG to neck and axilla 124) Patient at discharge.

Fig. 125

Fig. 126

Axillary contracture in young boy with good pliable skin on both sides of the contracture and a large hypertrophic scar. The band was excised with Z- plasty reconstruction (markings are for a parascapular flap which was initially planned).

reconstruction. Again the contracture should be **less than 60°.** The limb of the Y is through the scar, and the V portion is in the advancement flap in the normal central axillary skin. Actually the V is best incised like a U to give the best possible blood supply to the tip of the advancement flap. Care should be taken in dissecting the advancement flap to keep the superficial fascia with the flap. In contractures of the anterior axillary fold, the release should extend up to the coracoid process of the scapula. This will be the mid-axial point of the anterior axilla. It is important to make the V portion long enough to reach. This is done by undermining the entire flap, and also releasing all the surrounding tissue, not just the flap. If the flap has been raised but will not reach the tip of the release, then limbs should be extended, or a back-cut may be made at the base of one limb of the V. This may give an extra 1-2 cm. of advancement.

For posterior axillary fold contractures, the incision can be carried up to an imaginary point for the mid-axis, 180° from the coracoid. The V advancement flap is taken from the central axilla, as in the anterior fold contracture.

For these contractures, books will often describe many other complex Z- plasties and W-plasties. In the significantly scarred axilla, the author has found the techniques described above reliable. With scar tissue on either side of the contracture, multiple small flaps do not advance as one would like, or as some

Fig. 127

Fig. 128

Axillary contracture with burned chest wall skin, but good central axillary skin. Y-V advancement performed. Note good skin in axilla. Scarred skin does not require removal, as the patient will have excellent function post-op. Long term splinting is not necessary.

textbooks suggest. Also, these local flaps in burned skin will often not survive, and there will be tip necrosis. They frequently require debridement and even grafting, with necessary long term splinting for a good result. This creates a problem when there is poor patient compliance and follow-up.

If there is scarring in most or all of the axilla, then a **parascapular flap** must be used. This is an axial fasciocutaneous flap supplied by the descending branch of the circumflex scapular artery, and should be long enough to reach the coracoid process anteriorly. This vessel can be found and traced with a Doppler, and the point of rotation of the flap is where the vessel exits between the teres major and teres minor muscles. This is found by identifying the posterior apex of the axilla, and measuring 2 fingerbreadths superiorly and 2 medially (toward the spine). The flap length can be 3 to 4 x the width of the flap, or up to 30 cm. in length. The center of the flap is an imaginary line straight down inferiorly

Fig. 129

Fig. 130

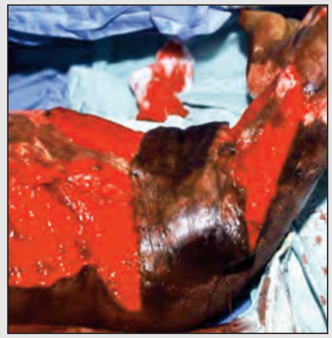

Fig. 131

Fig. 132

129) Axillary contracture with deep back burn. 129) Parascapular flap with lateral half of latissimus dorsi muscle. 131) Tip of flap inserted at coracoid process and STSG above and below flap. 132) Y-V plasty used for reconstruction on right side.

toward the iliac crest from the exit of the vessel. This exit point can be identified with a Doppler. The medial portion of the flap overlies the scapula. If the flap skin is burned and scarred and viability is questioned, it can still be used. The muscle fascia of the latissimus dorsi, or even the anterior half of the muscle can be taken with the flap. In young people this muscle is relatively thin and not bulky. In the rare case where there is very thick scarring over the parascapular area with keloids, then all or a portion of the muscle can be used, and a STSG placed over the muscle. The axilla should never be reconstructed with just a split thickness skin graft alone.

Contraction will always recur due to gravity and the difficulty in maintaining abduction of the axilla with splinting, especially after discharge. Closure of the donor area depends not only on the width of the flap taken, but also on the quality of the skin around the flap donor site. If the donor area is only 6-8 cm wide, then it may be closed primarily. If the flap is greater than 8 cm wide, or if there is significant scarring in the area, then the donor site must be grafted. A skin graft at the donor site is away from the axilla and will not lead to recurrent contracture. In some cases of severe axillary contracture, the flap, no matter how wide, will not cover the recipient area in the axilla and skin grafts must be placed above on the arm and below on the chest. Again, these grafts are not over the joint, and recurrent contracture will not occur even if the grafts are meshed. One should not discharge the patient, however, until these grafts have taken well—usually about two weeks.

Post-op, a bulky dressing is applied in the axilla, and the arm is elevated to an IV pole for 7-10 days. Skin grafts in donor area, or above and below flap should be dressed with Vaseline® or non-adherent gauze, wet cotton balls, wet and then dry gauze, and a stent or bolster dressing. At ten days, unless there are some large areas within the donor site or around the recipient area that have not healed completely, the patient can use the arm normally without the need for a splint. Some children may still have pain at the skin-grafted sites and may need elevation for an additional week.

(**Editor's note**: The methods above showing the use of flaps do not always remove the entire old scar as the methods described by Dr. Eriksen. Post-op, the patient will have good range of motion but scarring may still be present with an unacceptable cosmetic appearance. Most of the time these scars will be hidden by clothing.)

Elbow

1 **Reconstructive surgery of elbow region, forearm and hand should always be performed with a tourniquet!**

2 Longstanding elbow contractures due to burn scar tend to be difficult to release completely, as ligaments and joint capsule are involved in the contracture. Care must be taken to avoid injury to major peripheral nerves.

3 When releasing the elbow joint, the transverse incision ends laterally and medially in a Y-shaped incision. Related scar tissue needs to be dissected and removed, thereby allowing maximum extension of the contracted joint.

4 The wound needs to be covered with a thick graft, either STSG or FTSG. If conditions

permit, a local rotation flap may also provide an excellent cover.

5 A Plaster splint to be used for 4-6 weeks is recommended.

6 Once the splint has been removed, the elbow joint may be mobilized gently over weeks and months and regain more and more range of motion.

Elbow Using Flaps

The same flap techniques can be used for the elbow contractures. Z-plasties or Y-V advancement will work if the contracture is less than 60°. As in the axilla, one or more Z-plasties may be used if there is good skin on both sides of a linear web contracture. A Y-V-plasty can be used when there is burned skin on one side of the contracture and normal skin in the antecubital fossa. A back- cut may be used to gain 1-2 cm, but one must be careful, since an extensive back-cut may divide needed blood supply.

The flap of choice for a contracture greater than 60° is a cubital artery fasciocutaneous flap from one side of the forearm in an unscarred or minimally burned area. In the author's experience, this flap can be taken from either side of the forearm with the length up to 3X the width. The donor site may need grafting if the width is greater than 6 cm. If all the skin in the cubital fossa and forearm is severely scarred and flap rotation difficult, then skin grafting maybe necessary. Full-thickness grafts are best, but a thick STSG may be used with prolonged splinting for at least 12 weeks/3 months to prevent recurrence. Other more complex flaps for the elbow include a proximally based radial forearm flap, distally based lateral arm flap, a brachioradialis flap with skin graft, and a pedicled flap from abdomen. The proximally based radial forearm flap may also be used to cover


Fig. 133


Fig. 134

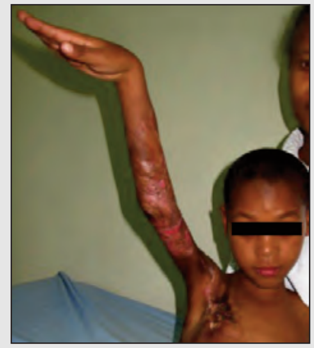
Fig. 135

Axilla and elbow contractures. These were released, with sheet grafts placed over joints, and STSG over other areas.


Fig. 136


Fig. 137


Fig. 138

136) Y-V Elbow Reconstruction.
137-138) Elbow contracture: Y-V plasty with back-cut. When arm was extended pre-op, contracture was slightly >60° and backcut at red arrow on right to lengthen flap.


Fig. 139


Fig. 140


Fig. 141

Snake bite with >90% contracture. Repaired with long antecubital artery fasciocutaneous flap reconstruction, with step-cut lengthening of biceps and fractional release of the brachialis, release of anterior joint capsule, and STSG for donor site. Note: muscle fascia remains with muscle and is not part of flap.

the olecranon.

Heterotopic Ossification (HO)

HO must be ruled out with any unusual elbow contracture and especially in burns where the elbow is not burned or minimally burned. HO can occur in the elbow with distant burns. X-rays need to be taken to rule out HO in these unusual cases.

The treatment of HO is controversial. If both elbows are involved, then aggressive release of one side is usually performed early. If only one elbow is affected, then surgery is usually delayed until maturation of the HO with no further progression. If there is also a skin contracture, this will be treated appropriately after the HO is removed. HO is usually removed through a medial mid-axial approach with ulnar nerve decompression and transposition.

(**Editor's note**: The above methods do not always remove the entire scar. Some unsightly scars may be left behind. Later, these can be removed to give a better post-op appearance.)

Hand and Wrist—General Considerations

1 Hand & wrist contractures are among the most common post burn contractures the surgeon will encounter.

2 Most of these contractures may not be too difficult to manage, like scar contractures involving the palm and the flexor side of the finger joints.
   - One should remember that flexed PIP joints that have been in a hyperflexed position for many years may be difficult to manage due to stiffness of the joint capsule and ligaments.
   - Other contractures may involve deeper structures like tendons, ligaments, and bone, and pose a real challenge for the surgeon.

3 Contractures affecting the dorsum of the hand and wrist frequently affect the MCP joints, pulling them in hyperextension.
   - Once the MCP joints are in a hyperextended position, the PIP joints become flexed.
   - This combined position of the MCP and PIP joints is the worst possible position for a finger.
   - When these contractures are present for several years, they are very difficult to correct properly, and should be appropriately managed by surgeons with experience in hand surgery.

4 Scar contractures involving the volar or dorsal aspect of the wrist are usually easy to correct unless deeper structures like tendons are involved.

All surgical procedures on hand and wrist must be carried out under tourniquet!

Wrist Joint

1 Care must be exercised not to damage underlying vital structures.
   - The surgeon must be very careful not to open the thin paratenon over the tendons.
   - As long as paratenon is not damaged, a skin graft will be a good solution for skin coverage.

2 When releasing wrist contractures:
   - The surgeon should aim at overcorrecting the joint to some extent.
   - Immobilize the joint after surgery with a cast for several weeks, in order to neutralize the flexing force from forearm muscles.
   - If tendons, ligaments, and even wrist joints are affected, a skin graft will not be of help.
   - The only solution will be to design a local rotation flap.
   - A distally based radial forearm flap may provide an excellent cover whether it is the dorsal or the volar wrist joint that is affected.
   - This flap, however, should only be used by surgeons with experience, and if the volar forearm skin is acceptable.
   - If scar tissue prevents a local rotation flap, which often may be the case, an abdominal or groin flap may be the best solution.

Fig. 142

Fig. 143

Deep burn—Extensor tendons missing. A thick STSG was applied, with good return of function but the patient was still unable to extend fingers. Wrist grafted with FTSG.

Fig. 144

Fig. 145

Fig. 146

Fig. 147

Fig. 148

Contractures completely released, and scarred skin excised with FTSGs.

Palm

1 Scar contractures in the palm reduce the hand function considerably, as the patient is unable to fully extend the fingers, thereby preventing the hand from grasping larger objects.

2 The scar has to be completely released and covered with a FTSG.

3 Apply a Plaster cast to keep the graft in position, especially in children.
- The cast should be used for **6 weeks** before allowing free movements of the hand and fingers.
- In adults, the risk of developing stiff fingers must be addressed when deciding how best to care for the volar graft.

Fig. 149

Fig. 150

Palm and finger burn released in stages with FTSG. One additional stage remains—to release syndactyly between small and ring.

Fingers

1 Many patients who have suffered a burn to the volar aspect of the hand may experience scar contracture at the finger joints. The fingers are contracted and prevent the patient from extending the finger joints properly.

2 Additionally, the interdigital web spaces are also often affected with scars obliterating the webspace.

3 In the majority of these patients, the best and only way of correcting the contractures is to:
- Make a proper and complete release.
- Excise significantly scared tissue.
- Reopen the web spaces to anatomical position.
- Application of a FTSG.

4 When several fingers are affected, a number of smaller wounds may be the result after correction of the contractures. All of the wounds need to be grafted with a FTSG. The procedure may take as long as 2.5-3 hours.

5 A Z-plasty may be used to correct a finger contracture if there is a linear scar with normal surrounding skin. In most instances, the contracted hand is full of scar tissue, and there is a shortage of normal skin. Z-plasty as a reconstructive procedure in these cases is seldom an option.

Wrist, Hand, and Fingers Using Flaps

(Hand Surgery Techniques)

Wrist: both dorsal extension and volar flexion contractures occur.

Flexion Contracture of Wrist
In long standing flexion contractures, full volar release with near normal range of motion may not be possible without division or lengthening of flexor tendons. **This is avoided if possible**. If, after transverse release of skin and scar from mid-axis to mid-axis, the wrist cannot be extended to at least neutral, then a **proximal row carpectomy** with a dorsal approach will be necessary. A skin graft, usually a FTSG, is used to reconstruct the volar side after release. The wrist should be splinted or pinned for at least 3 months to limit recurrence. A nighttime splint should be used an additional 3 months. Any residual flexion deformity at the wrist will limit function. Every effort should be made not to expose the tendons with the volar release. Flexion contractures at the wrist may be associated with MPJ extension contractures in a Z deformity pattern—see below. In recent years, the author has seen a number of mildly recurrent volar wrist contractures with only skin grafting—FTSG or STSG and even with long term splinting. Any volar flexion deformity limits full use of hand. Therefore, a radial or ulnar artery perforator flap or Becker flap has recently been used instead of a skin graft after the volar release (see chapter 30 on Upper Extremity Reconstruction).


Fig. 151


Fig. 152


Fig. 153

Burn contracture with wrist, MPJs and PIPJs in a Z deformity pattern: required volar wrist release and proximal row carpectomy, capsulotomies of MPJs, passive stretching of PIPJs with pinning, excision of scarred dorsal skin, and thick skin grafts for the volar wrist and dorsal hand.


Fig. 154


Fig. 155


Fig. 156

Volar wrist contracture previously released without full correction. Proximal rom carpectomy resulted in full correction.

Extension contractures at the wrist may occur if the burns are dorsal, and these may be severe, with the back of the hand adherent to the forearm. Care must be taken to leave soft tissue and paratenon over the tendons during release. After the release, severely scarred skin may be excised for improved cosmesis. In most cases, split thickness skin grafting—sheet grafts are better than meshed grafts—and splinting for 3 months is sufficient. (The author's method of FTSGs is best here.) Occasionally after release, when the burns are very deep, tendons may be exposed. In these cases, a flap will be necessary. A distally based radial forearm flap, groin flap, or superficial inferior epigastric flap are best. These contractures may be associated with MPJ flexion contractures. (See chapter 27 on Flaps for description of radial forearm flap.)

(**Editor's note**: In the case shown in Figs. 157-158, the dorsum of hand should have been covered by a FTSG as described in the section above.)

Once the wrist contracture is released, **any MPJ contractures** should be addressed at the same time. Often MPJ extension contractures may be passively corrected in children and pinned in the position of protection—MPJ in 80-90° flexion. In long-standing contractures, this will not be possible. MPJ extension contractures may be due to the severe scarring on the dorsum of the hand. In such cases, not only should the skin over the MPJs be released from mid-axis to mid-axis (all digits including the thumb are often involved), but significant scar tissue on the dorsum

Fig. 157 **Fig. 158**

Severe extension contracture wrist: careful release with preservation of soft tissue and paratenon allowed for STSG reconstruction. Splinting of wrist for minimum of 3 months Today, the editor would use thick STSG sheet graft or FTSG, and not a meshed graft.

Fig. 159 **Fig. 160**

Severe MPJ extension contractures. Release with mid-axis to mid-axis incision, care to preserve soft tissue and paratenon over tendons, open capsulotomies of MPJs with release of dorsal capsule and collateral ligaments, and pins through flexed MPJ and extended IPJs and brought out through finger tips. Dorsal skin did not require excision in this case.

of the hand should also be excised. This allows not only MPJ flexion, but improved cosmesis as well. If extension contractures remain, then capsulotomies must be carried out in the following sequence: 1) release of dorsal joint capsule, 2) release collateral ligaments, 3) release of accessory collateral ligaments, and 4) free the volar plate. These are performed sequentially and from one side to the other as necessary until the joint is released. All structures may not require release. Release until the MPJs can be placed in 80-90° flexion. Attempt is made to preserve the soft tissue over tendons and bone by carefully dissecting down to the joint through soft tissue on one side of each joint. The sagittal bands are retracted distally.

The ligaments on both sides of the joint may be released through this one incision along one side of the extensor tendon. In unusual cases, the MPJ extension contracture is >90° and, following release, the metacarpal head is exposed and the extensor tendons subluxed to one side. In this situation, a flap will be required. Rarely the extensor tendons will need to be lengthened. If required, this is best performed in the distal forearm to prevent subluxation at the MPJ. In this situation, the MPJs need pinning for 6-8 weeks. The flap of choice is either a distally based radial forearm flap if the proximal volar forearm skin is preserved or most likely a superficial inferior epigastric artery flap which covers the dorsum of the hand well (see again chapter 27 on Flaps).

Fig. 161 **Fig. 162** **Fig. 163** **Fig. 164**

Severe wrist flexion and MPJ extension contractures that required PRC and complete capsulotomies of MPJs, with resulting subluxation of extensor tendons and exposed MC heads. Pins were placed antegrade through MC heads and brought out through fingertips. Extensor tendons centralized around tips of pins, as seen in Fig. 164. Covered with superficial inferior epigastric flap.

In this Zigzag contracture pattern with wrist flexed and MPJ extended, the PIPJ will often be flexed. These PIPJ flexion contractures are discussed below. Figs. 166-167 show the use of the distally based radial forearm flap for covering the dorsal hand. This looks like a burn, but it was road traffic accident ("road rash") down to the wrist joint with extensor tendons missing. This patient had a two stage tendon reconstruction. The same flap can be used to cover the wrist and hand in burn reconstruction.

Fig. 165

Fig. 166

A young 12 year old girl sustained a deep dorsal hand injury from road traffic accident. This was reconstructed with reverse radial forearm and two stage extensor tendon reconstruction.

Flexion contractures of the MPJs often involve all four fingers. Again, it is very important to release from mid-axis on the radial side of the index to the ulnar side of the small. Normal appearing skin in long-standing contractures will also require release. It is important to first incise the skin and then push with the scalpel so one does not injure vessels, nerves and tendons. A FTSG is preferred for reconstruction, but if not available, a thick STSG is used. It is important to mold the wet cotton balls into the crevices, apply a bulky gauze dressing and then splint or pin the MPJs in extension for at least 3 weeks. Continue nighttime splinting for six additional weeks. (**Editor's note**: Palmar burns should be excised completely and covered with a FTSG.)

Flexion Contractures at PIPJ and DIPJ

One should check for co-existing syndactyly with PIPJ contractures, as it is best to release both at the same operation. PIPJ contractures also require mid-axis to mid-axis release with care not to injure neurovascular structures. Passive extension while the scalpel is pushed through the scar is important. Once the subcutaneous tissue is reached, any remaining contracture is released through passive extension. If full extension cannot be gained, then one must be certain one has divided the skin to mid-axis on each side. **In very rare situations, the check rein ligaments and collateral ligaments may need to be released to gain full extension**. (Collateral ligaments will grow back to give a stable finger.) Full-thickness grafts are always used. The PIPJs may be pinned with K-wires. In children, hypodermic needles (18 to 21 gauges) are used, as they are cheaper and more likely available in large quantities. At one time the author tied stent or bolster dressings over the wet cotton ball dressings, but now the fingers are just dressed with a wet cotton

Fig. 167

Fig. 168

Fig. 169

PIPJ contractures. Released mid-axis to mid-axis, with FTSG and pins for 2-3 weeks. Note: previous incomplete release of Index PIPJ. Grafts will be darker forever.

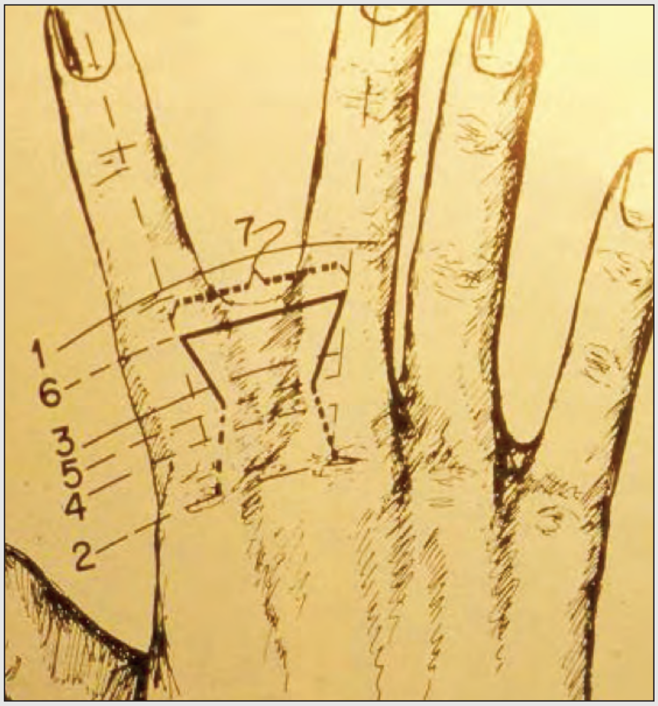

Fig. 170

Markings for hour-glass flap.

1) at PIPJ, 2) at MPJ, 3) halfway between 1 and 2, 4) halfway between 2 and 3, 5) halfway between 3 and 4 and narrow point in web, 6) halfway between 1 and 3 and end of flap, 7) width of distal end of flap is from midline to midline on adjacent fingers. The incision is as shown in solid line. Incision stops at 5.

Fig. 171 **Fig. 172**

Hour-glass release of Syndactyly: Important that dorsal flap reaches web space on volar side. There are no zigzag incisions as in congenital syndactyly—just straight line incisions through the volar skin (Salisbury and Bevin).

balls, wet and then dry gauze and splinted in extension for 2-4 weeks according to the severity of the contracture. If, in spite of careful release, the

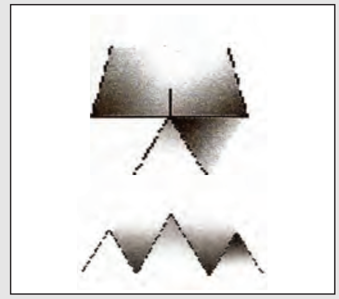

Fig. 173 **Fig. 174**

Dorsal ridge with normal volar skin in the web—may be treated with Y-V or Y-V plus two Z-plasties on either side—"Jumping man" Z-plasty.

flexor tendon sheath is opened and the tendons exposed, grafting can still be done acutely.

FTSGs over the finger joints usually do well. In dark skinned individuals, all grafts including FTSGs will be darker than the surrounding skin. This is especially noticeable on the light palm of dark-skinned patients. If only one or two fingers are released, then the final result may be improved by taking a FTSG from the palm (distal wrist area), hypothenar eminence, or the instep of the foot—but this is rarely done.

(**Editor's note**: The above technique releases the contracture but does not excise all the scar tissue. As seen in Figs. 167-169, there are contractures but little actual scarred skin. No scar was excised. Only the joint contracture was released through a transverse incision and the fingers passively and gently extended as the scalpel is pushed against the scarred tissue and down to subcutaneous tissue.)

Burn Syndactyly

There are numerous flaps for congenital syndactyly. In burn syndactyly, the skin is scarred and is not pliable. Therefore, an hour-glass flap has been found to fit into the defect best. It is important to advance the dorsal flap volarly to the level of the normal web space. The thickness of this flap is down to the level of the extensor tendon paratenon—leaving the paratenon on the tendon.

If fingers are badly burned and normal landmarks are difficult to identify, the volar web space is half the distance between the distal palmar crease and the PIPJ crease. FTSGs are always necessary.

(**Editor's note:** The above technique may use scarred dorsal skin in the web space reconstruction, but often there is relatively normal skin as seen in the Fig. 171. FTSGs are required on either side.)

When the syndactyly involves a dorsal ridge only and extends only to level 3 above with a normal volar web, then a Y-V advancement alone or combined with Z-plasties on each side, so called "jumping man Z-plasty," may be the best procedure. These small dorsal flaps do not rotate well if the skin is severely scarred.


Fig. 175


Fig. 176


Fig. 177

Four flap Z-plasty is ideal when good pliable skin available. This is rare with a burned first web.

First Web Space Contracture with Thumb Adduction

The following techniques have been used for thumb adduction contractures:

- Z-plasty.
- Four flap plasty—ideal if skin is pliable Index finger flap.
- Dorsal hand transposition flap Reverse radial forearm flap Groin flap.
- FTSG/thick STSG—requires pinning/splinting for 6-12 weeks.


Fig. 178


Fig. 179

First web contracture. Reconstructed with dorsal transposition flap and STSG to donor site. Blue arrow points to flap, and green arrow points to donor site.

A flap reconstruction is best. As in the contractures discussed above, the type of reconstruction depends on the availability of good quality skin for transfer. In long standing tight adduction contractures, the **adductor pollicis** must be released at its insertion at base of thumb proximal phalanx. It may then be recessed and sutured back to the metacarpal proximally to maintain some adduction of the thumb. If most of the surrounding skin is badly scarred, a reverse radial forearm flap gives an excellent reconstruction. Figs. 175-182 show the extremes of reconstruction: Four flap Z-plasty and radial forearm flap.


Fig. 180


Fig. 181


Fig. 182

Severe burn contracture of first web space. Release of Adductor Pollicis (AddP) from proximal phalanx, recessing the muscle back to the proximal metacarpal and reverse radial forearm flap.

Lower Limb

Perineum/Groin/Hip Region

1 Reconstructive principles applied to other regions also apply to the groin area.

2 Third-degree burns affecting the thigh and/or the abdomen often involve the groin and the hip region with a flexion contracture.

3 What has been emphasized regarding children and burns, also applies for this region: **Contractures developing in childhood often**

Fig. 183

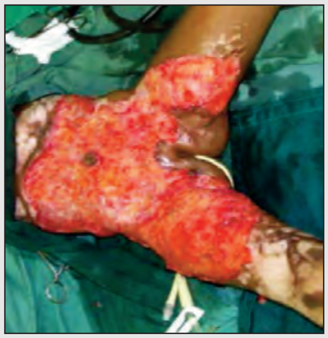

Fig. 184

Fig. 185

Fig. 186

Chronic burn wound. Note wide excision, FTSG directly over hip joint area, and STSGs elsewhere, with simple splinting to expedite healing.

Fig. 187

Fig. 188

Thigh and perineal burn—excised and grafted and splinted for 3-4 weeks.

Fig. 189

Fig. 190

Release and Tensor Fascia Latae (TFL) flap reconstruction. No splinting or compliance required post-op.

tend to become more pronounced as the child grows.

4 The basic principle in approaching the groin /hip contracture is as follows:
- Release and excise all contracting scar tissue.
- Plan for a thick STSG or a FTSG to cover the inguinal area.
- Mesh graft the remaining open wounds.

Fig. 190

Fig. 191

Fig. 192

Four-year-old burn contracture, required multiple procedures followed by long term stay at local rehab facility.

(**Editor's note**: the splinting technique shown in Figs. 186 and 188 is easy to do and very effective. This holds the legs wide apart and much better than an external fixator can. One can attach the wooden splint to an overhead bar to elevate the perineum from the bed and help keep the perineum clean.)

Lower Extremity—Flaps for Groin Reconstruction

These contractures may be flexion and/or adduction contractures. Every previously described technique may be used according to the extent of the contracture and the quality of skin remaining. In severe cases tensor fascia latae flaps may be required. STSGs will usually be needed for the donor area, and possibly above and below the flap. Splinting the extremities in extension and abduction can be carried out after skin grafting by Buck's traction, and later with a spica cast if necessary. **The method above**

Fig. 194

Fig. 195

Fig. 196

Severe burn contracture with hip flexion deformity bilaterally and umbilicus at pubis. Release with TFL flaps over hip joints and skin graft above joints on abdominal wall and over donor areas. Kept in hospital until skin grafts healed and no splinting was necessary.

is excellent. If only skin grafts have been used after the release, then splinting may be needed for 3 months or longer.

(**Editor's note**: sometimes the TFL flap cannot be used because of severe scarring. In such cases, wide excision of the scars, FTSG over the hip joint–groin/inguinal area, and splinting as above until the grafts are healed is the best method.)

Knee Joint /Popliteal Area

1 Knee joint contractures are more common than contractures in the hip and groin. There are several important issues to remember when planning the knee joint contracture release:
   - Longstanding knee contractures might have damaged the cartilage.
   - The posterior joint capsule is most likely tight.
   - The peroneal nerve running around the neck of the fibular head may be overstretched.

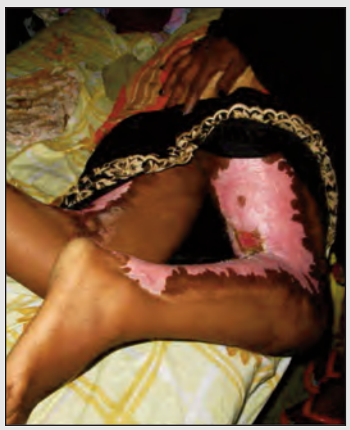

Fig. 197

Fig. 198

Fig. 199

18 year old, pregnant girl, popliteal areas grafted with large thick STSG. 199) Final result 12 months later without recurrence. In cases like this, the wound is dressed but splinting is not used (by the author).

Fig. 200

Fig. 201

Fig. 202

21 year old burned at age 6 months. Initial release, then external fixator, twice weekly serial extension. The injury required arthrodesis of knee due to destruction of knee cartilage, but patient was able to stand and walk 4 months later.

- Great care must be exercised to avoid damage to the common peroneal nerve.

2 The first procedure is surgical removal of all scar tissue contributing to the contracture. In mild contractures, reconstruction as described below can be done in one stage with a FTSG over the joint.

3 This procedure will always extend the knee joint considerably, but be careful never to apply force to extend the joint.

4 The joint may be stabilized with either an external fixator or wooden bars.

5 Once the scar tissue has been excised, the patient is brought to the operating theatre 2-3 times per week for gentle extension of the knee joint under sedation.

6 The joint usually gains full extension within a couple of weeks following this conservative approach.

7 It is of greatest importance to extend the knee joint gradually to prevent overstretching the peroneal nerve.

8 Once the joint is fully extended, skin graft procedures will close the defect using a thick sheet graft (STSG or FTSG) running across the popliteal area. The remaining wounds may be covered with a meshed graft.

9 In longstanding cases when the knee joint is destroyed, arthrodesis is the only way of stabilizing a painful unstable joint.

10 After routine release and FTSGs, the knee, like the elbow, is splinted for 4- 6 weeks.

Knee Reconstruction Using Flaps

Popliteal contractures are common and disabling. Skin grafts usually do not do well as the primary method of reconstruction in district hospitals. If skin

Fig. 203

Fig. 204

Fig. 205

Fig. 206

Severe flexion contracture of knee. A long saphenous flap was used to reach mid-axis on lateral side, and skin grafts where needed, but joint is covered with the flap.

Fig. 207

Fig. 208

Fig. 209

Missed diagnosis: this was not a burn contracture, but secondary to septic arthritis. After release, defect was reconstructed with medial gastrocnemius muscle flap, STSG, and serial lengthening over two weeks. Same can be done for severe popliteal fossa burn when medial leg skin is severely burned and saphenous flap cannot be used.

grafting is performed as above, then post-op care must include long term (3-6 months) splinting, or long term inpatient care under the supervision of excellent nurses and therapists. The primary author gets excellent results with skin grafting. His success is based on complete scar excision and excellent postoperative care by an experienced nursing team. On initial exam, it often appears that Z-plasties and Y-V plasties will work and occasionally they will in minimal contractures with good skin. However, in the author's experience, these local flaps do not work well in the popliteal fossa.

The saphenous flap, a fasciocutaneous flap from the medial side of the leg, is an ideal flap to use if the skin of the medial leg is unburned. It is very important to extend the release to the mid-axial line on the lateral side of the knee, and the flap must reach this point. The axis of rotation of this flap is at the joint line. If the medial leg skin is badly burned, then a medial gastrocnemius flap can be used. The fascia over the gastrocnemius is scored several times longitudinally to increase its width when it is rotated into the defect. A skin graft covers the muscle. The leg is kept in extension until the grafts are well healed. Long term splinting is not necessary.

With contractures of the popliteal area, other causes of contractures, such as joint injuries, must be ruled out. Occasionally, step cut lengthening of the posterior tendons, hamstring tendons, and release of the posterior joint capsule may be necessary. If the distal pulse is lost when the leg is extended, then the reconstruction should be carried out, the leg flexed back to where one feels a pulse, and then followed with serial lengthening over several weeks.

(**Editor's note**: The methods above using flaps still require some skin grafting, but as soon as grafts have healed, usually less than two weeks, the patient can be discharged without the need for follow-up if there is good range of motion. Further compliance is no longer necessary.)

Ankle & Foot

1 Ankle and foot contractures are quite common, and often seem very difficult to correct surgically,

Fig. 210

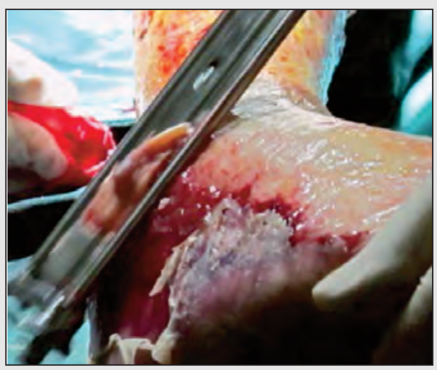

Fig. 211

Fig. 212

Fig. 213

Fig. 214

The entire process: debridement with Humby knife, FTSG or thick STSG over ankle joint, STSG over other areas, dressing with fine mesh/non-adherent gauze, and final result.

especially if the burn accident happened in early childhood.

2 One should, however, always try to release the contracture in children and young people, even if the contracted foot seems to be very twisted, as the possibility of improving the function of the foot is very good.

3 The procedure follows the guidelines underlined in this chapter:
- Apply tourniquet.
- Excise the scar tissue until healthy subcutaneous tissue is reached or paratenon and ligaments are encountered.
- This dissection might be time-consuming, as the scar and fibrotic tissue is quite often very thick.
- Provided the dissection removes all fibrotic scar tissue, it is remarkable to observe how the foot regains its normal look.
- Contractures involving the dorsum of the foot and the toes often retract the toes in a dorsal-vertical position.


Fig. 215


Fig. 216


Fig. 217

5 year-old with total release of scar tissue, grafting, with later normal appearance.


Fig. 218


Fig. 219


Fig. 220


Fig. 221

14 year-old burned when stepping into burning trash while playing football 7 years previously. Note 90 degree hyperextension of toes. Release, pinning with K-wires, thick STSGs, 7 weeks in hospital.


Fig. 222


Fig. 223


Fig. 224


Fig. 225

Wide excision and grafting. Pre-op. knees were bent so that heels would touch ground. Patient required 12 months at rehab center after surgery.

- With meticulous dissection, the toes can be brought back into normal position.
- K-wire fixation of the toes is a good option during the time of graft healing.

In these cases, there is not always lot of scar to excise, but the release must be from mid-axial to mid-axial at the ankle or from lateral to the medial malleolus. After the skin incision, a further release is performed


Fig. 226


Fig. 227


Fig. 228


Fig. 229

Deep burn to sole and heel. Cross leg reconstruction with tensor fascia lata pedicle flap (TFL) from opposite side at age 16, pedicle released after three weeks. Good final result without contracture of the knee.

- Thick split thickness sheet grafts are the grafts of choice when resurfacing the ankle, dorsum of the foot, and the toes/interdigital web spaces.

(**Editor's Note**: Once again, the author gets wonderful results because he excises all the burn scar and contracted skin.)

(**Editor's note**: The excellent methods above cannot be improved on by flaps, though a cross leg flap may be used to cover exposed ankle joint after it is released (see Figs. 230-231). With perforator and reverse sural artery flaps now available, there are more alternative reconstructive methods available than before when there is a severe contracture of the ankle.


Fig. 230


Fig. 231

Severe dorsiflexion contracture of ankle with exposed joint after release. Cross leg (saphenous) flap reconstruction and external fixation for 3-4 weeks. One must graft donor site before inset of flap.


Fig. 232


Fig. 233


Fig. 234


Fig. 235

Severe lateral contracture at ankle secondary to burn at 6 months of age; now 3 ½ years old

Fig. 236

Fig. 237

Fig. 238

Fig. 239

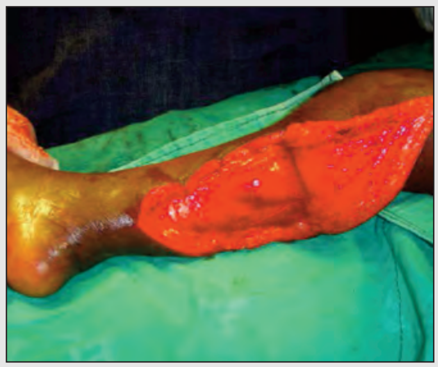

Fig. 240

Fig. 241

Severe medial contracture with illustration of incision from mid-axis to mid-axis. After complete release on with pins from calcaneus up into tibia and pins through toes into hindfoot. Elevation of fasciocutaneous cross leg flap with inset and external fixator to hold securely in place.

by pressing the scalpel through the tissue while gently extending the foot. The release will likely extend into the ankle joints, and ligaments will need to be released as for a club foot release on the medial side.

Once the bones are aligned as well as possible, a large K-wire or Steinman pin should be inserted from the sole through the calcaneus, talus, and into the tibia. Pins should also be inserted retrograde through the toes into the hindfoot. These pins are left six weeks, and the foot casted another 3-6 months. The main problem will be coverage of the open joint. A cross-leg flap will be the easiest procedure in these cases, for coverage with an external fixator to hold the legs securely together.)

Perineum/Genitals/Buttocks

1 Deep burns in the buttocks requiring surgical intervention will need to be treated in the same way as deep burns other places. The need for regular positioning and avoidance of pressure on the grafted areas might be a challenge for the nursing staff.

2 Burns in the perineum/perianal region pose a big challenge to the burn team.

- Deep perianal burns requiring excision/debridement and skin grafting need proper planning.
- A diverting colostomy may have to be performed prior to any skin graft procedure, as the risk of graft loss without colostomy is likely.
- Deep perianal/perineal wounds left for healing through scar formation may become a great challenge for the reconstructive surgeon (as the cases in Figs. 243-246 indicate).
- Meticulous nursing care of wounds and grafted areas are of greatest importance for a positive outcome in these difficult burns.
- If the burns are deep and sphincter function is found later to be inadequate, a gracilis flap may be used to reconstruct the sphincter (Contact author/editor for details of such procedure).

Fig. 242

Fig. 243

Fig. 244

Fig. 245

Required initial colostomy and nutrition for 2 months. Thick STSG were used around anus and STSG for other areas. Legs were elevated for healing.

3 Third-degree burns of the entire penile shaft will need a FTSG skin graft or a thick STSG, once the wound has become clean.
- The FTSG has to be applied as sheet grafts. Minor, smaller wounds may be left for secondary healing, or simply excised and closed directly. (**Editor's note**: Thick meshed STSG also works well.)
- These burns are fortunately uncommon.
- Technique: A Foley catheter is inserted, the penile shaft extended by sutures through glans and attached to Foley and grafts applied. Stent sutures are inserted at penile base and at corona, and tied over a bulky dressing as described previously. If the graft has been meshed, a stent should be left in place for 10-14 days.

Editor's Conclusion

This chapter has given general surgeons several different options for care of burn deformities. Certainly the techniques of Dr. Eriksen are excellent. Unfortunately, many in district hospitals will not be able to carry out some of his methods because they lack his resources and funds.

You are also referred to the book ***Primary Surgery***, by Maurice King, which contains a lot of important information about burns and skin grafts.

Addendum: Burn scars often lead to hypertrophic scars and keloids. These are covered in Chapters 1 and 34. For hypertrophic scars, pressure is the best answer. Vitiligo, depigmentation of the skin, is an unsightly result of deep burns, especially if on exposed areas. The best treatment for these "white" scars is waiting, as over time most of these areas will re- pigment especially in young people. The next best treatment is excision and grafting of these areas. Tattooing with appropriate colors can be used for small areas. Women can use various cosmetics on exposed areas but these measures are temporary.

Please see algorithm for hypertrophic scars and keloids at the end of Chapter 1.

Chapter 13
Neural Tube Defects

A. Leland Albright

Spinal Neural Tube Defects

Myelomeningoceles

Babies with myelomeningoceles (MMCs) are rarely diagnosed prenatally in developing countries. Many are born at home and the MMCs covered with dirty cloths. Most MMCs have an intact sac of thin, abnormal skin topped with a pink neural placode, but a few sacs rupture and drain cerebrospinal fluid (CSF). MMCs range in size from small to very large, and in extent from sacral to thoracic. They can be associated with no evident neurologic deficit or with deficits ranging from leg weakness to paraplegia. In my experience, infants with MMCs have been brought for medical attention as young as 1-2 days old and any time thereafter. After 3-4 months, the MMC usually becomes covered with fibrous tissue.

If an infant presents with a "raw" MMC placode, it should be covered with gauze moistened with saline. Motor function should be tested by painfully stimulating the infant above the MMC; stimulation below the lesion causes reflex, rather than voluntary, movements. A 22-gauge needle can be inserted into the sac through insensate skin just caudal to the sac to aspirate CSF for WBC counts and culture1. It is appropriate to begin IV antibiotics in babies with raw or leaking MMCs because of the likelihood that CSF is, or will soon become, infected. Ciprofloxacin and gentamycin are reasonable choices in the first month of age; few CSF infections in infants with MMCs in our hospital are sensitive to ceftriaxone.

Head circumference should be measured and a head ultrasound obtained if the circumference is above normal. Normal circumferences at birth are 31-37cm.

The decision about whether to operate to close a MMC is affected by many factors including family preference, feasibility of follow-up, motor level, severity of hydrocephalus, and by associated problems such as severe spine or chest wall deformity, or a symptomatic Chiari malformation (causing stridor, nasal regurgitation with swallowing, or apneic episodes).

The traditional method of closing MMCs, which

Fig. 1

Elliptical incision around the base of the MMC and dissection at the fascial level, then around the dural stalk as it exits the spinal canal.

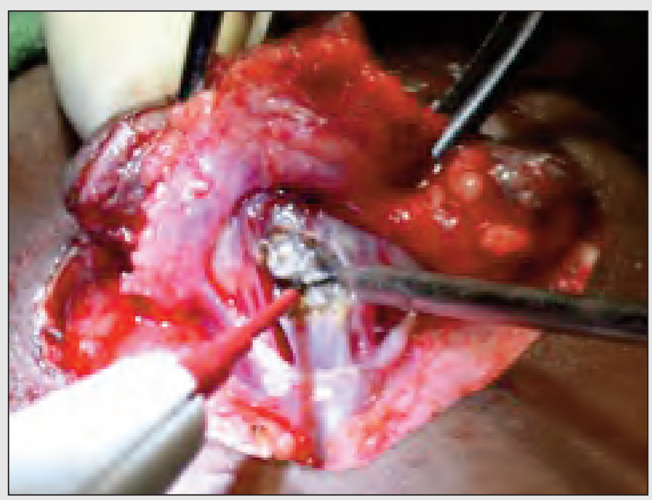

Fig. 2

Dura has been opened transversely to expose the junction of the distal cord and the bottom of the neural placode. That junction is transected with a monopolar cautery set at low voltage. Nerves exiting the placode are transected, the dura opened completely circumferentially, and the placode and exiting nerves are excised. Dura is closed with a running 5-0 suture.

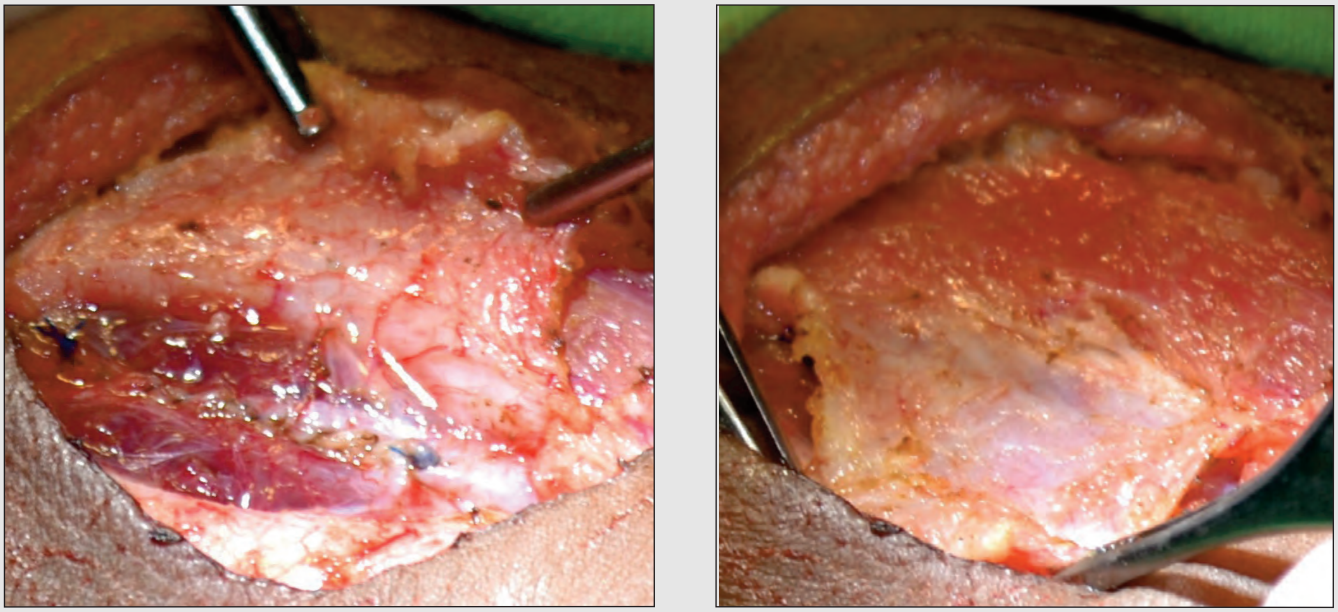

Fig. 3

Unilateral fascial flap mobilized from underlying paravertebral muscle (left) and approximated over the dural closure (right). A thin layer of paravertebral muscle can be mobilized with the fascial flap to provide a more substantive tissue barrier.

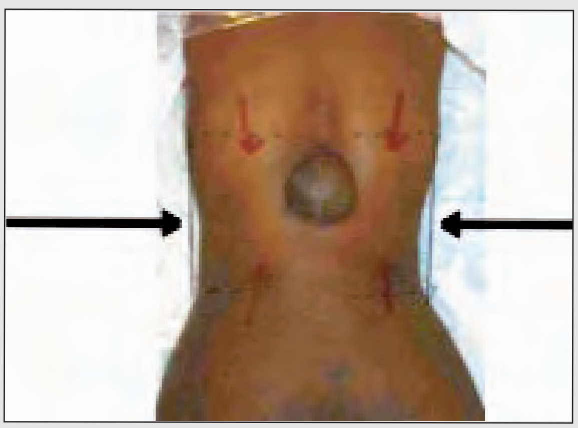

Fig. 4

Shows bilateral bipedicle flaps—blood supply from superior and inferior. The lateral incisions (black arrows/blue lines) are in the mid-axillary line. The tissue between these incisions and the defect is raised beneath the superficial fascia (Scarpa's fascia in the back). Blood supply comes into the flaps from perforators, superior (thoracodorsal) and inferior (lumbosacral and superior gluteal). The closure is in the midline. The defects created laterally can be grafted or allowed to heal by secondary intention. This is the easiest way to close these defects if one does not have experience with other flap techniques. Those techniques include closures such as rhomboid flaps, lumbar perforator flaps, superior gluteal artery flaps, and keystone perforator island flaps, and are described in plastic surgical literature.[4, 5] In my experience with over 700 MMCs, they are needed rarely.

preserves the neural placode, is as follows. First, incise circumferentially around the placode, then fold its edges toward the midline and secure them together at the midline with 5-0 suture.[1] Dura around the closed placode is then dissected off the underlying fascia and closed watertight at the midline with 5-0 suture. Lastly, the skin is undermined laterally to the mid-axillary line, and the subcutaneous fascia and skin are closed in layers at the midline. If the skin closure is taut, interrupted sutures are indicated so that if there is a focal wound breakdown, the entire incision does not have to be opened as when continuous running sutures are used.

Recent studies have indicated that the neural placode is non-functional and our technique has changed.[1] We incise elliptically around the MMC at its junction with normal skin, and then dissect subcutaneously medially to the dural sac that comes up out of the spinal canal. The periphery of the sac is exposed and the dura opened circumferentially just below the bottom of the placode. The distal spinal cord is transected at its junction with the bottom of the placode, then the placode and nerves exiting it are removed. The dura is closed with a running 5-0 suture and a Valsalva maneuver performed to make sure there is no CSF leak.

After the dural closure, subcutaneous tissues and skin are bluntly dissected off the underlying fascia out to the mid-axillary line. If those tissues are substantial enough to provide good coverage of the dura, they can be closed with subcutaneous and cutaneous sutures. If those tissues are quite thin and more substantial coverage of the dural sac is desired, unilateral or bilateral semi-circular leaflets of fascia and muscle adjacent to the dural sac can be developed with the cautery and sutured over the sac.

If subcutaneous tissues are mobilized to the mid-axillary line and then approximated at the midline, primary wound closure is possible in the great majority of cases. At times, however, the closure is under tension at its mid-portion. If that tension is thought to result in a probable wound breakdown, vertical relaxing incisions in the mid-axillary line will reduce the tension and will usually heal by secondary intention; skin grafts are needed rarely. This technique may be the best method for one not trained in flap surgery when the defect is quite large. Figure 4 shows incisions in the mid-axillary line, the dual blood supply from the thoraco-dorsal perforators superiorly, and the lumbosacral and superior gluteal perforators inferiorly.

Fig. 5
Giant lumbosacral meningocele (left) and its transillumination (right).

Post-operatively, children can lie on their backs or sides or abdomens. The importance of keeping incisions clean and free of fecal contamination must be emphasized to the mothers. Most infants with MMCs have a "neurogenic bladder" and do not empty the bladder sufficiently. Their caregivers should be taught clean intermittent catheterization (CIC) and instructed to use it every 3-4 hours during the day. At AIC Kijabe Hospital, CIC usually begins the first day or two after MMC closure. The anterior fontanel should be evaluated daily, and the head circumference should be measured every 2-3 days. Normal fontanels are soft, concave and pulsatile; those with hydrocephalus become convex, firm, and non-pulsatile. Treatment is then needed. CSF should be analyzed before any shunt insertion to confirm that the WBC count is low (ideally, < 10) and that the culture is negative.

Meningoceles

Meningoceles are dorsal herniations of dural sacs, filled with CSF and occasionally containing non-functional fibro-neural strands. They are usually skin covered; never have a neural placode, and trans-illuminate. They are associated with normal lower extremity function and bladder function and rarely with hydrocephalus.

At operation, after prepping and draping, I prefer to make a small incision at the dome of the meningocele and aspirate the majority of its CSF before making an elliptical circumferential incision near its base. The incision must be high enough above the level of the back to be able to close the skin without tension. After incision, dissection continues down to the fascia, as with MMCs, then medially to the dural stalk. The circumference of the stalk is typically much smaller than the diameter of the meningocele. The majority of the dural sac can be excised and the dura then closed in a watertight manner. Subcutaneous tissues and skin are closed in

Fig. 6

Lipomyelomeningocele with a caudal appendage (top), and lumbar hairy tuft indicating a split cord malformation (with an associated subcutaneous hemangioma) (bottom).

two layers. Wound breakdowns are uncommon, and musculocutaneous flaps are almost never needed. A postoperative evaluation one month later is advisable.

Occult Spina Bifida

Several cutaneous abnormalities suggest the presence of underlying occult spinal dysraphism and, usually, an associated tethered spinal cord. The cutaneous stigmata may exist singly or in combination. A cutaneous elevated hemangioma or a subcutaneous lipoma usually indicates a lipomyelomeningocele. A hairy patch indicates a split cord malformation, as does asymmetrical lower extremity function. A sacral (not coccygeal) dimple may indicate a tight filum terminale. Operations for lipomyelomeningoceles and for split cord malformations are elective, are difficult, and should be performed only by neurosurgeons experienced in their management.

Cranial Neural Tube Defects

Posterior Meningoceles and Encephaloceles

Posterior **meningoceles** are CSF-filled dural sacs that herniate through defects in parietal or occipital bones. They are usually covered by skin, although the skin may be attenuated at times, and they rarely rupture. They contain no neural tissue and occur < 5% as frequently as posterior encephaloceles. They typically will trans-illuminate, and their lack of neural content can be verified by ultrasound. If untreated, they may slowly enlarge over the subsequent months.

Surgical repair involves an elliptical incision around the sac, but, as in closing lumbar meningoceles, taking care to leave ample skin and dura above the base of the sac so that they can be closed without tension. If the bone defect through which the meningocele protrudes is < 2 cm in an infant, it will decrease in size over time and does not need to be covered with bone. Larger defects can be filled with bone taken from adjacent parietal regions; underlying dura and overlying periosteum at those sites regenerate the removed bone in infants. Postoperatively, hydrocephalus is uncommon, and children are usually neurologically normal.

Posterior **encephaloceles** range in size widely, from minimal lesions to ones that are larger than the head. Most are covered by skin. They contain neural tissue and CSF in proportions that cannot be determined by clinical examination. One clue to the amount of brain in the encephalocele comes from the shape of the forehead: if it slopes posteriorly, then brain that would normally be intracranial has been displaced posteriorly into the encephalocele. Brain within the encephalocele is abnormal and lacks the normal six-layer cortical structure. Posterior extensions of one or both lateral ventricles are often present within the encephalocele.

Encephaloceles may transilluminate in areas of CSF, but CT scans are needed to document the extent of brain herniation. The size of the encephalocele does not indicate the extent of brain malformation since, in some cases, the majority of the encephalocele content is CSF.

The decision about whether to operate on infants with posterior encephaloceles needs to take into account factors similar to those when MMC operations are considered: family preference, extent of brain tissue within the lesion, and the clinical condition of the child. Infants who require continual oxygen or who cannot suck and swallow can be assumed to have hindbrain or brainstem malformations, and those symptoms almost never improve after operation.

The operation is done with the infant in a prone position with the head resting on a horseshoe head holder or in a foam or rolled-towel doughnut. For surgeons who are not experienced operating on these lesions, one unit of blood should be available, though blood loss requiring transfusion is uncommon in experienced hands. The apex of the lesion can be prepped first, then held up with sterile gauze or gloves while the base of the lesion is prepped. I often aspirate CSF from the sac before making an incision at its base to make manipulating the encephalocele easier and making it easier to determine where to make the elliptical incision above the base. A mistake in this operation is to incise normal scalp on skull adjacent to the base of the encephalocele, not leaving enough scalp to close. Scalp on the encephalocele should be incised high enough above its base to allow subsequent closure without tension, and then the subcutaneous tissue layer is dissected medially and around the circumference of the dural stalk.

Numerous subcutaneous vessels that need to be coagulated may be encountered on either side of the sac during the dissection. As the dural or arachnoid opening begins, underlying neural tissue sometimes bulges out. It can be cauterized with bipolar cautery and aspirated with suction or removed with the remainder of the herniated tissue when the dura is completely opened. There is no single, optimal way to excise encephaloceles. At times, it is possible to work from one site transversely across to the opposite side. At other times, dissection needs to be done from multiple approaches before the stalk is completely transected. If the transection creates an opening into the ventricle, nothing different has to be done other than minimizing blood draining into

Fig. 7

Occipital meningocele (left) and opened meningocele sac.

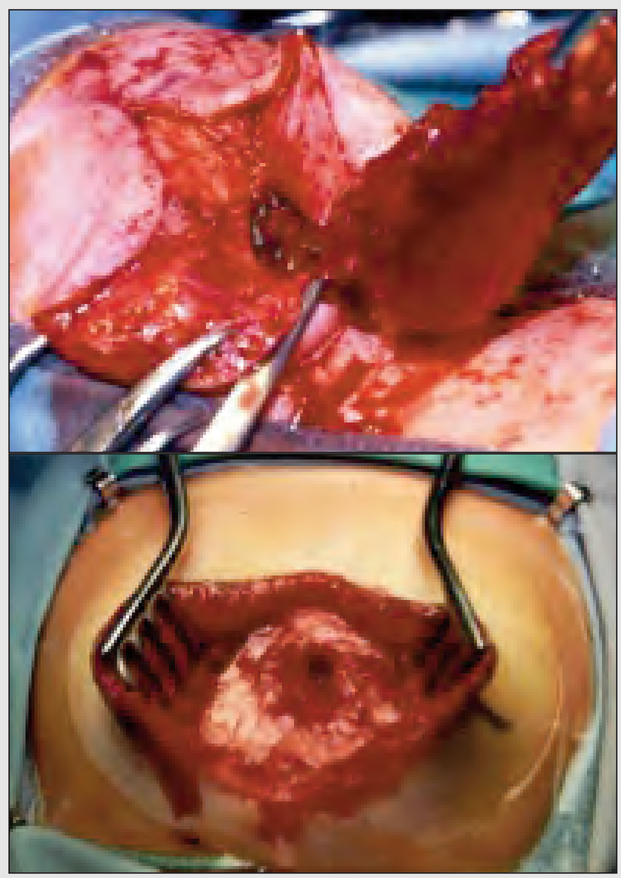

Fig. 8

Stalk of dural sac (left) and cranial defect through which the meningocele herniated.

Fig. 9

Occipital encephalocele associated with posterior slope of the forehead, indicating cerebral tissue displaced posteriorly within the encephalocele.

it. Once the encephalocele is divided and removed, the dura is closed in a watertight manner. The same approach to the skull defect applies here which was described for meningocele repairs above.

Because neural tissue within an occipital encephalocele is dysplastic, it is routinely amputated. Pediatric neurosurgeons have reported attempts to preserve that tissue by expansion cranioplasties, but those techniques have not been widely adopted.

Fig. 11

Skin and dura have been opened circumferentially high enough above the skull to permit their closure after the arachnoid sac is opened and herniated cerebral contents excised.

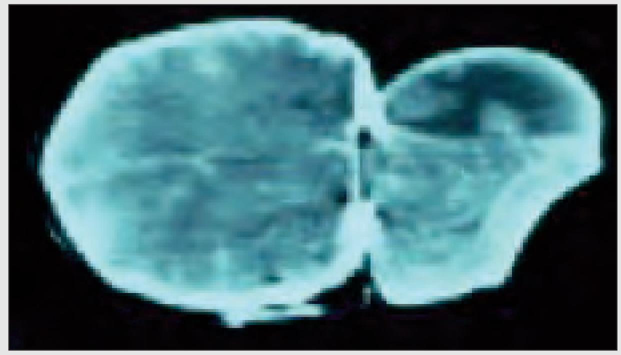

Fig. 10

Axial CT scan demonstrating cranium and brain to the left and posterior encephalocele to the right. Within the encephalocele, CSF (dark) is superior and herniated brain is inferior.

Postoperatively, 50-80% of infants with posterior encephaloceles will develop hydrocephalus, usually occurring within the first three months after surgery. It can be treated with a conventional VP shunt or with an endoscopic third ventriculostomy and choroid plexus coagulation. Prognosis of an infant with an occipital encephalocele depends primarily on the amount of tissue within the encephalocele. Most (>80%) infants with occipital encephaloceles are substantially developmentally delayed and 30% have epilepsy.

Anterior Encephaloceles

In developing countries, anterior encephaloceles occur almost as frequently as posterior encephaloceles; in developed countries anterior encephaloceles are rare. They range widely in size, are almost always covered with skin, are more likely to contain a high relative amount of neural tissue than posterior encephaloceles (though a far less absolute amount), and are less likely to be associated with hydrocephalus.

Anterior encephaloceles are classified as follows:

- Cranial vault
- Sincipital
    - Naso-frontal
    - Naso-ethmoidal
    - Naso-orbital

Cranial Vault Encephaloceles

Cranial vault encephaloceles are the rarest of the anterior encephaloceles. They transgress the frontal bones and are evident above the eyebrows. They are associated with larger skull defects than sincipital or

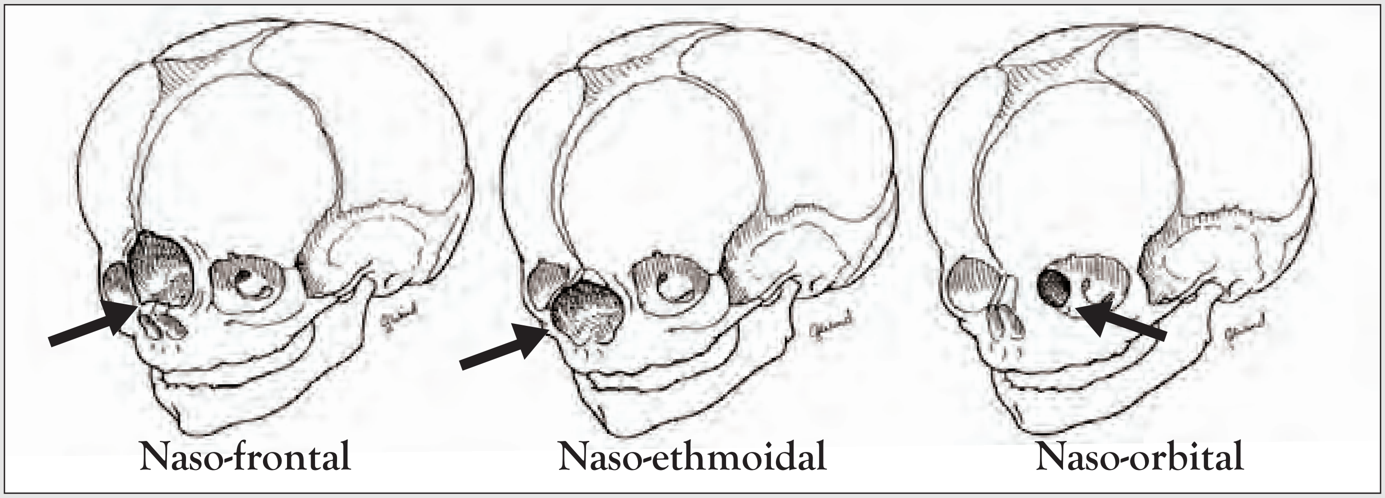

Fig. 12

Three types of nasal encephaloceles
(Sargent LA, Seyfer AE, Gunby EN, Journal of Neurosurgery,
April 1988/Vol. 68/No. 4/Pages 471-575. Reprinted with permission, Thieme).

basal encephaloceles. The size of the skull and dural defects requires both frontal and trans-cranial approaches. The dural defects can be closed with pericranium if no dural substitute is available and the skull defect can be closed with a split-thickness cranial graft from adjacent skull or with methylmethacrylate.

Sincipital (Frontoethmoidal) Encephaloceles

Nasofrontal encephaloceles

The defect is between the frontal and nasal bones and the protruding mass pushes the nasal bones down and the medial orbital walls out. The intracranial defect is at the frontoethmoidal junction.

Nasoethmoidal encephaloceles

The defect is between the nasal bone and nasal cartilages and the mass projects below the nasal bones. This is the most common type seen in East Africa. The herniating dura passes through a defect between the frontal and ethmoidal bones.

Naso-orbital encephaloceles

The defect is in the medial orbital walls between the lacrimal bone and frontal process of the maxilla and it presents as a mass between the nose and orbit. It may be obvious that the globe is pushed laterally. The frontal and nasal bones and the nasal cartilages are normal.

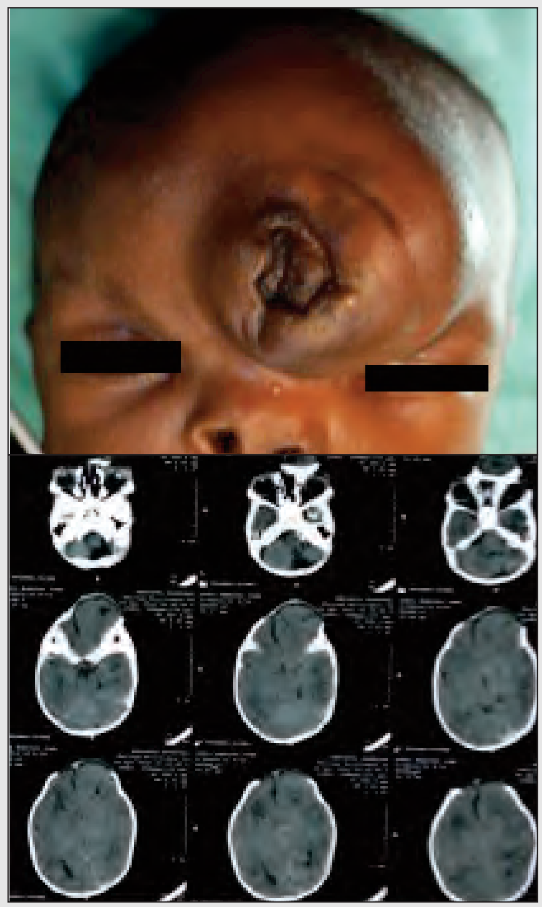

Fig. 13

Cranial vault frontal encephalocele (top) and CT scan showing the associated large skull defect and frontal lobe herniation (bottom).

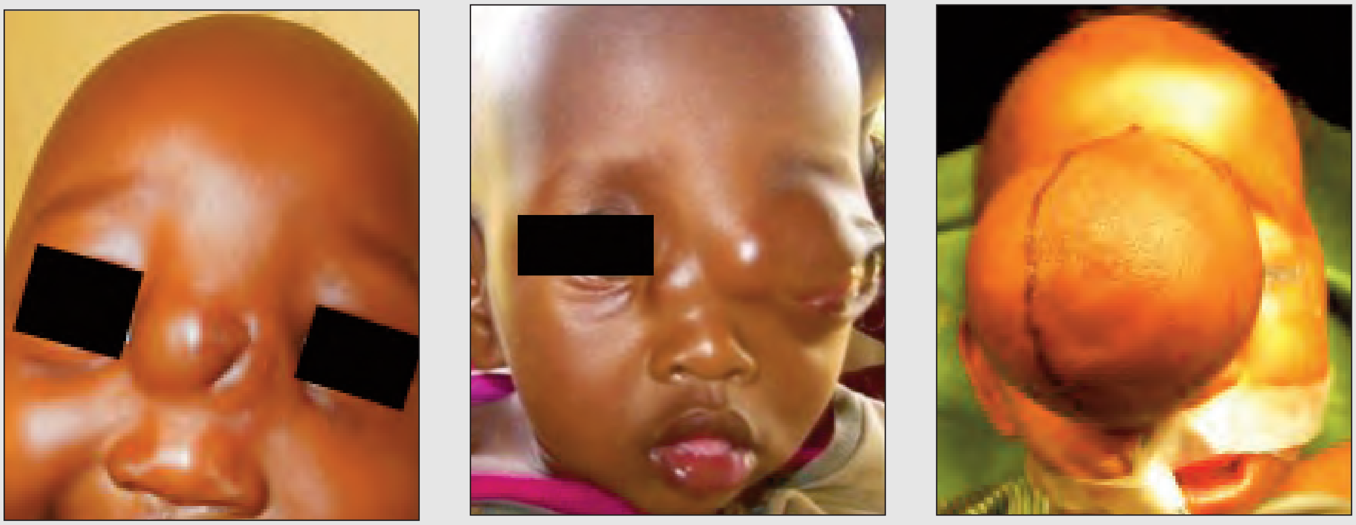

Fig. 14

Other examples of different types of anterior encephaloceles.

Sincipital encephaloceles are evident by inspection of the child's face. They range in size from small to very large and may be in the midline, paramedian, or orbital area.

Sincipital encephaloceles contain varying amounts of brain and CSF. Those proportions can be evaluated by CT or MR scans, though usually there is more brain tissue than CSF. The location and size of the skull defect can be evaluated well with CT scans.

Sincipital encephaloceles are often associated with hypertelorism, with occlusion of one or both naso-lacrimal ducts, with erosion of the medial wall of one or both orbits, and with other orbital deformities. The operations are far more complex than operations for posterior encephaloceles. Approximately 25% can be treated by a trans-facial approach, but the remainder will require a combined trans-facial and trans-cranial approach.

Facial approaches involve an elliptical incision up on the encephalocele, preserving enough tissue for closure without tension, then dissecting the skin and subcutaneous tissue off the underlying dura, and dissecting the dura away from the bone edges around the entirety of the lesion. The dura is opened in the midline, and herniated dysplastic tissue is removed with bipolar cautery, suction and scissors. The dura is then closed in a water-tight manner. The underlying bone defect can be left open if it is <1.5cm in diameter, but larger defects (far more common) should be closed. The two most commonly used options for closure are either a piece of skull taken from a secondary incision in the posterior frontal region or metal mesh. Tissues are closed vertically with interrupted subcutaneous sutures using 4-0

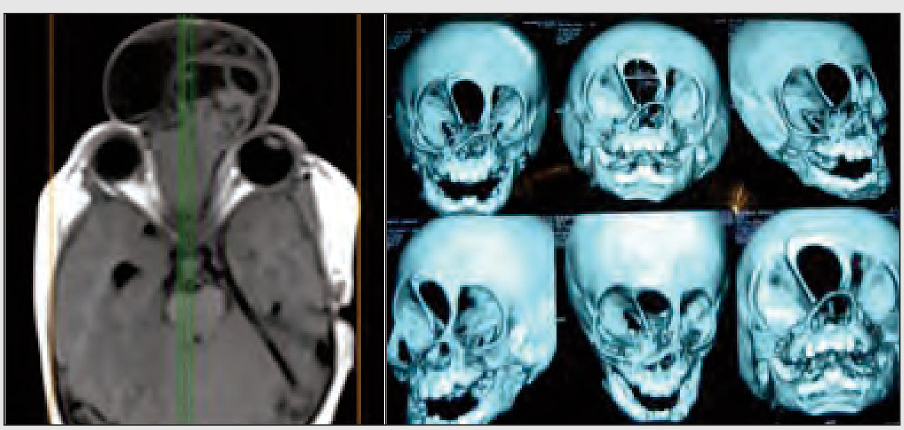

Fig. 15

Axial CT scan demonstrating the amount of brain (grey) and CSF (dark) in a sincipital encephalocele (left). 3D CT scans demonstrating the size and location of the bone defect in a sincipital encephalocele (right).

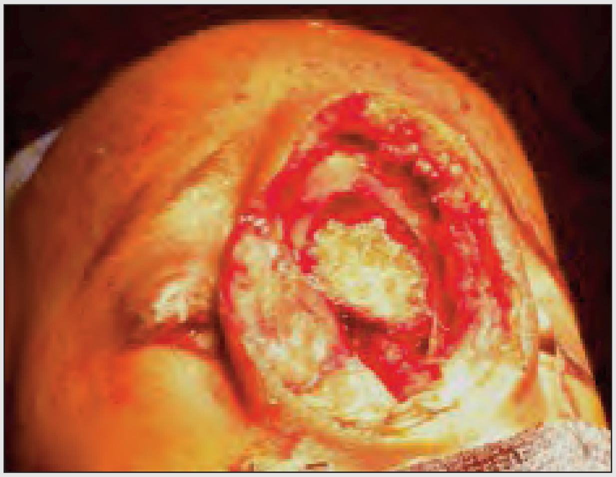

Fig. 16

Trans-frontal approach to a fronto-nasal encephalocele. The encephalocele has been resected and the dura closed, then augmented with fibrin glue. The contour of the elliptical underlying skull defect is evident.

Fig. 17

Positioning for a combined trans-cranial and trans-facial approach to a large sincipital encephalocele: A zig-zag incision is depicted in the appropriate location. The outline for a lateral incision on the encephalocele is too close to the right orbit and inappropriately low.

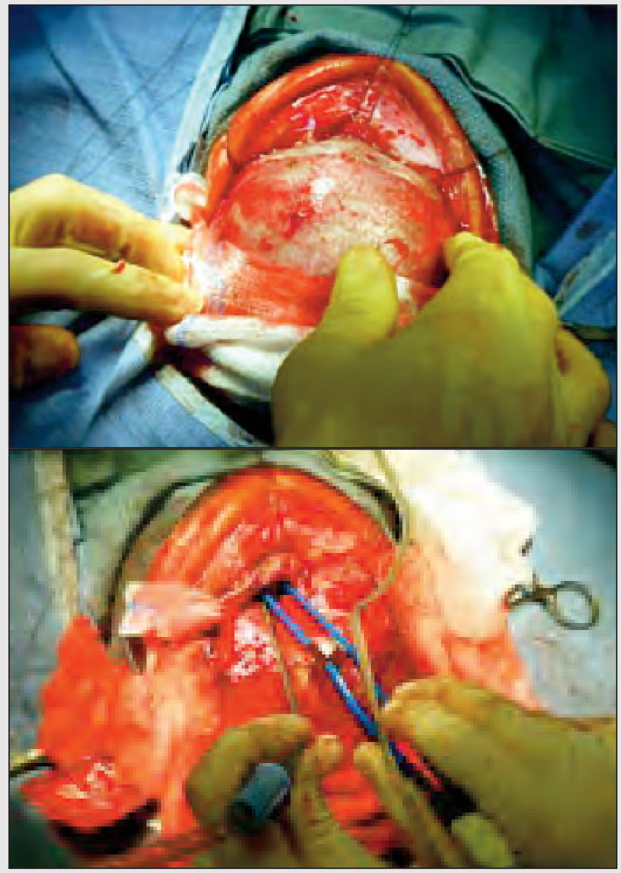

Fig. 18

Exposure of skull for bifrontal craniotomy (left). After craniotomy, retraction of inferior-frontal dura and opening of dura, bipolar coagulation is used to transect the herniated encephalocele.

Vicryl® and with skin closure using 5-0 sutures, either absorbable or non-absorbable (nylon or Prolene®).

Combined facial and trans-cranial approaches are needed for the majority of sincipital encephaloceles to obtain good closure of the dural and skull defects. Preparation for a case is shown in Figure 17.

I prefer to begin with the cranial approach, using a bicoronal incision. Scalp is reflected downward to the orbital rims. Then, a bifrontal craniotomy is made with either power instruments or a Gigli saw. Dura overlying the frontal lobes is retracted posteriorly and inferiorly until the site where the encephalocele exit the skull is exposed. Dura is opened as inferiorly as possible around the circumference of the opening, and the stalk of herniated brain is transected just above the bone defect. Margins of the skull defect are cleared of dura or other soft tissue and the defect filled with bone of appropriate size, obtained from skull just posterior to the craniotomy. The bone graft can be stabilized with Dermabond® or a Super-Glue® type product. Dura is closed either primarily or augmented with

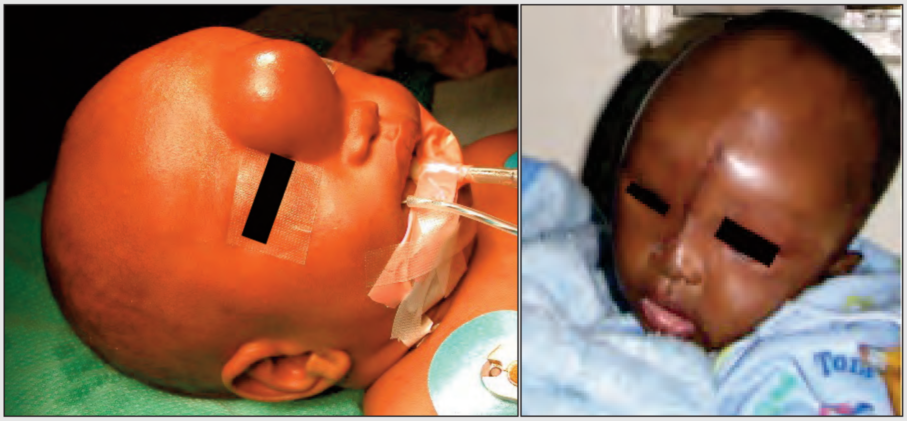

Fig. 19

Fronto-nasal encephalocele pre-op (left) and after combined trans-cranial and trans-facial approaches (right).

pericranium; the craniotomy flap is replaced, and the scalp is closed in a standard manner.

The facial approach to the remaining encephalocele is performed as described in Fig. 18 for cases without the trans-cranial approach.

(**Editor's Note**: The differential diagnosis of midline frontal masses include an encephalocele, glioma or dermoid. Many dermoids are quite large. Gliomas are firm and extend intracranially whereas a dermoid typically does not. An encephalocele may coexist with a glioma. A midline dermoid is less common than the lateral angular dermoid over the lateral eyebrow [Figs. 20-22].)

Basal encephaloceles

Basal encephaloceles are far less common than sincipital encephaloceles. They may present with upper airway obstruction, frequent respiratory infections and nasal discharge, CSF rhinorrhea, or meningitis. On examination, a nasopharyngeal mass is evident and may resemble a nasal polyp. It may fluctuate with pulse and may enlarge with a Valsalva maneuver. Cleft palate and ocular abnormalities including hypertelorism, microphthalmia, and coloboma are commonly associated with basal encephaloceles.

Treatment of basal encephaloceles is more difficult than of sincipital lesions because the skull defect and brain herniation is more posteriorly located. When untreated, the additional tissue may slowly herniate over months to years, but the primary risk is that of meningitis secondary to chronic CSF leak into the nasopharynx. These lesions should be treated by neurosurgeons if at all possible.

Conclusion

Both spina bifida and encephaloceles can present with a wide spectrum of abnormalities that range from small, relatively straight-forward lesions which can be repaired without significant difficulty, to large, complex lesions that challenge experienced pediatric neurosurgeons. The risk of postoperative complications from these disorders is high, even for pediatric neurosurgeons. There are few neurosurgeons in sub-Saharan Africa though even

Fig. 20

Fig. 21

Fig. 22

This is a midline dermoid in a teenage girl. It is superior to the usual nasoencephalocele. Longstanding dermoids will leave a depression on the skull but the skull is not involved.

fewer with pediatric neurosurgical training. In some circumstances, it will be more prudent to defer operations for these disorders than to overestimate one's ability, as is a common tendency among surgeons. Pediatric neurosurgeons can often be consulted via the Internet to discuss these cases.

Further Reading

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Chapter 14

Cleft Lip Repair

Paul Lim

Editor's Note: Why a Chapter on Cleft Lips?

Fortunately there has been widespread dissemination of information about the repair of clefts throughout Africa, thanks to Operation Smile, Smile Train, and the many cleft surgeons who have visited and taught throughout Africa. Many DVDs and instructional videos have been distributed all over the African continent and around the world.

So why should one write a chapter on clefts for this publication? All of these other wonderful educational tools tend to leave out subtle but important steps. The authors have looked for a complete publication but have never found one. An attempt has been made in this chapter to cover all the details for the surgeons in remote hospitals who have not done many of these procedures.

The authors recommend that surgeons preparing to repair cleft lips read and re-read this chapter and other chapters and watch the videos from Smile Train before performing the repair. Many resources describe the pathology of the cleft lip and the reader is referred to these classic works.

Introduction

Cleft lips are seen throughout the world. Since it is a visible deformity, there is an associated stigma, especially in countries where a correction or repair cannot be carried out at an early age. For years, the main goal of cleft lip surgery was simply to bring the lip together. In more recent years there has been an emphasis on correction of the cleft nose deformity, as cleft surgeons have come to understand that the best opportunity to repair the nose is at the time of lip closure.

The ideal age to repair a cleft lip is 3 months after full-term gestation, as long as the child is healthy. It has been shown that a 10 week old child with a weight of 10 pounds (4.5 Kg) and hemoglobin of 10 g will go through surgery well—the so-called, **Rule of 10s.** With any cleft deformity, feeding will be difficult immediately after birth. This is especially true with children with cleft palate who **cannot generate the necessary suction to feed**. A child with a complete cleft lip may have similar problems. The child should be fed in an upright position with the mother's breast filling any gap in the lip or alveolar ridge. Sometimes it is necessary that these children be fed with a bottle or spoon, and the mothers should be taught to express milk from their breasts—EBM.

When a child is seen late with cleft lip and cleft palate (**older than 10 months**), there is a temptation to repair the lip first and leave the palate until later. The lip is always easier. This is **not in the best interests** of the young patient or their family. At this age the child needs to have the palate repaired in order to give the best chance for normal speech. If only the lip is repaired, then the parents may not be concerned at this young age about the palate as there no longer will be a stigma associated with the hidden cleft palate. Regurgitation of food will still be a problem but a personal one and often not seen publically. If the patient and institution criteria as prescribed in Chapter 15 (Cleft Palate) are met, then the palate should be repaired first and the lip can be repaired at the same time or later. When performing both at the same operation, the palate should be repaired first so that the Dingman retractor for cleft

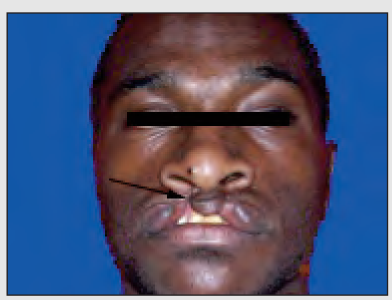


Fig. 1

Fig. 2

Patient in the jungles of Papua New Guinea, before and after. The stigma is world-wide. Black arrow—Simonart's band.

palate surgery is not stressing the newly repaired lip. If only the palate is repaired, the stigma of the lip remains and the parents will more likely bring the child back for lip repair.

Cleft Lip Classification

- Unilateral.
  - Microform.
  - Incomplete.
  - Complete.
- Bilateral.
  - Microform.
  - Incomplete.
  - Complete.
  - Combinations of above.
- With or without Cleft Palate.
- With protruding premaxilla/prolabium—usually in bilateral CL.
- With Nasal Deformity except in Microform.
  - Moderate.
  - Severe.
  - Mild.

Cleft Lip Facts

Unilateral CL/CP is more common on the left side and in boys. Cleft Lip/Palate is more common than CP alone.

- CL/CP left 41%
- CL/CP right 20%
- CP alone 22%
- CL/CP bilateral: 17%

Cleft palate alone is associated with syndromes and more common in girls.

Incidence by ethnic origin (number/births):

- 1/1000 in Caucasian populations.
- 1.7/1000 in East Asian.
- 0.3/1000 in African.

Risk of Clefts in next generation—Facts to give parents whose child has a cleft lip. Chance of cleft with next child:

- One child with cleft: 4%
- One parent with cleft: 4%
- Two children with cleft: 9%
- One parent and one child with cleft: 17%

Timing of Repair

- Cleft lip—Ideal is3 months of age and when at least:
  - 5 kg. (10 pounds).
  - 10 grams Hemoglobin.
  - 10 weeks of age.
- Cleft palate—see Chapter 15 Cleft Palate.

Anatomical Definitions (See Fig. 4)

- Cleft and non-cleft sides.
- Cupid's bow.
- Philtral columns.
- Vermillion – lip skin (non-hair bearing).
- White roll (slightly thick skin along the vermillion border).
- Mucocutaneous line (red line)-between wet and dry vermillion.
- Columella.
- Alar base.
- Nostril sill.
- Commissure.

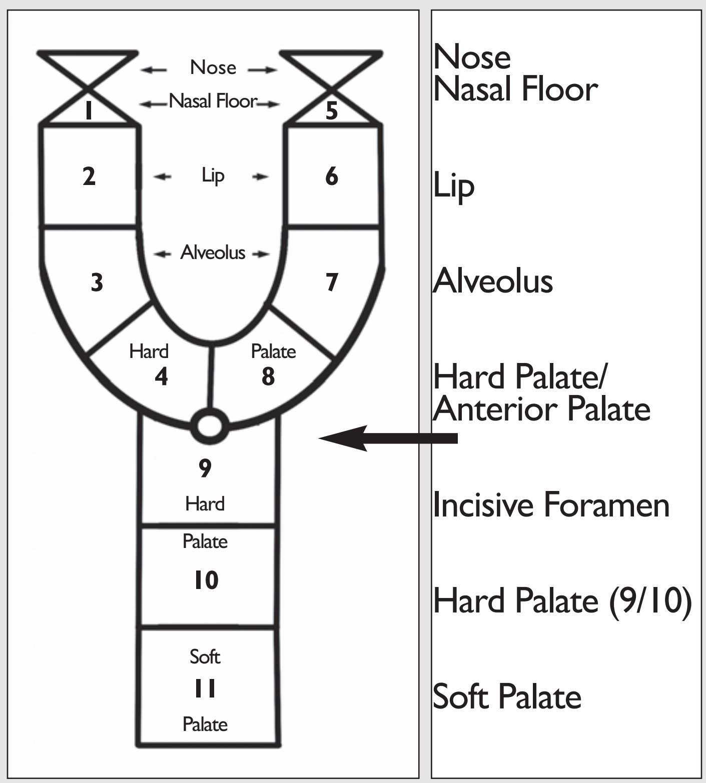
Surgical Definitions

- Advancement flap.
- Rotation flap.
- C-flap.

Types of Unilateral Repair

- Straight line.
- Lower lip Z-plasties.
  - Randall-Tennison.

Kernahan Y Classification



- Incisive foramen at junction of limbs.
- Primary Palate: palate anterior to incisive foramen.
- Secondary Palate: hard and soft palate distal to incisive foramen.

Fig. 3

Fig. 4

Note #1 midline of Cupid's bow and #2 the peak of Cupid's bow on non-cleft side. #1 to #2 gives the distance for #1 to #3, #5 and 6 are at the alar base. #4 is where vermillion of the cleft side is fullest or thickest. It is also found by measuring the distance from #2 to #5, then measuring the same distance from #6 to the point where it intersects with the vermillion border or white roll. This distance is usually about 10 mm. in young children.

  - Triangular.
  - Fisher.
- Upper Lip Z-plasties.
  - Millard Rotation Advancement—this is the easiest to use and will be the only one described in this chapter.

Advantages of the Millard Repair

- Measurements are not definite, and one can "cut as you go"—cut a little more to bring edges together.
- Mid-course corrections are possible.
- Restores normal philtrum.
- No scars across philtrum.
- Z-plasty at base of columella, which is not easily noticed after lip has healed.

Disadvantages of the Millard Repair

- Requires wide undermining in wide clefts.
- Tendency for short lip on cleft side.
- Notching of vermillion in wide clefts and when Cupid's bow is not level after rotation.

Problems with All Techniques

- Do not address the alveolar ridge defect—this can be reconstructed by the use of an orthodontic appliance to bring the alveolar ridges in approximation for the option of gingoperiosteoplasty at the time of lip repair. Such orthodontic care is only available in a few major cleft centers in the U.S. and rare in Sub-Saharan Africa.
- Do not address nasal deformity adequately—can also be minimized by appliances if available.
- Philtral column on cleft side not adequately reconstructed.
- Size and placement of nostril difficult.

Pre-operative Preparation

- Hemoglobin.
- Malaria smear if from an endemic area (even if the patient is asymptomatic).
- Weight.
- NPO 6 hours prior to surgery.
- One dose of a cephalosporin antibiotic after IV started (before incision made).

Anasthesia

- Ideally general endotracheal anesthesia is used with the ET tube, preferably a RAE tube, brought over the midline of the lower lip. Midline location is best for the tube so as to give symmetry

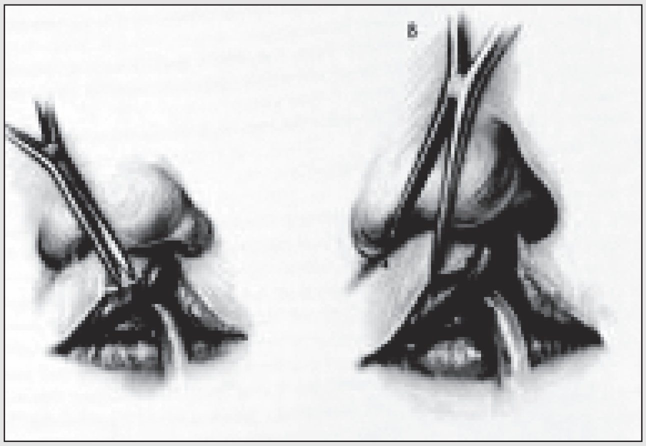


Fig. 5

throughout the repair.

- It must be well taped in place in the midline so that it does not shift during surgery.
- The head is stabilized with sand bags/IV bags on either side by the ears.
- A throat pack may be placed if there is a leak around a non-cuffed ET tube. However, this should be well documented so that it is remembered to be removed before extubation (it is relatively hidden with a cleft lip repair, since it is far back in the oropharynx). With extubation, this becomes a life-threatening obstruction of the upper airway.
- This operation can be done in older children/adults under local anesthesia with ketamine (or straight local). Infraorbital nerve blocks on each side should be done as well as a field block for the vasoconstrictive effects of the epinephrine. There still must be control of the airway.

Basic Operation

Ideally photographs are taken before the patient is given an anesthetic.

Markings: Place Marks at Key Points (see Fig. 4).

- Midline Cupid's bow #1.
- Height or peak of Cupid's bow on non-cleft side #2.
- Measure distance from #1 to #2 and then mark the peak of Cupid's bow on cleft side #3. Distance from 1 to 3 will be the same as 1 to 2, usually 4 mm.
- Alar base on each side, #5 on non-cleft side and #6 on cleft side.

Measure distance from alar base #5 on the non-cleft side to #2. This distance, about 10 mm. in a young

Fig. 6

#2 to #5 equals #6 to #4 (though the picture does not show this clearly.).

Alar base to the fullest point of the lip on the cleft side equals #5 to #2 on the non-cleft side.

Fig. 7

This picture shows it clearer (cleft on right side).

Alar base to the fullest point of the lip on the cleft side #4 to#7 (red line), equals #5 to #2 on the non-cleft side (blue line), also equals the height of the philtrum column on the non-cleft side, and also the length of the rotation flap, #3 to #8.

Fig. 8

Distance from A to B (4 to 7), the Advancement Flap, equals A' to B' (3-8), the Rotation Flap. (This is the same measurement as #4 to #7 and #3 to #8.)

This also equals length of normal philtrum column on normal side, non-cleft side

child, should be measured on cleft side from alar base to where it intersects with the vermillion border, #4. This should be where **vermillion is the fullest**.

The non-cleft side measurements are the basis for determining points on the cleft side. So 2 to 5 should equal 4 to 6 with the lip slightly pulled down on the cleft side. The commissure should never be used in these measurements.

The Rotation (R) flap should be drawn from #3 upward as a slight convexity following the cleft margin and then curving just below columella to non-cleft side (as seen in Fig. 5) It should not cross the philtrum column on the opposite side—non-cleft side. The end point of the rotation flap is #8—the end of green arrow below in Fig. 6—though this point is not definite until the surgeon is satisfied by the downward rotation of the rotation flap with a level (transverse) Cupid's bow and lip.

Markings on the cleft side from #4 to nostril sill #7 should equal #3 to #8. These are not definite but a guideline as will be seen in Fig. 8. In that image, A to B is the same as 4 to 7.

In a complete cleft lip, the incision between #4 and #7 is along the vermillion border and it is the same distance as #2 to #5 and #4 to #6 and #3 to #8 on the non-cleft side as mentioned above—see red arrow in Fig. 9.

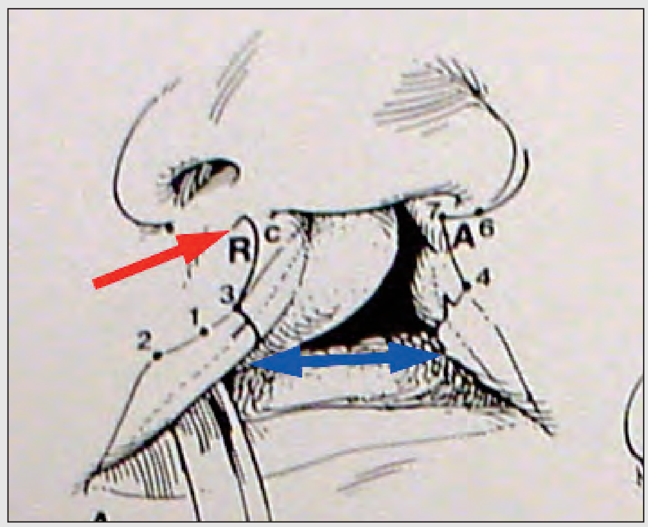


Fig. 9

When the rotation flap (R) has been developed, the lip should be horizontal as the blue line above—level.

If not, the "back cut" must be deepened just medial to the philtrum column (red arrow) on the non-cleft side. Never should the backcut cross the philtrum column.

(Original illustration, *Grabb and Smith Plastic Surgery*, Fig. 9-7, page 280, courtesy of Lippincott Williams Wilkins.)

Incisions

The R-flap should then be incised, dividing the vermillion perpendicularly at #3. The flap is then pulled down very gently with a skin hook. Cupid's bow should lie horizontally, level, with very slight tension on it. If it is not horizontal, then a "back-cut" should be made at the end of the R-flap (end of the red arrow in Fig. 9). This should be downward and **not crossing** the philtrum column on the non-cleft side. One continues incising until Cupid's bow lies horizontally as the blue line in Fig. 9. **When extending the back cut, it is important to divide the muscle completely, through and through, to allow complete rotation downwards of the flap**.

The line between #4 and #7 is along the vermillion border and should equal the distance from #3 to #8 after the back-cut. These are not definite but a guideline.

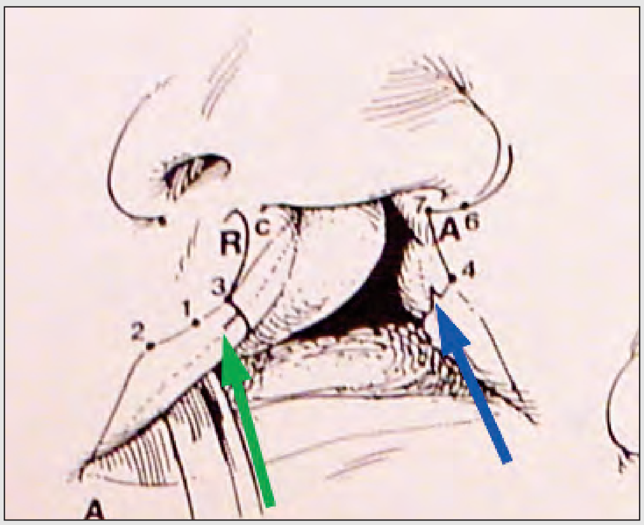


Fig. 10

Showing the importance of equalizing the thickness of the lips: A wedge from the cleft side, blue arrow, should be taken to fill the deficiency on the non-cleft side at point #3—green arrow.

Note Fig. 3: vermillion at #3 is not as thick as at #4.

Incising from #4 to #7 is along the vermillion border. It is extended past #7 into the nose along the mucocutaneous line to free up the alar base and later close the nostril floor.

(Original illustration, *Grabb and Smith Plastic Surgery*, Fig. 9-7, page 280, courtesy of Lippincott Williams Wilkins.)

The vermillion at #3 is always narrow. A triangle/wedge shaped flap is taken from the cleft side vermillion just below #4 to fill in the non-cleft side in order to give a full and equal lip on both sides. This wedge inserts at the green arrow in the figure below. The lip at #3 on the non-cleft side is not as full as the cleft side and should be augmented.

An incision is made from #7 to #6 below the alar base in most clefts. In wide clefts, one may have to extend the incision around the alar base for the Advancement (A) Flap to advance over to meet the R-flap—see black arrow in Figure 10. **Cleft lip repairs in western texts now encourage the surgeon not to incise around the alar base, but where there is no pre-surgical orthodontic care, the complete cleft lip is often still very wide and requires the extension of this incision around the alar base in Millard repairs**.

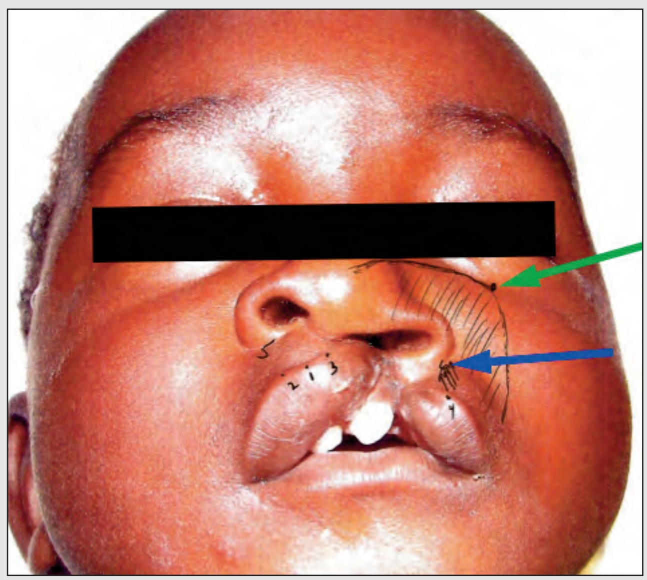


Fig. 11

Blue arrow shows the where the abnormal orbicularis muscle must be divided as it extends up to the alar base.

The shaded area shows the area that requires undermining down to the periosteum.

Green arrow points to area of infraorbital nerve.

Fig. 12

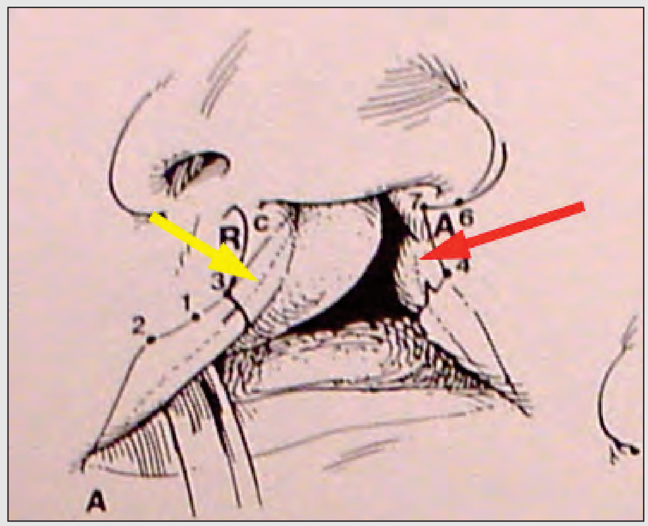


Fig. 13

(Original illustration, *Grabb and Smith Plastic Surgery*, Fig. 9-7, page 280, courtesy of Lippincott Williams Wilkins.)

Whether or not this incision is carried around the alar base as shown in incomplete clefts, it is still very important that the abnormal orbicularis muscle that extends up to the alar base (at #6) on the cleft side is divided.

An incision is also made in the buccal sulcus beneath the Advancement flap so that the entire flap and lateral cheek musculature may be elevated off the periosteum and up to the inferior orbital nerve.

The alar base is then elevated with a skin hook and the alar base dissected free from the underlying maxilla as is seen in Fig. 12. The dissection is carried above the periosteum up to the infraorbital nerve.

The mucosal pairings along the cleft side of the defect (along the advancement flap) are incised in such a way that a vermillion flap is created based along the alveolar ridge. This is the Lateral (L) Flap, (red arrow in Fig. 13). As one incises from #4 to #7 along the vermillion border, the incision can extend past #7 up into the nose along the mucocutaneous line in complete clefts. This allows elevation of the medial aspect of the alar base so that the floor of the nose maybe closed. The L-flap may later be turned up and over (mucosal side down) into the floor of the nose. See Fig. 13 for an outline of L and Medial (M) flaps.

The Columella (C) Flap is the tissue remaining on the cleft side of the rotation flap and under the columella (see "C" in Fig. 13). A double hook is placed in the nose on each side of the columella to elevate the nose, and the C-flap is rotated into the columella to lengthen it on the cleft side. The remaining C-flap can be used to fill the defect left by the downward rotation of the R-flap. **The C-flap may have two functions: first to lengthen the columella and second to fill the defect left by the R-flap**. The mucosal pairings along the cleft border of the C-flap (the yellow arrow shown in Fig. 13) are incised in such a way that the base of the flap is the alveolar mucosa—this will be the M-flap. This flap is used to fill in the buccal mucosa deficiency at the frenulum. Also, the incision along the vermillion of the C-flap (the green line in Fig. 13) is extended in complete clefts up into the nose along the mucocutaneous line. This allows for reconstruction of the nasal floor with an approximation to the alar base.

The alar base is then elevated with a skin hook and dissected free from the underlying maxilla as is seen in Fig. 11 and Fig. 15. The dissection is carried above the periosteum up to the infraorbital nerve. In this way, the advancement flap is advanced into the defect left (see red arrow in Fig. 15) by rotating the rotation flap down so that the Cupid's bow is level or transverse.

The orbicularis muscle is then dissected free from the overlying skin and underlying mucosa on each side (again, see Fig. 15). There is a minimal dissection of 2-3 mm on the non-cleft side so that the philtral dimple is not disturbed. The dissection on the cleft side depends on the width of the defect. If an incomplete cleft, then the dissection needed is minimal. If the defect is wide and in an older child

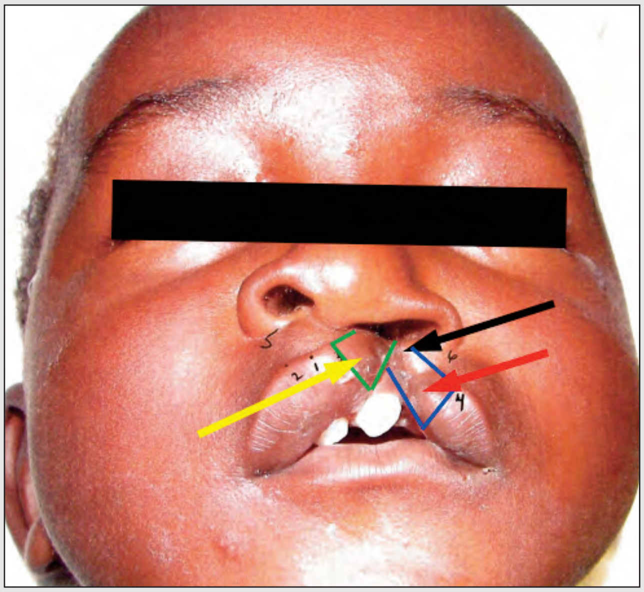


Fig. 14

This picture is just to show the mucosal pairings. This is an incomplete cleft lip and the lateral pairing, red arrow and outlined in blue is usually discarded. The medial pairing, yellow arrow and outlined in green may be preserved and used to fill in the mucosal deficiency after the frenulum is divided. It is outlined in green.

In this case, the tissue between these pairings and below the nostril sill is Simonart's band, black arrow, and is excised.

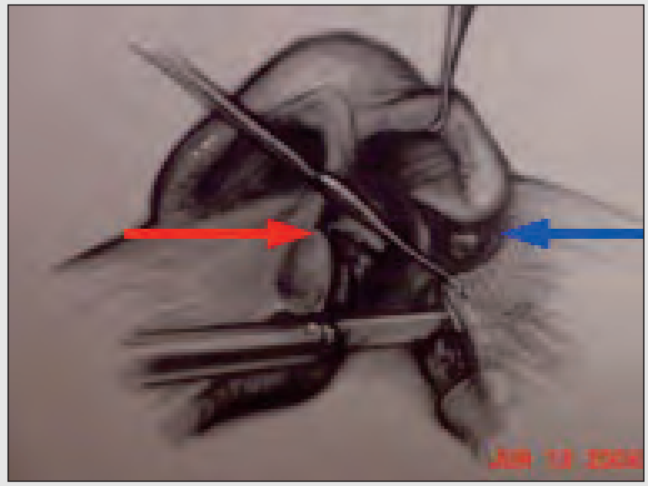


Fig. 15

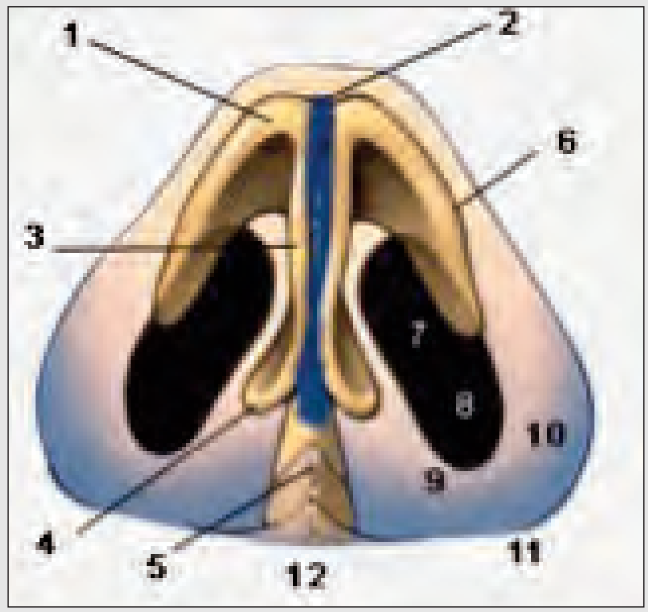


Fig. 16

The lower lateral cartilage (#6) is freed up from the overlying skin up to the dome. The medial cartilages, medial crura, (#3), are freed up to the dome. The two dissections meet at the dome, (#2). Sutures can be placed through the dome to elevate the dome and correct any asymmetry.

This is usually performed at the end of the case, when the lip has been repaired.

with a complete cleft lip, then 5-10 mm. of muscle must be dissected free.

It is important to understand that the buccal sulcus is incised under both the Rotation and Advancement flaps to allow rotation and advancement. The buccal sulcus is later closed at the beginning of the repair.

Nasal

In recent years early correction of the nasal deformity has been found to provide better results than delaying it until later in life. In Africa, early correction is best, since the patient may not return for later nasal repair. The alar base must be completely freed from the underlying periosteum of the maxilla and piriform rim (see Figs. 11 and 12). The lower lateral cartilage is carefully freed from the overlying skin up to the dome, from lateral to medial. The dissection begins at the cut edge of the alar base (as shown by the blue arrow in Fig. 15). Dissection in the midline is carried out between and over the medial crux (cartilages), and then over the dome cartilages. This dissection is begun at the junction of the R-flap with C-Flap (at the red arrow in Fig. 15).

Fig. 17

This shows the **key suture** from the advancement flap to the depths of the backcut.

(Original illustration, *Grabb and Smith Plastic Surgery*, Fig. 9-6, page 278, courtesy of Lippincott Williams Wilkins.)

This dissection is then carried up over the dome cartilages to meet the previous dissection over the lower lateral cartilages. Some will even free up the dome cartilages on the non-cleft side. Suspension sutures may later be used to hold the domes and lower lateral cartilages in position (see Fig. 18).

Reconstruction/Suturing

Suturing with absorbable material (chromic gut or polyglycolic acid) begins with the closure of buccal sulcus mucosa, since it is difficult to do later. This general principle of reconstruction is to close deep to superficial, or "inside to outside".

The columella on the cleft side is then lengthened by the advancement of the C-flap superiorly. Non-absorbable sutures are used to approximate the C-flap to the opposite side columella, and ends of suture left long so they can be easily removed. The remaining C-flap can then be used to fill the defect left by the back cut. Several sutures are needed (See arrow in Fig. 17).

A long lasting absorbable or non-absorbable suture is next used as a "cinch" suture. This may not be necessary for incomplete clefts. The suture is placed under the alar base on the cleft side, then in the midline beneath the columella, and then under the alar base on the non-cleft side. If properly placed, this suture brings the alar bases in proper alignment to the columella and at the same level. This suture is just tied down **loosely**, so as to bring the alar bases in alignment. **This is a KEY SUTURE**. It should not be tied down tightly, as this makes the nostril too small.

The orbicularis muscle is closed with 3-4 horizontal mattress sutures (3-0 Vicryl®; larger gauge sutures are used because of presumptive relative malnutrition in children in developing countries compared to smaller gauge sutures recommended in textbooks in the West), beginning above the back cut on the non-cleft side and above the tip of the A-flap on the cleft side.

A second muscle suture is placed inferiorly, approximating the muscles at the level of the vermillion to reconstruct the aesthetic fullness of the lip (and avoid notching). One to two more sutures are placed between these two to complete the muscle repair.

A deep dermal suture is placed from the tip of the advancement flap (#7) to a point at the end of the back cut (#8). **This is also a KEY SUTURE. (This is the loose suture illustrated in Fig. 17 that has not been tied down)**.

A subdermal suture is placed to approximate white roll precisely to avoid "step off" deformities of the vermillion. A few more subdermal sutures completes the closure.

Skin sutures of 5-0 or 6-0 nylon are then placed to close the lip and the vermillion.

In complete clefts, the nasal floor may be closed with absorbable sutures, and the lip mucosa is closed up to the buccal sulcus with small absorbable sutures.

If the patient is to be discharged soon after surgery, and if Fast Absorbing Plain Gut suture is available, then this suture may be used for all the skin sutures. Skin glue (Dermabond®), if available, may be used if the skin was well-approximated with the subdermal sutures.

The dome and stent sutures for correcting the nasal cartilages are not absolutely needed. One may contact the author for more information (See Fig. 18).

Remove throat pack and carefully suction throat.

Fig. 18

Showing elevation of domes to create symmetry. Never as perfect as one would like especially in wide clefts.

Sutures used in the repair

This depends on what is available

- Mucosa—Chromic or Vicryl® 4-0 to 6-0.
- Muscle/Deep dermal—Chromic, Vicryl®, PDS 4-0 or 5-0 or 3-0, see below.
- (If available, a 3-0 Vicryl® [polyglycolic acid] should be used for the muscle and especially in bilateral clefts. The nutritional status may be poor and a larger suture in the muscle may reduce the dehiscence risk).
- Subdermal/deep dermal—5-0 Monocryl® or Vicryl®
- Skin—5-0 or 6-0 Nylon/Fast absorbing Plain Gut.

Important Aspects of Nasal Repair

- Ideally, preoperatively, the patient wears an appliance, such as a Latham appliance, that approximates the alveolar ridges and also has an extension to mold the nose—this is often not available in Africa.
- Must have adequate undermining of cleft side alar base.
- Release lower lateral cartilages from overlying skin with fine scissors.
- Cinch suture to align alar bases and size of nostril—nonabsorbable suture (See below).
- Some use traction and bolster sutures to place nostril dome and lateral cartilages in proper position—this only good if left in 7-10 days with return visit unless one uses absorbable sutures. These are the **dome** sutures mentioned above (Please contact the author for more information).

Potential Problems

- Cupid's bow not level (transverse), and may lead to notching: **Reccomendation**—adequate back-cut of R-flap.
- Inadequate vermillion beneath Cupid's Bow on cleft side: **Reccomendation**—triangular vermillion flap from lateral lip on cleft side to augment vermillion.
- Large area left by back-cut that is difficult to fill by A-flap: **Reccomendation**—may use part of C-flap
- The incision around the alar base on cleft side leads to scarring: **Reccomendation**—one should limit the incision around the alar base, but in wide clefts these incisions will be necessary. Remember, in the West, appliances are used beginning at one month of age to approximate the alveolus and lip defect. This narrows the defect and a wide excision around the alar base is not necessary when lip surgery is done at three months.
- Throat pack NOT removed.

Potential Problems

- **Be sure the throad pack is removed.**
- Keep head elevated.
- Breastfeeding initiated immediately after the operation, as soon as the child is awake and alert.
- If the patient also has a cleft palate (and cannot generate suction for breast feeding), then resume pre-op feeding method (squeeze bottle, syringe, spoon, etc...).

- If non-absorbable sutures have been used, these are removed at five days, and skin glue applied.
- The patient should be followed so that a cleft palate, if present, can be repaired by 9-12 months.

Incomplete Cleft Lip

The incomplete cleft lip is repaired in the same way. The nasal deformity is often not as severe, but still requires the same dissection to obtain a good result in most cases. The nasal sill is intact, and it is elevated in continuity with the lateral alar base and over to the columella. It is carefully elevated off the periosteum, up to the piriform rim, without damaging the nasal mucosa. The skin, **below the nostril sill**, between the C-flap and A-flap, is not needed and can be excised. This is the Simonart's band (blue arrow in Fig. 19, black arrow in Fig 1). The width of the nostril sill on the cleft side will be slightly more than the non-cleft side. One can allow the extra tissue in the sill to fold up into the nasal floor or excise 1-2 mm. The author feels it best to do the former—do not excise tissue from the sill—as this extra tissue will settle in time with a good cosmetic result. If the tissue is removed, invariably after suturing there will be narrowing of the nostril.

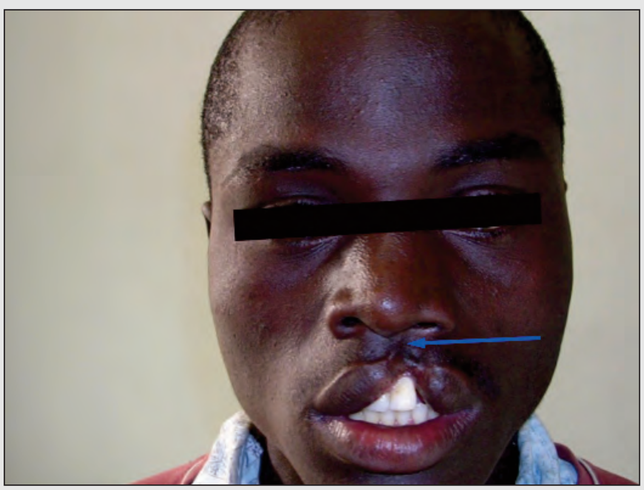


Fig. 19

Simonart's Band.

This is the tissue in the incomplete cleft lip thatis beneath the nostril sill, and will be excised in a Rotation-Advancement Repair.

Bilateral Cleft Lip

Bilateral cleft lips may be complete, incomplete, microform, or combinations of these. It is easy to miss a small microform cleft prior to surgery on what was thought to be a unilateral cleft lip (the "non-cleft" side actually being a microform cleft). The most important findings in a bilateral cleft lip are a protruding premaxilla and prolabium, and a very short columella. The premaxilla contains all the incisors. Also, feeding can be a very difficult problem as many of these infants will also have a cleft palate.

In Africa, patients with bilateral clefts may present late with **severe protrusion** of the premaxilla. These can be extremely difficult to treat. Without specialized skills and equipment, it is difficult to set the premaxilla back. Unfortunately, if the patient comes in late (2-3 years old or later), the palatal arches may have collapsed behind the premaxilla, making the setback impossible without orthodontic expansion of the palatal arches (or maxillary osteotomies).

If a baby is seen early with a severe protrusion, **pressure** may be placed on the prolabium with narrow tape across the prolabium and back to the ears. The parents can be given tape and shown how to apply it each day. **Slight pressure** for one month will do wonders if the infant is young, and future repair will be considerably easier. Anytime a child presents before two years of age, this is attempted, unless the palatal arches have closed behind the premaxilla. The older the child is, the less likely he/she will tolerate taping and the more likely the palatal arches will have collapsed. Other devices have been tried that put pressure on the prolabium and premaxilla. **All require the parents' understanding and daily adjustments**. An older child definitely requires orthodontic care to expand the arches to get a good result.

Lip adhesion operations have been used to narrow the defect in preparation for formal lip repair. This is accomplished by making mirror image "book flaps" (U shaped flaps in opposite directions) on the adjoining medial and lateral lip edges just below the nostril. The skin and mucosa flaps are approximated. (One may Google "Lip Adhesion Procedure" by Randall.) This procedure will prevent further widening of the cleft and protruding of the maxilla when one does not feel it is possible to formally close the lip primarily.

An osteotomy of the vomer has occasionally been used in severe late cases of bilateral complete clefts to setback the premaxilla. This has been accomplished either by gentle pressure on the

Fig. 20

Fig. 21

Fig. 22

Fig. 23

Bilateral Cleft Lip with excised prolabium and premaxilla. Reconstruction with Abbé Flap. LeFort procedure planned at 18 years old.

premaxilla (causing a green stick fracture) or by performing a subperiosteal dissection of the vomer with an osteotomy. This has the potential complication of damaging mid-facial growth and is not used in the West. On the other hand, the author has occasionally used this method in remote locations when there is no other way to set the premaxilla back posteriorly and level with the palatal arches. This can only be used when the palatal arches **have not collapsed**.

The premaxilla and/or prolabium should never be excised to close the lip. **On the other hand, in rare cases in very remote locations and far from an orthodontist, if the child is older and the palatal arches have collapsed** (making it impossible to push back the premaxilla level with the arches), the premaxilla has been excised. The prolabium is not excised but pushed up to lengthen the columella, and the lip is closed in a straight line. An Abbé flap (lower lip to upper lip switch flap) can be done later to give the child a near normal appearance. This is recommended only in the very unusual circumstances listed above.

(**Editor's note**: Wide bilateral clefts have always been repaired. If seen early in life when the palatal arches have not closed, then pressure with tape for one or more months over the prolabium has helped. The baby and mother have been admitted, and the nurses observe the mother applying the tape across the prolabium and back to the ears for several days. The mother is given appropriate narrow tape upon discharge. At surgery, if the premaxilla is still protruding and making closure difficult (and the palatal arches are not collapsed), then the surgeon/assistant should apply pressure with his finger/thumb over the prolabium while the flaps are being raised. The lateral lip elements are mobilized widely for closure. At this point of the operation, if closure still seems impossible, then additional pressure can be applied to the prolabium to produce a greenstick fracture of the vomer. This is rarely necessary. If the closure is still not possible, reluctantly one may perform a formal osteotomy of the vomer as described above to gain lip closure. This may interfere with midfacial growth. This can be corrected later in major centers with a LeFort I osteotomy.)

The following is a simplified description of the bilateral cleft lip repair from an early edition of Grabb and Smith's Plastic Surgery text. There are other methods, but this is one of the easiest to learn.

Markings

- 1 is at the midline of the Cupid's bow. 2 is the peak of Cupid's bow and measured distance from 1 based on usual anatomy. In an infant, it is 4-5 mm. The opposite cupid's bow peak is likewise marked along the vermillion border.
- 3 is at the base of the columella as is the contralateral marking.
- 4 is where the vermillion is fullest, and 6 is at the alar base along the vermillion border.

The distance from 5 to 6 should equal that from 2 to 3, and one would like for this distance to be 10 mm. Often 2 to 3 is short, and one may attempt to lengthen it **by curving the incision from 2 to 3 or**

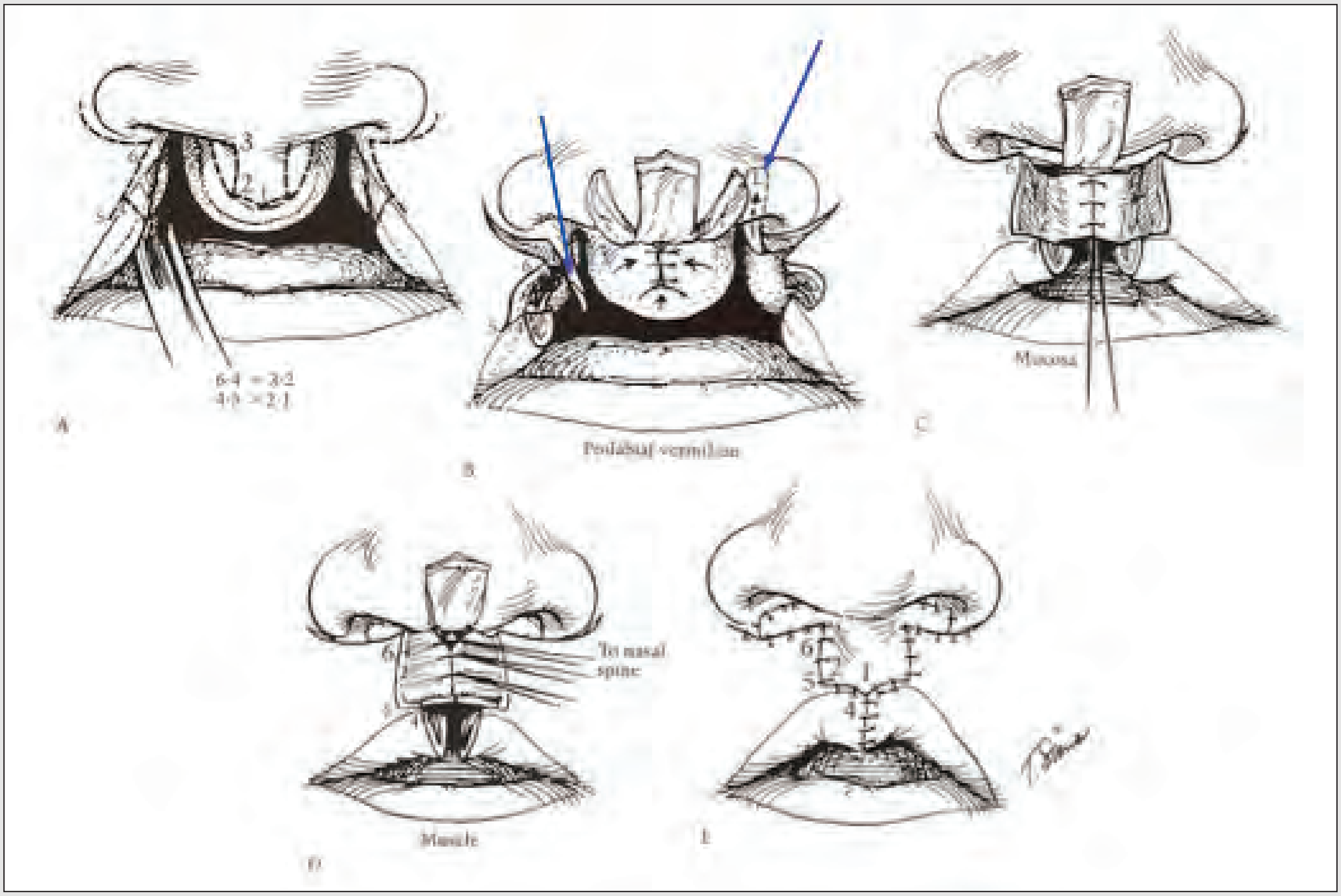


Fig. 24

(Original illustration, *Grabb and Smith Plastic Surgery*, Fig. 9-11, page 283, courtesy of Lippincott Williams Wilkins.)

extending 3 up inside nose on each side. If 5 to 6 is longer than 10 mm., shortening may be carried out later when closing. The incision from 4 to 5 is taken 1-2 mm. above the vermillion border or white roll. **This will also lengthen the distance to the peak of cupid's bow**, once these flaps have been rotated in.

So, the distance from 2 to 3 will always be short, but it can be lengthened 3 ways:

- **Slightly curved incision from 2 to 3.**
- **Place 3 up inside the nostril along above the columella.**
- **With the extra 1-2 mm from 4 to 5.**
- The distance from 4 to 5 on each side should be approximately equal to the width from 1 to 2. 4 and 1 will come together in the midline of the repair/midline of Cupid's bow (Same for the opposite side).
- The C-flaps are seen in Fig. 24. These are often very small. If large they can help create the nostril floor at the sill.

Incisions

- Usually, the prolabium incisions are made first. Incisions 1 to 2 and 2 to 3 are made down to the premaxilla, and the prolabium dissected off the premaxilla as shown in diagram B of Fig. 24. The vermillion left after the C-flaps have been raised is used to close over the raw surface of the premaxilla.
- The incisions along the vermillion can be continued up into the nose along the mucocutaneous line. This will provide medial skin edges to close the nasal floor.
- The lateral incisions for the A-flaps are made bilateral from 4 to 6, and then around the alar base as needed. These incisions are carried down to 5, so that the vermillion from 4 to 5 can be used to recreate Cupid's bow and midline vermillion. It is important to incise the muscle attachments to the alar base.
- The incision from 4-6 should be extended up into the nostril along the mucocutaneous line, so

that the alar bases can be elevated off the periosteum and piriform rims and up to the infraorbital nerves on each side. This will allow advancement of the alar bases and closure of the nasal floor on each side.

- The orbicularis is dissected free as described for a unilateral cleft. On wide clefts 10 mm. may be freed on each side. There is no muscle beneath the prolabium, so the lateral orbicularis muscles are brought together in the midline.
- The freed mucosa is also brought to the midline and sutured for lip mucosa.

Fig. 25

Fig. 26

The distance between the philtrum columns is wide. This will be narrowed in the second stage repair when some of this tissue will be used to lengthen the columella.

- The lateral mucosal parings off of the advancement flaps, as L-flaps in the unilateral lip and shown with blue arrows in diagram B of Fig. 24, are turned over with the mucosal surface used for buccal mucosal lining in the floor of the nose if needed.

Closure

- The mucosa of the A-flaps is then sutured in the midline as shown in C.
- The muscle is then approximated with 3-4 sutures. The superior suture is also sutured to the nasal spine to suspend the lip.
- The prolabium is then sutured to the vermillion portions of the A-flaps to reconstruct Cupid's bow. (**1 is sutured to 4 and 2 is sutured to 5 bilaterally.**) These key sutures in the midline, and from 2 to 5 on either side, are placed with deep dermal absorbable sutures or even small nylon sutures. Skin sutures are placed in the midline vermillion—usually a small nylon suture.
- The L-flaps are then advanced to the prolabium. Often, the height of the A-flaps is greater than 2 to 3, and a wedge of tissue on each flap is removed for symmetry.
- The C-flaps are then rotated to fill in the nasal floor and nostril sill.

Post-operative Care

- Similar to that for the unilateral cleft.
- Lengthening the columella will be needed in most cases of bilateral cleft lip. Note wide philtrum in Fig. 26 post-op picture. This may be narrowed and the columella lengthened at a later operation when the child is older. For details of cleft rhinoplasties, a plastic surgery text should be referenced and/or the author contacted.

Chapter 15
Cleft Palate Repair

Paul Lim

Introduction

Major surgical textbooks describe cleft palate repair in great detail. The aim here is to describe standard techniques with reproducible outcomes which general surgeons can carry out in the setting of sufficient anesthesia expertise, required surgical instruments, and satisfactory nursing expertise for post-operative care.

Adequate anesthesia requires a practitioner experienced and equipped with general endotracheal anesthesia, pulse oximetry, and, ideally, end-title CO2 monitoring. The **most important instrument** is the Dingman mouth retractor (gag). This requires either an oral RAE endotracheal tube (short tube with a sharp angle to fit under the retractor) or a wire reinforced endotracheal tube which remains patent despite the bend caused by the retractor.

Since the surgery is carried out in a deep and narrow "hole" (an infant's oral cavity) and not on the surface, **forceps and scissors must be 7-8 inches long**. Although a Freer elevator may be used for the entire operation, a sturdy elevator as a Woodson or an Obwegeser is helpful to perform the mucoperiosteal elevation of the palatal mucosa. Right angle elevators are best to elevate the nasal mucosa from the nasal side of the hard palate. Fine toothed pickups 7-8 inches long are ideal for the procedure.

Post-operative care is best carried out in a small ICU or in a ward where experienced nurses with cardio-respiratory monitors and suction machines are available for the first 24 hours. **Speech-language pathology** evaluation is worthwhile after all palate repairs if available, as some of these children would benefit from speech therapy. The best outcomes for speech occur with a technically good repair done when the patient is between 9-18 months old; the outcomes diminish the older patient is at the time of surgery.

Though conceptually simpler than cleft lip repairs, cleft palate repairs are more technically challenging and require more sophisticated anesthesia, surgical expertise, and nursing care as described above. Because of the relative ease in repairing a lip (an un-aesthetic result takes no great surgical skill) with far fewer resources required, often cleft lips are repaired and the cleft palate forgotten until the child is noticed to have unintelligible speech—perhaps at school age. The cleft lip carries with it significant visible stigma, whereas the unnoticed cleft palate causes little concern and social shame for the parents other than the feeding difficulties and regurgitation of food through the nose. Furthermore, even a poorly repaired cleft lip can significantly improve a patient's appearance compared to an unrepaired deformity. A poorly done cleft palate repair, however, may leave the patient in a worse condition than having no repair at all. Simply put and important to remember: ***a bad lip repair is usually better than no lip repair, but a bad palate repair is always worse than no palate repair.***

This chapter will deal with the practical aspects of cleft palate care and one standard method of repair. A popular repair of the soft palate in the past 20 years has been the Furlow double opposing Z-plasty repair. This repair is not recommended in this chapter due to the complexity of the repair and the high fistula rate. Acellular dermal matrix has been used to replace nasal lining when it is difficult to approximate these Z-plasty flaps in the Furlow or other repairs—its use is controversial and is outside the scope of this text.

Initial Treatment and Pre-operative Assessment

Many children will have a cleft lip and a cleft palate concomitantly—see chapter 14 on Cleft Lip. If the patient presents young, the lip repair can be performed at 3-4 months and the palate at 9-12 months. If the child presents at 1 year of age or older, the palate repair should be performed first, or together with the lip repair if he is a satisfactory candidate for the extended operative time. As discussed below, the palate should be performed before the child is a year old to give the child the best chance for normal speech. After 2 years of age, cleft palate repair will decrease reflux of liquids and food into the nose, but will have less effect on speech. The remainder of this chapter will deal with the cleft palate alone.

Initial Problem: A neonate with cleft palate in the developing world has a life-threatening problem due to the child's inability to breast-feed. The primary intervention at this stage is to teach the caregiver how to feed the child. With a cleft palate, the child cannot generate suction and what breast milk enters the mouth easily refluxes into the nose. Careful spoon-feeding is an option when baby bottles are not available. This should be done when the child is upright and not lying down. Once the milk reaches the back of the throat, the child will swallow normally. It is important the child is fed breast milk. Since the child cannot generate suction there will be inadequate stimulation to continue milk production. The mother should regularly massage her breasts and capture the milk in a clean container, and then immediately feed her child with a spoon, syringe, or cup (Expressed Breast Milk—EBM).

Unfortunately, many of these children will die of dehydration or malnutrition since they will not have access to a medical facility. However, some do survive this neonatal period and will present later in life with their parents seeking treatment for their cleft palate. Since the cleft palate is not noticed by those outside the immediate family, the children with an isolated palate are often brought late to the hospital. Most of these patients present with some degree of malnutrition and may need a period of nutritional support before undergoing surgery.

As with any patient being evaluated for potential surgery, a thorough history and physical examination must be performed. Some important points of which to be wary (in addition to a standard, complete evaluation) are:

History
- Isolated cleft palates are associated with many syndromes, so a thorough family history is important.

Physical examination
- Cardiac murmur: An isolated cleft palate has a higher association with cardiac anomalies; also, valvular disorders are common due to rheumatic heart disease secondary to streptococcal infections.
- Neurologic: If the patient has a neurogenic speech deficit, then the palate should not be repaired, as there will be no benefit from the operation.
- Wide, arching, cleft palates as in Pierre-Robin sequence, though "incomplete" maybe very difficult to close unless the surgeon is experienced at CP repairs.

Laboratory
- All patients should have their hemoglobin levels measured. Most will have iron-deficient anemia. They should be treated with oral iron supplements as well as nutritional support and parental education (meats and vegetables high in iron). Cleft palate repair is contraindicated if the Hgb < 10 gm/dl as there can be substantial intra-operative blood loss.
- Malaria smear: If positive on an asymptomatic patient, delay surgery until after the treatment course is complete. If febrile/symptomatic, treat the malaria and delay surgery for a few months to allow recuperation and anemia resolution.
- Any patient who is old enough to crawl or is ingesting anything but breast milk is assumed to have intestinal worms and will likely be malnourished. So, these patients (the vast majority) are treated with albendazole (for the worms) and multivitamins before surgery.

Goals of Cleft Palate Repair

Restore velopharyngeal competence. The primary goal is to allow the patient to speak intelligibly by reconstructing the palate to its normal mechanics. The palate functions to regulate the air and sounds projecting through the nose and mouth. The hard palate is a static, fixed barrier between the nasal cavity and oral cavity, whereas the soft palate is a dynamic structure that adjusts airflow from the pharynx out through the nose. When the palate is cleft, the patient has no way to regulate the air/sound flow so has great difficulty generating intelligible speech. This mechanical disability is called **velopharyngeal insufficiency (VPI)**. Cleft palate is not the only cause of this disability, but it always has this as a feature. The resulting speech disorder is called **hypernasal** speech (if instead of too much sound coming out of the nose, a person had too little sound coming out the nose, such as with an upper respiratory infection causing nasal occlusion, the speech would be called **hyponasal**).

Though patients with cleft palate typically have normal mental capacity, they are thought to be unintelligent. Being effectively mute is a substantial social disability which prevents the patient from going to school or gaining employment. This is not only a quality of life problem but, in the developing world where there are few welfare programs or social "safety nets", it is potentially a quantity of life problem.

Restore separation of oral and nasal cavities for improved feeding. This is not a primary goal but a secondary benefit to the cleft palate repair. The patients with cleft palate are able to eat. Having an intact hard palate, however, will prevent passage of food and liquids that irritate the nasal mucosa, and will improve social interaction by removing the stigma of food or liquid draining from the nose.

Restore eustachian tube function: Although a cleft palate causes dysfunction in eustachian tube drainage, the repair does not restore this function. There is active research in this area (reconstructing the tensor veli palatini muscle), but the current standard treatment for middle ear disease in children with cleft palate is placement of pressure equalizer (PE) tubes. A description of this operation is outside the scope of this text. It is a straightforward procedure but requires specialized equipment, optical magnification, and instrumentation. Learning this procedure from a visiting ENT surgeon (who would also need to bring the instrumentation) can make a substantial difference in these patients' lives, particularly if the middle ear disease is treated early (before speech development). Children with cleft palates have very poor hearing, which compounds their already substantial speaking difficulties, as it is very difficult to learn to speak when one cannot hear (a significant component of speech development is mimicking speech heard).

Timing of Repair

- Ideal age of patient at time of repair: **9 months to 18 months of age**. The earlier the repair, the better speech the child will have especially where speech therapists are unavailable, but the earlier the repair the more likely there may be impairment of facial growth. The later the repair, as in 18-24 months, there will be less impairment of facial growth, but greater speech impairment with less chance for good speech acquisition.

- In addition, there is a balance between anesthesia risks, speech acquisition and facial growth impairment.

- Early surgery, 9-12 months: better speech acquisition, more anesthesia risks and greater chance for midfacial growth impairment; if excellent anesthesia and surgical expertise is available, then this is the preferred age of repair (standard of care at U.S. cleft centers); 12-18 months of age is acceptable.

- Later surgery, 18-24 months: poor speech acquisition, fewer anesthesia risks and less chance for mid-facial growth impairment.

- Older children (> 18 months): There is progressively less speech benefit with the repair, but there is still the secondary benefit of preventing nasal regurgitation. So, as long as the repair can be done safely and well, it is still indicated in older children.

- Adults. It must be clear to the patient that there is very little probability of speech improvement with a primary cleft palate repair in adulthood. So, the main goal of surgery for adults is to prevent nasal regurgitation. The judgment for recommending surgery must be balanced with the patient's medical fitness and other peri-operative risks, for instance, venous thromboembolism (which is very rare in children).

Contraindications for Cleft Palate Repair: Patient Qualities

- **Anemia**. Hemoglobin < 10 gm/dl.

- **Asymptomatic, untreated malaria**. Refer to "laboratory" section above.

- **Malnutrition**. This is all too prevalent in developing countries, but children with cleft palates are at particular increased risk.

- **Central neurologic disorder that prevents speech**. Since the primary goal for the repair is speech, the operation should not be done if the patient has a CNS origin of aphasia.

- **Upper respiratory infections**. Peri-operative airway edema may make a URI a life-threatening complication in this elective operation.

- **Pierre Robin Sequence** is a relative contraindication. The palate is often arched and difficult to repair by the occasional cleft palate surgeon.

- **Advanced age**. If the patient is physiologically advanced in age (nearing the end of his life), the risks of cleft palate are increased and the benefits are reduced (years of nasal regurgitation-free life). Life expectancies vary in different regions and chronologic age does not always correlate with physiologic age. Also, it has been observed in Ethiopia that the older the patient and the more rural of an area the patient resided in, the more likely he/she was unsure of his age. So, with older adults, chronologic or stated age is dubious at best. For that reason, there is no strict age cut-off for cleft palate repair.

- **Other medical problems** conferring prohibitive risk such as cardiomyopathies.

Contraindications for Cleft Palate Repair: Institutional Qualities

- **Inexperienced surgeon**. Cleft palate surgery is significantly more difficult than cleft lip surgery and, as mentioned above, **a poor cleft palate repair will result in a worse outcome than the original defect** (scarred tissue in addition to the original VPI and oral-nasal fistula).

- **Inexperienced or ill-equipped anesthesia providers**. If cleft palate repair is going to be performed in the ideal age group (9 – 18 months old), well-equipped and experienced pediatric anesthesia providers are necessary.

- **Lack of anesthesia and surgical equipment** as mentioned earlier. Once again, an honest, thoughtful, critical appraisal of skills, training, and equipment must be done by the anesthesia provider in consultation with the surgeon to discuss particular airway issues with cleft palate surgery before deciding the absolute or relative contraindications to surgery from an anesthesia perspective.

- **Ideally the anesthesia provider will be able to monitor end tidal CO_2. This will not be possible in many district hospitals. If this is not available, the surgeon must be certain the O_2 saturation is near 100% before beginning surgery. An O_2 concentration of 90% is not adequate and may indicate there is esophageal intubation and not oral intubation. Any unstable O_2 saturation indicates the same—possible esophageal intubation. Surgery must not be started unless the O_2 saturation is near 100% and stable. Never use the excuse that the O_2 saturation is low because of high altitude conditions. Assume an esophageal intubation until proven otherwise. Infants will go in to cardiac arrest quickly in such situations.**

- **Inadequate post-operative nursing care or equipment**. Similar to anesthesia infrastructure, the appropriate level of expertise is tiered based on the age of the patient. Pulse oximetry, monitors, and suction machines that work are always necessary.

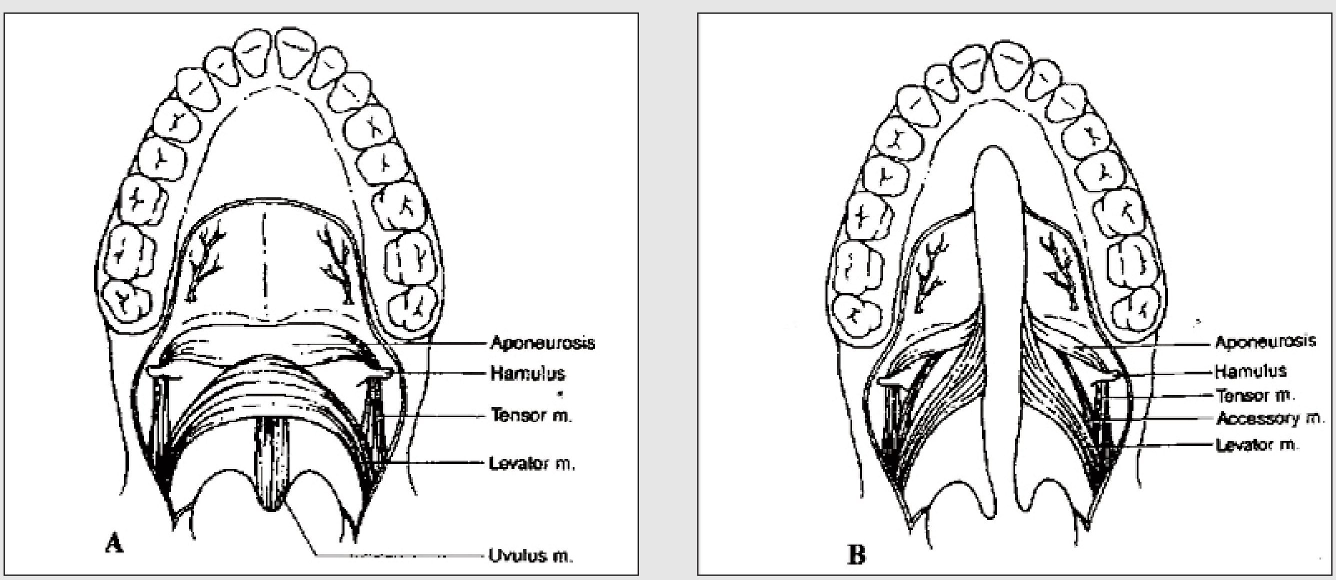


Fig. I

Normal palate (A) and cleft palate (B) anatomy.

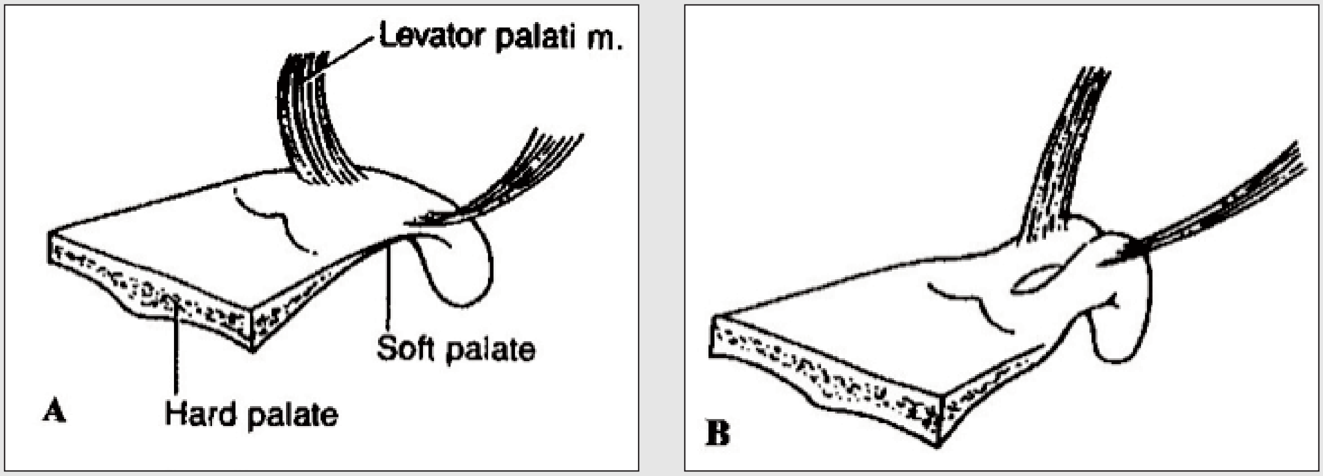


Fig. 2

Normal (A) and cleft (B) levator sling mechanics.

Operative Technique and Peri-operative Care

Anatomy

Fig. 1 shows the surgically relevant anatomy of the hard and soft palate. The hard palate mucoperiosteal flaps are axial flaps based on the greater palatine vessels on either side of the posterior aspect of the hard palate (the only blood vessels depicted in the illustrations). In Fig. 1B, the levator veli palatini (LVP) muscles do not form a sling but insert into the hard palate in a cleft palate. The levator veli palatini (LVP) muscle must be reconstructed to restore the sling effect that regulates air and sound flow to the nose from the larynx. The normal sling mechanics are depicted in Figure 2.

Pre-operative Care

All patients are admitted to the hospital ward the day before their scheduled operation to obtain blood work, to be bathed (at least once on the day before surgery and for a face wash on the day of surgery), and, **most importantly, to ensure fasting status** to reduce the risk of aspiration during anesthesia induction. Fig. 3 shows the standard pre-operative orders form developed for the CURE Ethiopia Children's Hospital (CECH). Pre-printed order sets are very helpful in reducing communication errors, compared to relying on hand-written orders that may be illegible to the nursing staff. Also, it acts as a reminder checklist to reduce the risk of forgetting important orders. The order sets should be tailored to the resources and infrastructure available locally.

Classification of Cleft Palate Deformities

- Unilateral CP—vomer attached to palate on the non-cleft side.
- Bilateral CP—vomer is not attached to the palate.
- Soft palate cleft—vomer is normal and not involved.
- Submucous cleft palate—includes a bifid uvula, notching of hard palate, diastasis of soft palate musculature, possible speech impairment.

Routine Preparation for All Palate Cases

- Prophylactic antibiotics: 3rd generation cephalosporin IV or amoxicillin/clavulanic acid IV infused within 1 hour before incision made.
- Local anesthesia for both anesthesia and vasoconstriction for control of bleeding. Use 0.5 % Lidocaine with epinephrine (1:200,000). **Maximum dosage is 1ml/kg of body weight**. Ideally wait 7 minutes before starting surgery to allow maximum vasoconstriction (**1 ml of ½% Lidocaine with epinephrine = 5 mg., so this is well-within safe dosage**).
- Tube myringotomies can be performed if expertise is available.
- Throat pack.

Repair of Unilateral Complete Cleft Palate: Bardach Two-flap Palatoplasty

This is the **single best** repair to know for cleft palate repair started (before incision made).

1 Incision in the palate as in Fig. 4A: Along the alveolus, the incisions can be made with a needle tip cautery using low power coagulation.

CURE Ethiopia Children's Hospital

patient name sticker

cure INTERNATIONAL

Physician Orders: Plastic Surgery Elective Admission

Admit Date: date:______/ month:_______/ year: 201___ **Admit to:** ❑ ward ❑ ICU ❑ lodge ❑

Primary Dx: ❑ ________________________________ **Activity:** ❑ ad lib
❑ ____________________________________

Nursing:
❑ vital signs – on admission then qday ____
❑ bathe / shower patient on admission
❑ wash: face/ ________________ on AM of scheduled surgery
❑ enourage bladder/bowel emptying prior to transport to OR on day of scheduled surgery
❑ ____

Diet:
❑ age appropriate, general diet
❑ other:____

Alerts:
❑ notify H.O. for Temp > 38.0°C axillary
❑ notify H.O. for ____

I/O: ❑ monitor and record intakes & outputs – ___________________________

Consult: ❑ pediatrics ❑ lactation ❑ speech-language pathology ❑ physical therapy ❑ _______________________

Labs: ❑ Hgb/Hct/Plt ❑ HIV ❑ HBV ❑ pregnancy test ❑ malaria smear (q12h x 3 if from endemic region) ❑ sickle cell test
❑ u/a ❑ _______________

Xray: ❑ CXR ❑ PA/Lat ❑ PA ❑ AP
❑ ____

Other:
❑ ____
❑ ____

ALLERGIES/SENSITIVITIES: ❑ none
Med:____________________________________ Dietary:_______________ Enviromental:____________

Medications:
❑ albendazole _______ mg PO _________ (peds: <10 kg 200mg; >10 kg 400mg; adult: 400mg)
❑ Vitamin K _______ mg IM ___________ (peds: <20kg 5mg; >20kg 10mg; adult: 10mg)
❑ multivitamin syrup _______ ml PO q day (< 6mos/o: 1 ml; 6mo – 3y: 2.5 ml; 4y – 6y: 4ml; 7y – 10y: 5 ml)
❑ multivitamin tablet 1 PO q day (> 10yrs/old: 1 po qd)
❑ ____
❑ ____
❑ ____

Date: _____/_____/ **20**___ **Time:** _______**h** **Signature:**________________________ **print name:**__________________

Fig. 3

Pre-operative orders.

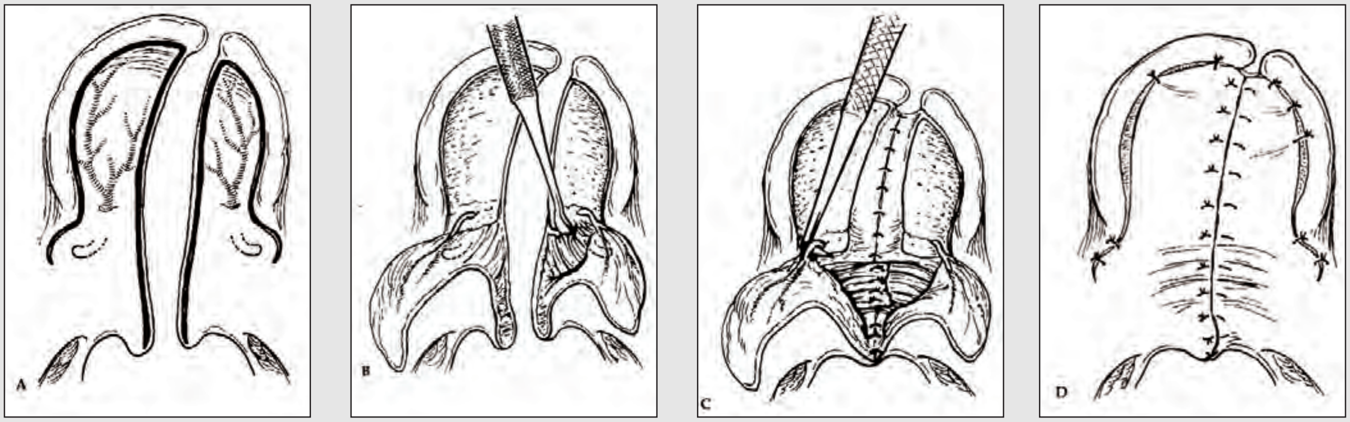


Fig. 4

From Diagnosis and Treatment of Cleft Lip and Palate Deformities, Sykes, J. in *Facial Plastic and Reconstructive Surgery*, Thieme. Used by permission.

2 Elevate the oral mucoperiosteum with a sturdy periosteal elevator. Care must be taken posteriorly and laterally to preserve the greater palatine vessels. These vessels must be completely freed up and, if necessary, they can be skeletonized up into the flap. A Freer elevator can be used along the medial and posterior edges of the palate and a fine right angle elevator may be used to dissect off the nasal mucosa and around the pedicle. **(All the instruments used are shown in Fig. 11 at the end of this chapter.)**

3 Elevate the soft palate mucosal flap with fine dissection off the palatal muscles. Err on the side of leaving some muscle on the flap rather than perforating the mucosal flap. However, if too much muscle is taken, then it will be inadequate to reconstruct the levator sling.

4 Complete the dissection and elevation of the Levator (LVP) muscle with fine dissection scissors. This includes dissection off the abnormal attachments to the posterior aspect of the hard palate and the attachments to the nasal soft palate mucosa.5. Nasal hard palate mucosal flaps are elevated with a fine right angle elevator. The dissection off the hard palate shelf is particularly difficult, since it is a partially blind dissection which must be done by feel. The elevator head must stay right on the contour of the bone or the mucosa will perforate.

5 On the medial cleft side (vomer side), the flap is raised off the vomer to reach the opposite side for nasal closure.

6 After dissection from the palate, the lateral nasal mucosal flap should be advanced to determine if the flap edge will reach the vomer side nasal flap at the level of the hard-soft palate junction. If not, then a **relaxing incision** should be made at the lateral cleft side nasal mucosal flap to achieve a tension-free repair. This longitudinal (parasagittal plane) incision through the nasal mucosa is **made laterally posterior to the greater palatine vessels. See Fig. 5.**

(**Editor's Note**: One must get a tension-free closure of the mucosa, especially at the junction of the hard and soft palate. This is an excellent suggestion. These incisions are made as far laterally as possible in the nasal mucosa.)

7 Nasal mucosal closure: use 3-0 or 4-0 chromic or Vicryl® on a small round needle (RB-1 or smaller) placing inverted, simple, interrupted sutures, hand tied knots starting anteriorly and progressing posteriorly, finishing the nasal side row at the uvula with a horizontal mattress suture (to reconstruct the uvula).

(**Editor's note:** Not everyone will have the exact sutures as described, so you will have to use the needle and suture closest to what is given.)

8 Levator (LVP) reconstruction: use 3-0 Chromic or Vicryl® on a small round needle (SH-1), placing a single figure of 8 suture to approximate the muscle in the midline (typically, >2 cm posterior to the hard palate).

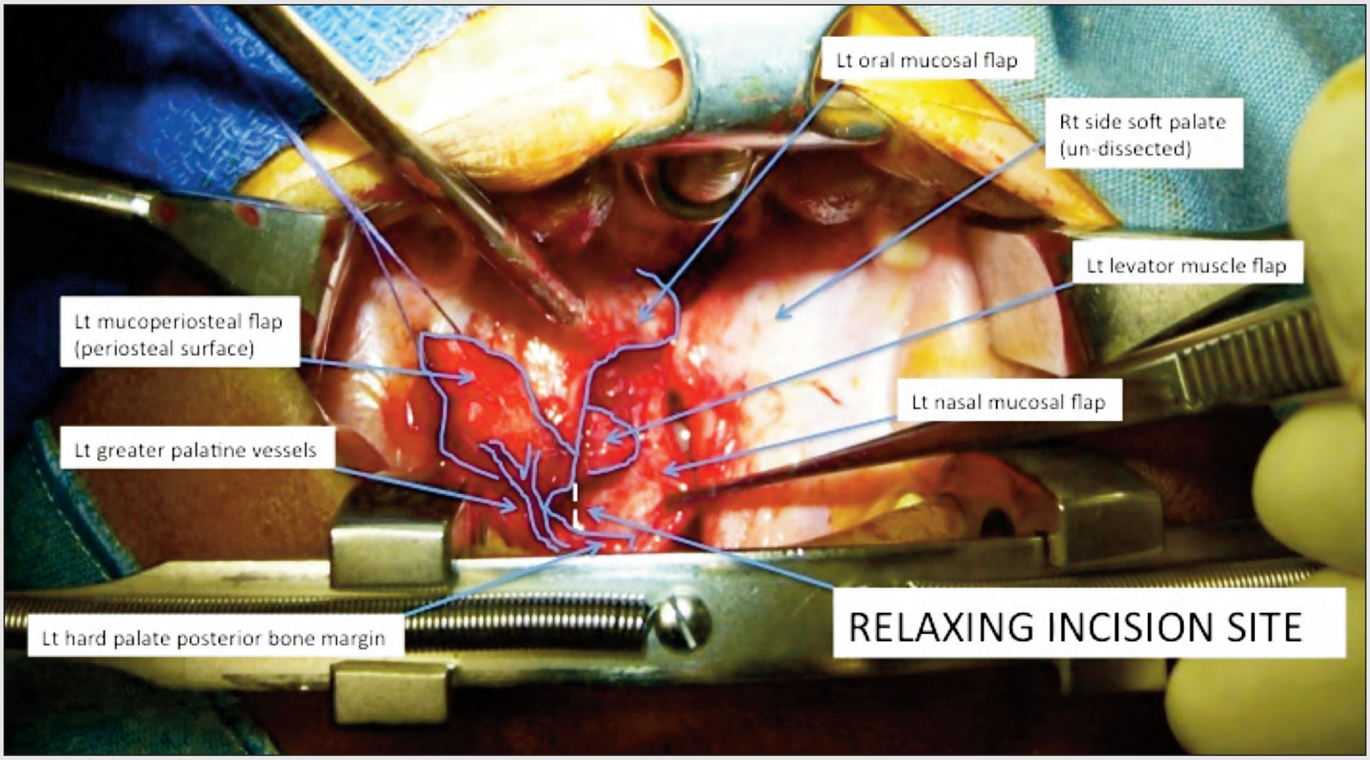


Fig. 5

Left unilateral cleft palate with left side flaps dissected. Relaxing incision site indicated for illustration purposes. Tension-free repair is easily achievable in this case, so a relaxing incision is not necessary. **Please see attached video at the end of the chapter.**

9 Closure of the mucoperiosteal flaps will be with 3-0 chromic or Vicryl® with RB-1 or PS-4C needles placing interrupted horizontal mattress or simple sutures. For the soft palate mucosal closure, a round needle (RB-1 or SH-1) is used, similarly placing simple or horizontal mattress sutures. It is important that before closure of the mucoperiosteal flaps, any bleeding is controlled. Cauterization along the edges of the flaps is important.

10 Start anteriorly, aligning the tips to position the flaps in the most favorable position to maximize cleft closure. The non-cleft side flap is typically longer than the cleft side, so the tips will be approximated with some offset. Tighten the mucoperiosteal retracting sutures after the first anterior suture is placed to facilitate suture placement. Complete the rest of the midline closure.

11 Then several simple or mattress sutures can be placed on either side to loosely approximate the mucoperiosteal flaps to the alveolar mucosa. These suspension sutures should be loosely placed as to not cause tension at the midline. See Fig. 4D.

12 **Remove throat pack**. Suction the naso-and oro-pharynx and pass soft catheter in to stomach to suction out stomach.

Bilateral Complete Cleft Palate Repair: Bardach Two-flap Palatoplasty with Vomer Flaps

The technique is similar to the unilateral repair except for the addition of vomer flaps, an additional row of sutures to place, and a few modifications.

1 Lidocaine with epinephrine should be injected into mucosa of the vomer in the subperiosteal layer as much as possible.

2 Vomer flaps: a No.15 blade scalpel is used to incise the vomer mucosa in the midline starting from just posterior to the level of the hard/soft palate junction and extending anteriorly to the pre-maxilla where a "Y" type extension is made avoiding the alveolus (see Fig. 5A). The Freer elevator is used to elevate vomer flaps on each

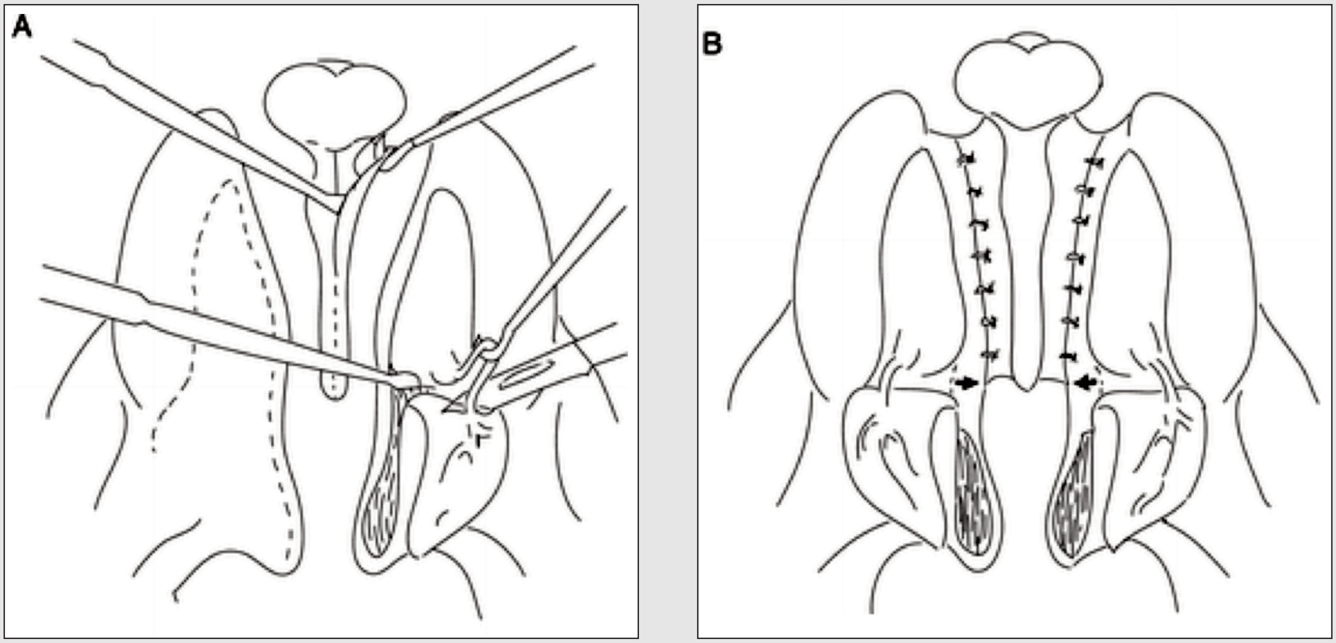


Fig. 6

Bilateral complete cleft palate repair.
(Cleft Palate-Craniofacial Journal, May 2011, Vol. 48, No. 3, Losken, H. Wolfgang. Used by permission.)

side so that they will reach the lateral nasal mucosa flaps.

3 After dissection from the palate, the nasal mucosal flaps should be advanced to determine if the flap edges will reach the corresponding vomer flaps at the level of the hard-soft palate junction. If not, then **relaxing incisions** should be made at one or both sides to achieve a tension-free repair. These longitudinal (parasagittal plane) incisions through the nasal mucosa are **made laterally posterior to the greater palatine vessels**. See small arrows in Fig. 6B; also Fig. 5. (**Editor's Note**: One must get a tension-free closure of the mucosa and especially at the junction of the hard and soft palate. This is an excellent suggestion. These incisions are made as far laterally as possible in the nasal mucosa.) **Please see attached video at the end of the chapter**.

4 Nasal mucosal closure: use 3-0 or 4-0 chromic or Vicryl® on a small round needle (RB-1 or smaller) placing inverted, simple interrupted sutures, hand tied knots starting anteriorly on each side, approximating the nasal mucosal flap to the vomer flap, and progressing posteriorly to the level of the hard/soft palate junction. The nasal mucosal flaps are then approximated in the midline starting where the vomer flaps end, finishing the nasal side row at the uvula with a horizontal mattress suture (to reconstruct the uvula).

(**Editor's Note**: Since some hospitals have a limited amount of suture material, some will have to instrument tie some of these sutures but it is important to hand tie the first 2-3. Also some surgeons carefully run these sutures in order to conserve suture material.)

5 Levator (LVP) reconstruction: use 3-0 or 4-0 chromic or Vicryl® on a small round needle (SH-1) placing a single figure of 8 suture to approximate the muscle in the midline (typically, >2 cm posterior to the hard palate).

6 Oral side closure: detach the mucoperiosteal retracting sutures from the Dingman suture holders (springs) on the maxillary side, and re-attach toward the midline to bring the mucoperiosteal flaps in closer approximation, but with some slack in the sutures.

7 Closure of the mucoperiosteal flaps will be with 3-0 or 4-0 chromic or Vicryl® with RB-1 or PS-4C needles placing interrupted simple or

horizontal mattress sutures. For the soft palate mucosal closure, a round needle (RB-1 or SH-1) is used, similarly placing horizontal mattress sutures.

8 Start anteriorly and align the tips to position the flaps in the most favorable position to maximize cleft closure.

9 Sutures can be used to tack the flaps anteriorly to the alveolar mucosa of the pre-maxilla (a single horizontal mattress suture incorporating the tips of both flaps). Several other simple or mattress sutures can be placed on either side to loosely approximate the mucoperiosteal flaps to the alveolar mucosa. These suspension sutures should be loosely placed as to not cause tension at the midline.

10 It is very important to ensure that there is no bleeding at the end of the case.

11 Suction naso- and oro-pharynx and pass soft catheter into stomach to suction out stomach.

Repair of Incomplete Cleft Palate: Veau-Wardill-Kilner VY Pushback Procedure with Intravelar Veloplasty

This technique can be used to repair all types of incomplete cleft palates including clefts of the soft palate. This VY procedure is recommended in this chapter because of its versatility and because of its similarity to the other repairs already described. This technique allows for good visualization for reconstruction of the LVP muscles and allows for full mobilization of the mucoperiosteal flaps for tension free closure of the hard palate component of the cleft. The "pushback" component is questionable as to whether it improves speech more than without it, "pushing" the flaps as far back as in the illustration (Fig. 6) is not recommended, as this leaves very large raw areas that scar down and cause facial growth restriction without any clear speech benefit.

1 This technique is similar to that of the Bardach procedure but with the different incisions on the hard palate.

2 The tips of the mucoperiosteal flaps should not be opposed at the very distal tips as in Fig. 7.

Repair of Post-Operative Oral-Nasal Fistula

Small anterior oral-nasal fistulas after cleft palate repair typically do not need to be repaired as they do not affect speech to a significant degree. The further posterior and the larger the fistula, the greater the impact on speech dysfunction and oral-nasal

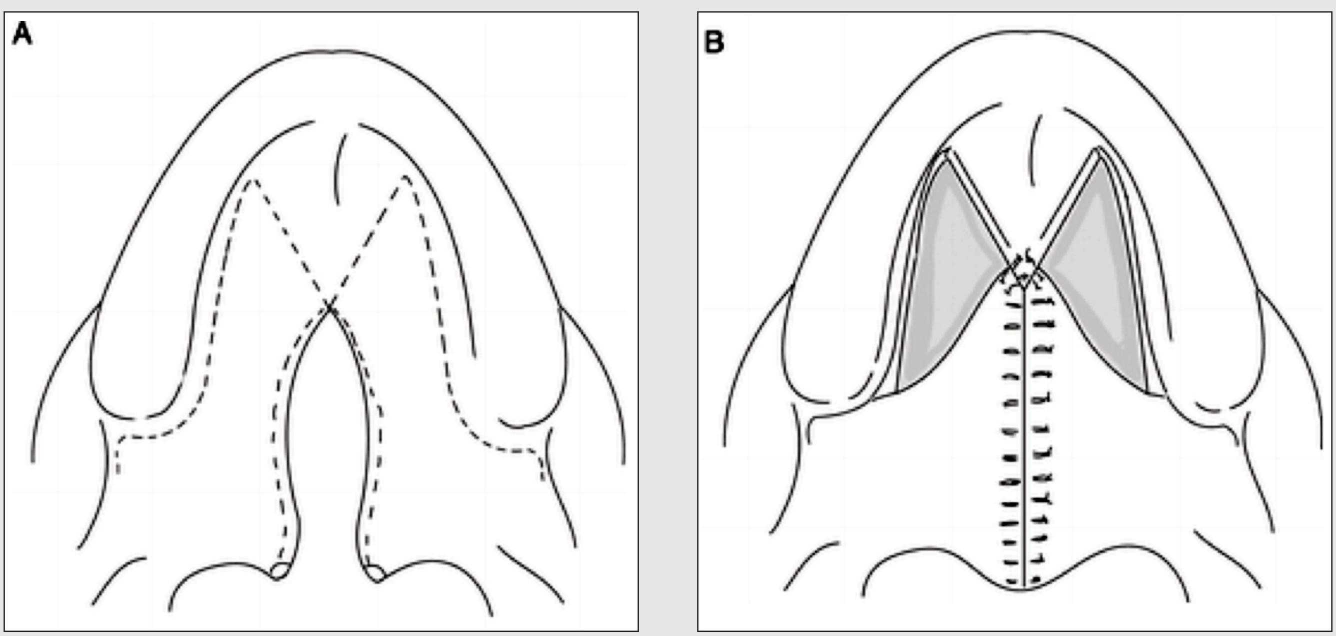


Fig. 7

Veau-Wardill-Kilner VY Pushback procedure.
(Cleft Palate-Craniofacial Journal, May 2011, Vol. 48, No. 3, Losken, H. Wolfgang. Used by permission.)

emission, such that proper operative repair can salvage the goals of the original cleft palate repair. Operations to repair the fistula may include local mucosal flaps, staged tongue flaps, pharyngeal flaps, local axial flaps (facial artery muscular mucosal flap), distant axial flaps (submental flap), and even microsurgical free tissue transfers (radial forearm flap) for large fistulas. These are difficult, complex operations with variable results even in ideal situations (specialized instrumentation, expert surgeon, etc...), **so a description of repairing fistulas is beyond the scope of this text**.

I recommend only attempting a fistula repair if sufficient expertise is available (for instance, a visiting plastic surgeon with extensive cleft palate surgery experience). For most small to moderate size fistulas, it is best to redo the cleft palate repair.

(**Editor's Note**: The author's admonition at the beginning of this chapter is important: "**a poor repair which results in a large fistula is worse than no repair**." So experience and the right instruments are important before performing a cleft palate repair. If a fistula still results, it is probably best to delay attempted closure until a cleft lip/palate team comes to your area, as secondary surgery is very difficult. As also mentioned, a small fistula that a parent observes is often not important to close, so the parent can be reassured. This may result in a small nasal leak of fluid but this is often intermittent and not a significant problem. Even small fistulae are difficult to close!)

Post-operative Care

- After leaving the recovery room, the patient should be admitted to a nursing unit where frequent (at least every 1-2 hours in children less than 2 years of age) monitoring of vital signs with respiratory assessments and operative site assessments (checking for blood in the mouth by inspection only—no instrumentation in the mouth. Pulse oximetry is a must during the first hours postop.

- Diet is clear liquids for the first post-operative evening using a cup or syringe followed by a soft diet the following day (and subsequently for two weeks). No hard eating utensils (spoon or fork) should be placed in the mouth for six weeks.

- A maintenance rate of intravenous fluids may be necessary for the first night if the patient is not interested in drinking fluids.

- No labs are necessary unless there are concerns from the intra-operative blood loss.

- Regarding medications: parenteral antibiotics are given for a total of 24 hours (including the pre-op dose). A narcotic is given IV or IM as needed for pain for the first 24 hours. Typically, no more than 1-2 doses are needed, since the local anesthesia is injected prior to the incision and the epinephrine prolongs the anesthetic effects for several hours. Then paracetamol elixir is given orally as a scheduled dose every 6 hours for 24 hours then as needed for pain. Anti-emetics are given as needed (if available). Ear drops are ordered if PE tubes are placed. Invariably, cleft palate patients will run a fever postop.

- The check lists in Figs. 8-9 ensure that nothing is overlooked or forgotten in the postoperative period.

Complications

- **Hemorrhage**. Slight oozing from the raw surfaces of the flaps is expected; however it is very important that the patient does not leave the operating room until the bleeding is controlled. A fine tip cautery is used to once again cauterize the edges of the oral mucoperiosteal flaps (not the nasal flaps as they are too delicate). Pressure for several minutes helps control the bleeding. The Dingman retractor should be left in place until bleeding is controlled. If available, Surgicel® or Gelfoam® or other hemostatic agents can be used, but one should not rely on these to control active bleeding, just any slight oozing.

- **Infection**. Operative site infection causing fever is very rare with cleft palate operations. Immediate postoperative fever should be considered malaria or some other infection overlooked pre-operatively. Otitis media, sinusitis, peri-orbital cellulitis may manifest a few days post-operatively, but the pre-operative prophylactic antibiotics typically prevent these infections. As mentioned above **a slight fever is common with any palate repair**.

- **Oral-nasal fistula**. See section on "Repair of post-operative oral-nasal fistula" above.

CURE Ethiopia Children's Hospital

patient name sticker

Physician Order: Post-operative Cleft Lip and/or Palate Repair

Non-Medication Orders Only

Weight (kg): ______________

Primary Dx: ❑ R ❑ L ❑ B ❑ cleft lip ❑ cleft palate ❑ VPI ❑ palatal fistula ❑ lip deformity ❑ nasal deformity ❑ alveolar cleft
❑ other/comment: ______________

Procedure: ❑ unilateral ❑ bilateral ❑ cleft lip repair ❑ cleft palate ❑ bilateral tube myringotomy
❑ cleft lip revision ❑ palatal fistula repair ❑ pharyngeal flap ❑ pharyngoplasty ❑ nose revision/rhinoplasty
❑ alveolar bone graft ❑ other/comment: ______________

Admit to: ❑ ward ❑ ICU ❑ lodge ❑

Activity: ❑ elevate head of bed 30° - 40° to reduce swelling
❑ do not position prone or allow incision to rub
❑ other: ______________

Nursing: ❑ vital signs – routine post-op then q ________
❑ pulse oximetry – continuous / intermittent q ______ hours
❑ respiratory assessment q2 hours and prn / ______________
❑ continuous cardio-respiratory monitoring
❑ replace dressing prn saturation; Do / Do Not apply antibiotic ointment with dressing change
❑ other: ______________

Diet: ❑ age appropriate, advance as tolerated
❑ feed with approved delivery device used pre-op (syringe, bottle, cup) – NO PACIFIERS
❑ soft diet
❑ formula/ full liquid / strained food without "chunks"
❑ Gunhild high protein shake ______________
❑ clear liquid diet
❑ other: ______________

IV care: ❑ Heparin/saline lock IV when tolerating oral intake > ________ ml / ________ hours
❑ IVF to _____ ml/hr when tolerating oral intake > ________ ml / ________ hours

Alerts: ❑ notify surgeon for excessive bleeding (oral/nasal)
❑ notify surgeon for O2 sats < 91% ______ or any signs of respiratory distress
❑ notify H.O. for Temp > 38°C axillary; Pulse > ______ or < __________; RR > __________ or < __________
❑ notify H.O. for SBP > ______ or < ________; DBP > __________
❑ notify H.O. for u/o < _______ cc/ _____ hrs

I/O: ❑ monitor and record strict intakes & outputs: ❑ discontinue when IV to (heplock / ____ ml/hr)
❑ other: ______________

Consult: ❑ pediatrics ❑ lactation ❑ ______________

Labs: ❑ Hg ❑ other (fill out lab form): ______________

Other: ❑ ______________
❑ ______________

Date: _____/_____/ 201___ **Time:** ______ h **Signature:** ______________ **print name:** ______________

Fig. 8

CECH cleft repair post-operative orders, page 1 of 2

CURE Ethiopia Children's Hospital

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patient name sticker

Physician Order: Post-operative Cleft Lip and/or Palate Repair

Medication Orders Only

ALLERGIES/SENSITIVITIES: ❑ none
Med:______________________________
Dietary:______________________________
Enviromental:______________________________

Weight (kg):__________

❑ IVF: D5W 1/3 NS @ rate:_______ml/hr ❑ IVF: ______________________ @ _______ml/hr

❑ bacitracin ointment to suture line BID (do NOT clean suture line)

❑ cephazoline (Ancef) ___________mg IV q8h x _______ doses (peds range 25 – 33 mg/kg/dose; avg adult 1 g/dose)

❑ promethazine (Phenergan) __________mg IM (circle one) q4 – 6h prn nausea or vomiting (**>3y/o only**: peds 0.25 – 0.5mg/kg/dose, max 25mg/dose; avg adult 25 mg/dose; IM preferred over IV due to respiratory depression)

❑ ondansetrone (Zofran) __________mg IV q4 – 6h prn nausea or vomiting (peds 0.1 – 0.15 mg/kg/dose; avg adult 4 mg/dose)

❑ morphine __________ mg IV q2 – 4h prn pain up to 3 doses total only (peds 0.05 – 0.1 mg/kg/dose)

❑ naloxone (Narcan) _________ mg IV STAT for respiratory depression, then call surgeon (peds <20kg wt: 0.1 mg/kg/dose; peds >20kg, adults: 2 mg/dose)

❑ paracetamol (Tylenol) 120mg/5ml syrup _________ ml PO q 6 hours
(peds 10 – 15 mg/kg/dose q 4h, max 5 doses in 24 hours; avg adult 500mg/dose, max 4g/day)

❑ paracetamol (Tylenol) 500mg tablet _________ PO q 6 hours
(peds 10 – 15 mg/kg/dose q 4h, max 5 doses in 24 hours; avg adult 500mg/dose, max 4g/day)

❑ total paracetamol (Tylenol) given from all sources will not exceed 5 doses for children and 4g for adults per 24 hours

❑ codeine 30 mg / 15mg / 7.5 mg (circle one) tablets _________ PO q4 – 6h prn pain
(peds 0.5 – 1 mg/kg/dose; avg adult 30 – 60 mg/dose)

❑ diphenhydramine (Benadryl) _________ mg IV / PO (circle one) q6h prn itching and restlessness
(peds IV/PO: 0.5 – 1 mg/kg/dose q 6h, max 50 mg dose)

❑ multivitamin syrup _______ ml PO q day (< 6mos/o: 1 ml; 6mo – 3y: 2.5 ml; 4y – 6y: 4ml; 7y – 10y: 5 ml)

❑ multivitamin tablet 1 PO q day (> 10yrs/old: 1 po qd)

❑ gentamycin otic solution 3 drops in each ear canal TID for 3 days; replace cotton balls in ear canals after every dose

Other: ❑ ______________________________
❑ ______________________________
❑ ______________________________

Date: _____/_____/ **201**___ **Time:** _______**h** **Signature:**____________________ **print name:**____________________

Fig. 9

CECH cleft repair post-operative orders, page 2 of 2

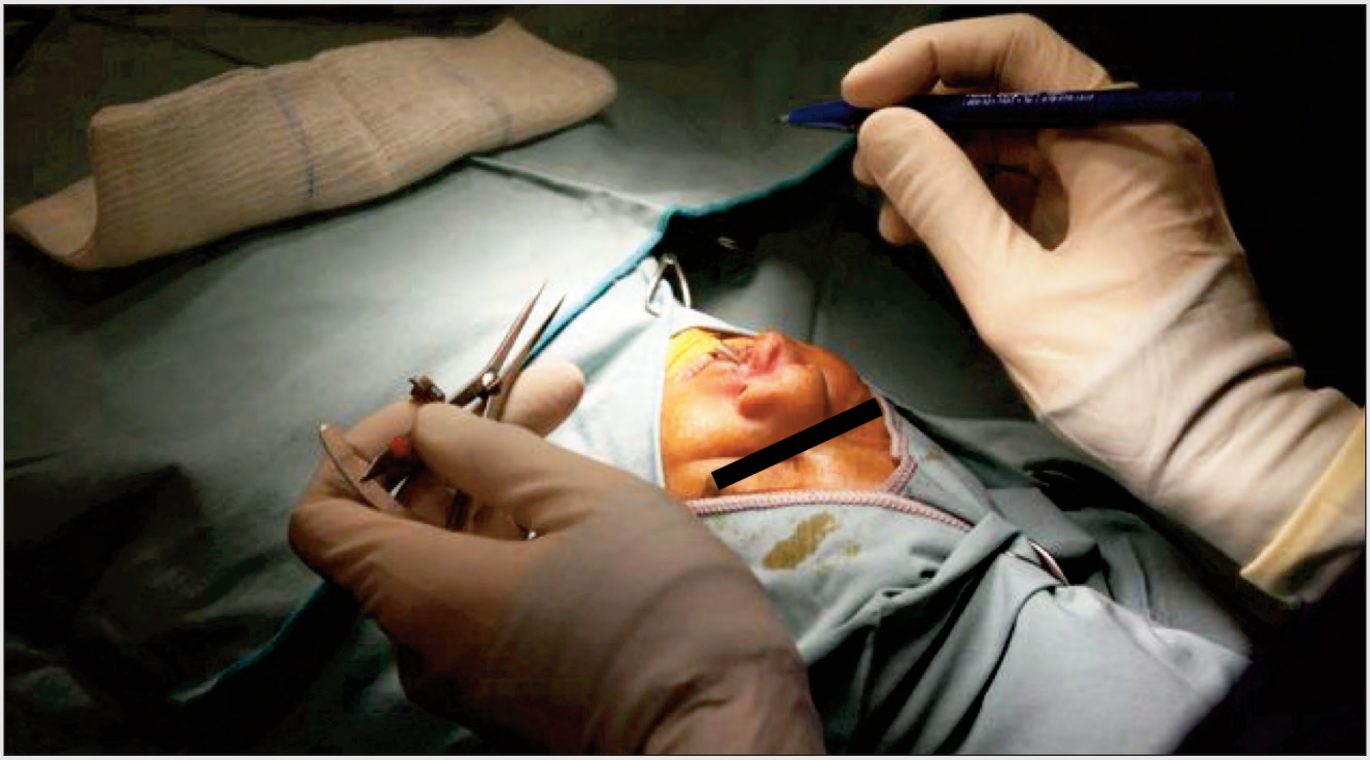

Fig. 10
Patient draped and ready for surgery.

- **Alloderm®—Acellular Dermal Matrix** has been used to replace nasal lining when it is difficult to approximate. It has also been used with good results in fistulae. It is expensive, difficult to obtain, and considered controversial in cleft palate repair, so is not currently recommended.

- **Velopharyngeal insufficiency (VPI)**. Although the primary goal of cleft palate repair is intelligible speech, even the assessment of speech requires a speech-language pathologist (masters and even doctorate level of training). Since this level of expertise is not available in most of the developing world, this complication is only mentioned as something of which to be aware. There are secondary operations (palatal flaps and pharyngoplasty) to treat VPI after cleft palate repair, but those are beyond the scope of this text.

Addendum: Some may notice that Furlow double opposing Z-plasty technique for soft palate closure was not included. The author felt this technique was beyond the expertise of the average general surgeon in Africa or Asia without extensive training.

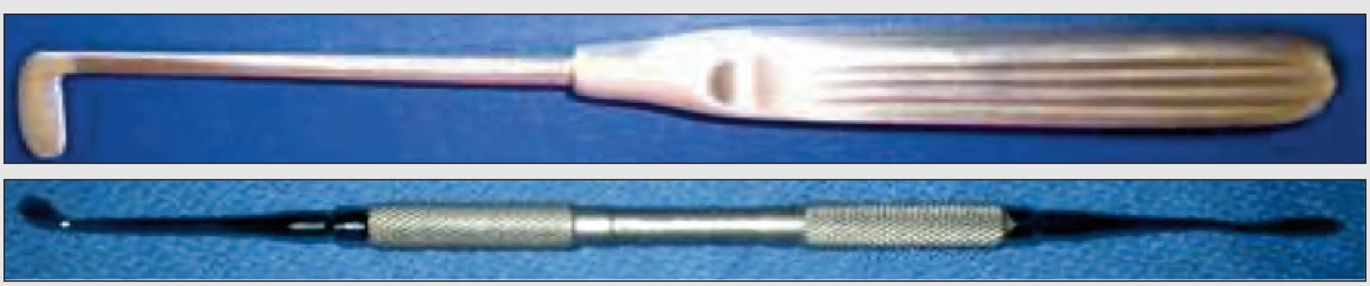

Fig. 11A
Instruments used in Cleft Palate Repair.
(One can use other instruments for cleft palate repair. These are the ones the author uses.)
Top to Bottom: Blair periosteal elevator; No.1 Woodson periosteal elevator.

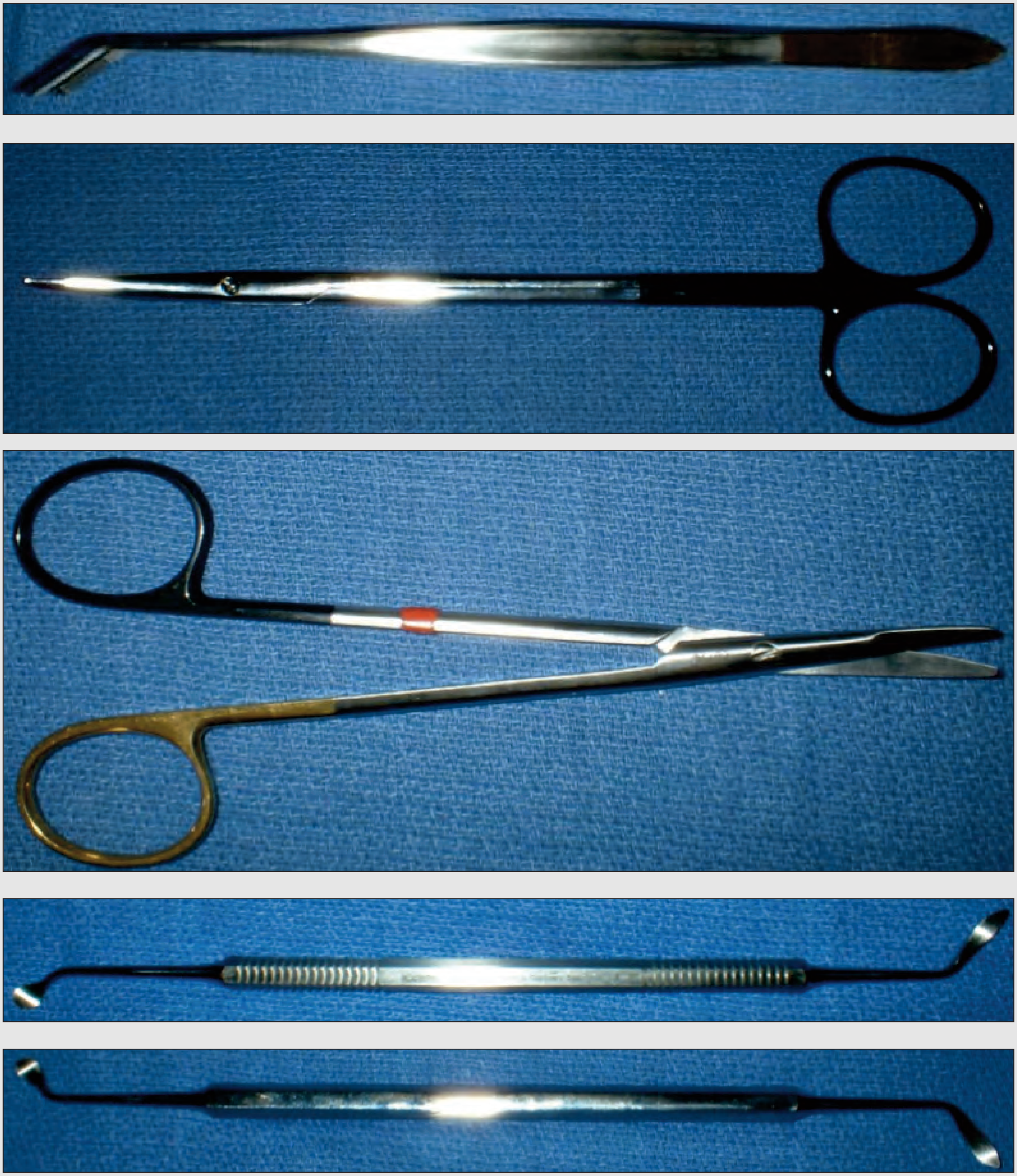

Fig. 11B

Instruments used in Cleft Palate Repair.
(One can use other instruments for cleft palate repair. These are the ones the author uses.)
Top to Bottom: Cushing forceps; Reynolds scissors, 16cm length; Kilner scissors, 13 cm length; Jeter-Woodson hard palate elevator, left side; Jeter-Woodson hard palate elevator, right side.

Chapter 16

Noma

Tertius H. J. Venter and Louis L. Carter, Jr.

Introduction

Noma, or cancrum oris, is an overwhelming invasion of micro-organisms of the oral orifice into the face leading to gangrene, sepsis and death. This is a necrotizing fasciitis-like process. It may be localized to the mouth and oral cavity, or it may extend up into the nose or laterally to the ears. It was first described by Carolus Barthus in 1595 in the Dutch textbook Handboek der Chirurgijen. The Greek term *noma* that means meadow/grazing/devouring and, metaphorically, "quickly spreading", was introduced in 1680 by Cornelis van Voorde. It is often referred to as "the disease of the poor" and was common in Europe and the United States in the previous centuries but disappeared from the developing world a century ago when even the poorest could feed their children. It reappeared, however, under the atrocious conditions in the concentration camps of World War II and in the Netherlands amid the severe food shortage at the time.

Epidemiology

The global incidence, according to the World Health Organization, is estimated at 140,000 people with active disease, mainly children. The mortality rate of noma is 90%, and mostly occurs in children between the ages of 1-3 years. Each year 3,000 to 4,000 children are likely to survive this infection and live with the sequelae of the disease. It is estimated that presently there are 770,000 people who have survived noma and are living with the consequences of the disease. This data is not completely reliable, as "a society only counts its dead when it can feed its living", and this is indeed a disease of the poorest of countries of the world. The areas most affected are East and West Africa, parts of Asia, and Latin America.

Noma is an entirely preventable disease. Food and vaccination are the critical components in the prevention of the disease.

Predisposing Factors

Malnutrition is the major predisposing factor. This is combined with the second component, a **concomitant infection** particularly measles, chronic malaria, tuberculosis, HIV or typhus. The third

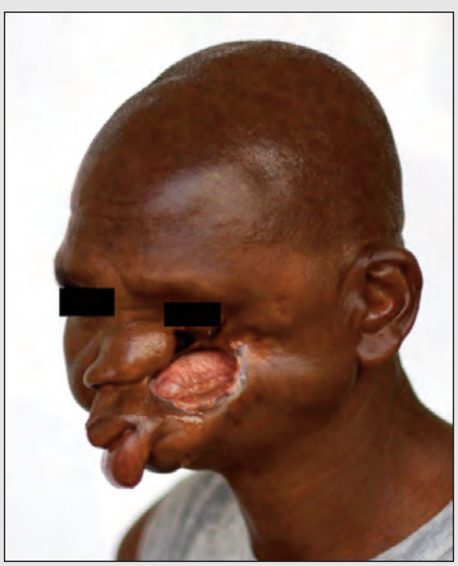

Fig. 1

Fig. 2

Fig. 3

Sequelae of noma in survivors (Courtesy Dr. Gary Parker, Mercy Ships).

component is **poor oral hygiene or stomatitis** and this sets the scene for a devastating and, most often, fatal disease. Malnutrition and other concomitant infections (such as measles) weaken the immune system. This depressed immune status combined with the high bacterial load in the mouth has the potential to cause an acute necrotizing gingivitis with rapid gangrene of the facial tissue. Sepsis and death may follow. An additional predisposing factor appears to be environmental, as noma is seen more frequently in arid, desert-like conditions.

The child's family often reports that "the child was bitten by a hyena." This is assumed, as there has never been a witness, and it is very unlikely, since the child should have been eaten and killed or at least have other injuries.

Bacteriology

There are no specific organisms associated with noma. It is a polymicrobial infection caused by anaerobic organisms that produce enzymes as well as pro-inflammatory mediators that degrade the intracellular matrix—a mixed infection of oral and extraoral opportunistic pathogens. Spirochetes and species of Fusobacterium have long been suggested to play a role in the disease process. The evidence available suggests that noma is caused by the normal

Fig. 4

Presented as a hyena bite in childhood, but most likely a noma.

(From *The Surgical Treatment of Noma*)

Fig. 5

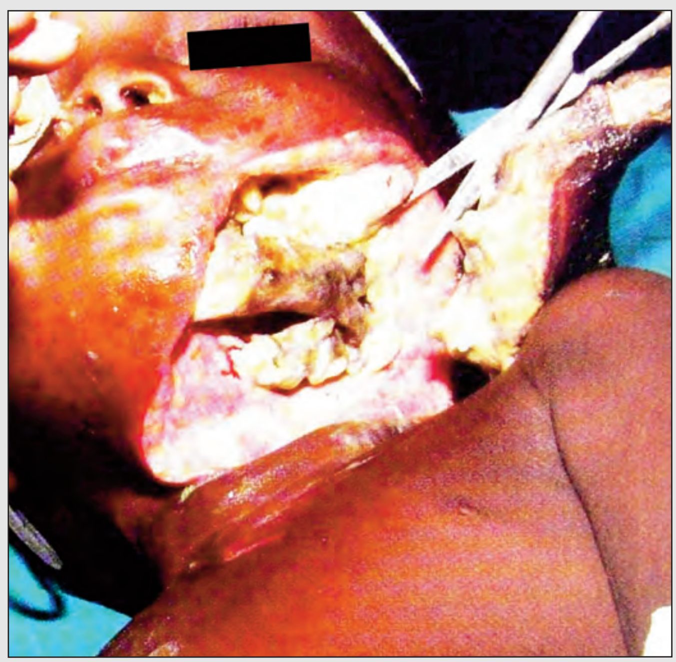

Fig. 6

Extensive full thickness necrosis of the facial tissue within a week after onset of the disease.

(From *The Surgical Treatment of Noma*)

Fig. 7

Fig. 8

Patient with HIV who developed noma as an adult.

7) Full thickness loss of cheek tissue. 8) Oral mucosa reconstruction with turnover skin flaps using skin and scar adjacent to the defect and a rhomboid flap closure of the cheek.

flora in the mouth. Although Fusobacterium nucleatum has been implicated in this condition, numerous other anaerobes have been identified. Noma appears to be simply an opportunistic infection in tragic circumstances.

Clinical Presentation

The first signs of the disease are:

- Swelling of cheek.
- Excessive salivation.
- Foetor ex ore/bad breath/halitosis.
- Within days, dark areas and ulceration appear on the cheeks. Unlike most infections, noma can spread through anatomic barriers such as muscle.
- Extensive intraoral slough follows, typically breaking through the skin a week after onset with

Fig. 9

Fig. 10

Early and long-term consequences of noma; healing complete but with severe contracture of the surrounding surviving tissues.

(From *The Surgical Treatment of Noma*)

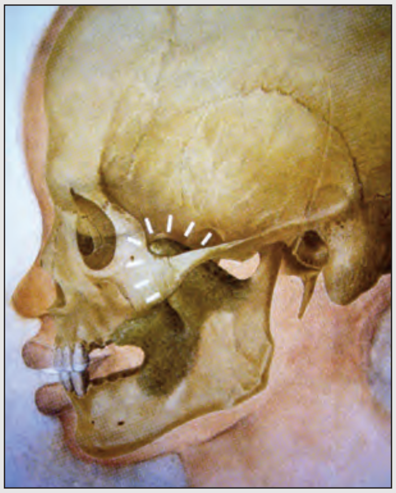

Fig. 11

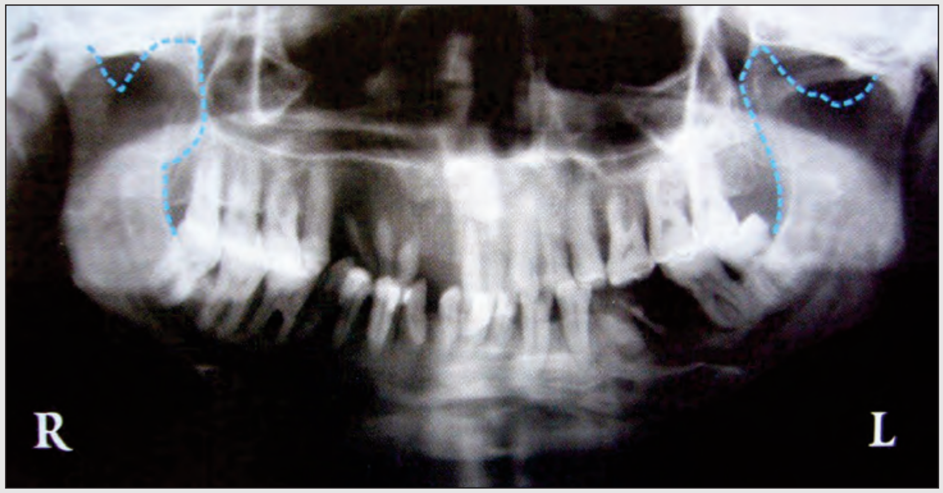

Fig. 12

11) Hypertrophy of the coronoid impinging on the zygomatic arch and bony fusion between the maxilla and mandible. 12) Hypertrophied coronoid process on the right side.

(From *The Surgical Treatment of Noma*)

full thickness gangrene that can extend to the ear, eye, sinuses, nose and to the contralateral side.

Ninety percent of children affected die from sepsis. The 10% of patients that survive are left with varying degrees of facial deformities and can have severe problems with eating, drinking, and speaking. As with leprosy and vesicovaginal fistula patients, these victims are often rejected by their communities. Of the patients that survive the acute infection, 50% will be left with ankylosis of the temporomandibular joint (TMJ), adding a further challenge to survival. Many will die of starvation as a result of the late complications of the infection, since they are unable to eat due to the facial mutilation and ankylosis and loss of teeth.

Treatment

Prevention

Prevention begins with adequate nutrition, immunization, and oral hygiene education. In an ideal world, feeding the hungry and malnourished is the overall answer. Vaccination campaigns against childhood infections and the use of mosquito nets must be increased. Infectious diseases wreak havoc in poor communities. Noma is a socio-political disease and must be addressed at the governmental level down to the level of each family. Effective prevention includes all three interventions: feeding, vaccination, and education on the importance of oral hygiene.

Acute Phase

Noma patients rarely present to a medical center in the acute stage of infection due to their poor socioeconomic status. Also, in most areas where noma is found, there is a lack of adequate medical facilities and surgical expertise to advise on early management. Survival, however, can be significantly improved with prompt treatment and staged debridement, should the patient arrive early at a sufficiently equipped medical facility.

The following steps should be considered:

- The patient must be stabilized with appropriate hydration and nutritional support. Intravenous fluids must be carefully selected to correct dehydration and electrolyte imbalance as indicated by the patient's clinical condition. A most important aspect of the management protocol is dietary supplementation; the patient is given a high-protein diet. Multivitamin preparations should be given as well. A naso-gastric feeding tube may be necessary for adequate nutritional intake.

- Laboratory investigation: Once the patient is moved to a medical center, the usual routine investigations, where available, include full-blood count with white blood cell differentials, serum electrolytes, urea and creatinine levels, serum protein level, stool microscopy and cultures, and HIV screening. Hypoproteinemia and anemia

Fig. 13

Fig. 14

13) Patient with acute noma with full thickness necrosis of the cheek, approximately one week after onset. 14) The same patient after repeated debridement of the wound. The sequestrum has not been removed yet (photos courtesy Dr. Abi Boys).

(usually of nutritional origin) are common findings. The stool examination often reveals worms, especially hook worm.

- Address predisposing infections such as measles, typhoid, HIV, etc.

- Administer appropriate antibiotics: As with any necrotizing infection, the patient with noma must be treated for gram positive, gram negative and anaerobic organisms. This mixture of aerobic and anaerobic bacteria include Group A Streptococcus, Clostridium perfringens, Fusobacterium, resistant Staphylococcus, and others. If available, high doses of intravenous antibiotics should be used. Drug therapy of choice in our setting is penicillin (ampicillin), gentamycin, and either metronidazole or chloramphenicol to cover anaerobic organisms. Newer drugs, as clindamycin and vancomycin can be used if available and not cost-prohibitive. These would replace ampicillin and metronidazole.

- The patients are routinely treated for malaria and dewormed using appropriate antimalarial and anthelmintic drugs.

- Effective local management of the ulcer demands regular/repeated debridement and frequent dressing changes. The wound should be kept moist (as described in chapter 2 on wound care). One may use saline dressings, honey, or even negative pressure therapy if the wound does not communicate with the mouth. Loose teeth and loose bony sequestrae must be removed.

- Treatment of sequelae: chronic complications from acute noma include fibrosis and formation of sequestrae. The fibrosis leads to ankylosis of the temporomandibular joint with limited ability to open the mouth. If a sequestrum is not loose, it is allowed to remain in hopes that an involucrum, new bone, will form around it. In the case shown in Figs. 13-14, the malar sequestrum is allowed to remain until one is ready to begin reconstruction. It is then removed and final debridement is carried out to prepare the wound for reconstruction. Most sequestrae will loosen and fall out in time.

Principles of Surgical Treatment

Timing

Ideally, one should wait for 1-2 years before initiating any reconstructive surgery. **Most patients, however, are not seen early** and come in many years after the acute episode. The orofacial defect is usually very extensive and requires multiple and highly specialized surgical reconstructions. There is an advantage to delaying surgery so that the patient is mature enough to cooperate in the postoperative period. Delayed surgical repair also ensures adequate tissue for reconstruction, and it allows the defect to contract and reduce in size.

Anesthesia

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

15) Fully matured wound of patient in Fig. 13. Note improvement of the nutritional status.

16-17) Defect closed with temporalis muscle flap and skin graft. The muscle on the oral side gradually epithelialized.

18-19) Healed appearance, but further contacture formation required scar revision and lower eyelid release (photos courtesy Dr. Abi Boys).

Fig. 20

Fig. 21

Fig. 22

Noma reconstructed with local turnover flaps and cervical flap for cheek reconstruction.

Fig. 23

Fig. 24

Fig. 25

Fig. 26

Fig. 27

23-24) Abbé -Eslan der flap reconstruction.

25-27) Reconstruction with turn over flaps for mucosa and split deltopectoral flap for the upper and lower lip skin.

With these orofacial defects, there is scarring of soft tissues and frequently trismus. Some will have a bony block between the mandible and maxilla or hypertrophy of the coronoid (See Fig. 36). Such cases will require nasotracheal anaesthesia. A blind nasotracheal intubation can be attempted, but a fiber-optic bronchoscope is usually needed. The use of the latter requires trained anaesthesia personnel. The patient may require a tracheostomy and postoperative ICU care. Surgery under ketamine is not recommended. Without good postoperative tracheostomy care, a tracheostomy should not be done. See the "Regional Anaesthesia" chapter. An alternative is the submental intubation (See addendum).

Fig. 28

Fig. 29

Forehead gives an excellent color match for reconstruction of the midface. Donor defect is skin grafted on periosteum with poor cosmetic result.

(This is not a noma, but shows the excellent color match with a forehead flap.)

Debridement

The edges of the defect must be sharply debrided back to viable, bleeding, well perfused tissue. If one plans to use a local turnover flap for mucosal reconstruction, the side of the proposed turnover flap is left intact. Only minimal freshening of the wounds on the face is necessary.

Temporomandibular Joint

If there is trismus, the TMJ may need to be released unilaterally or bilaterally. This can be performed though a preauricular incision with care to protect the frontal branch of the facial nerve—CN VII. The reader is referred to plastic surgery or ENT books for this technique.

Mucosal Lining

In most cases, the mucosa will need to be

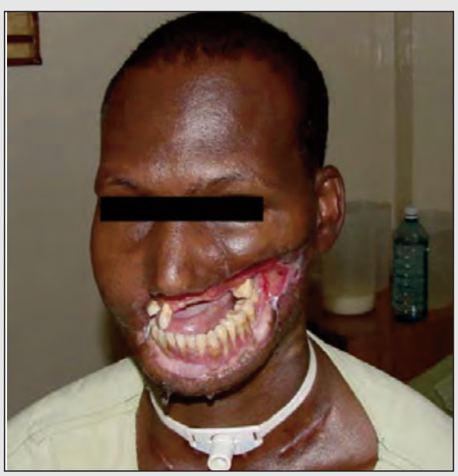

Fig. 30

Fig. 31

Fig. 32

Large defect with trismus. Turnover cheek flaps used to reconstruct mucosa. **Visor flap**, bilateral superficial temporal artery flaps, elevated after fore \head expansion. In this case, the expander became infected and had to be removed, leaving only hair bearing tissue for the flap. Ideally, the expander would have expanded both hairless forehead skin, for lower lip, and hair bearing skin, for the upper lip and mustache. The forehead flap would also cover the defect left by the cheek flaps which were turned over for mucosa. One could also skin graft beneath the visor flap for mucosal lining.

Fig. 33

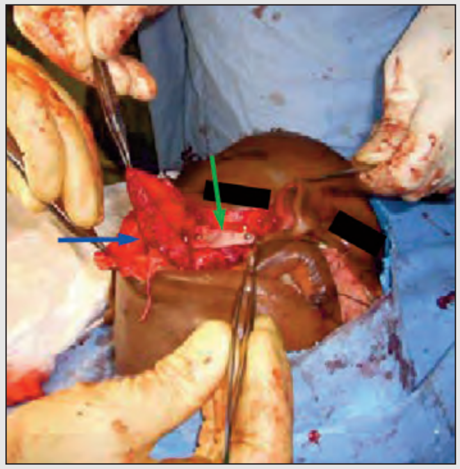

Fig. 34

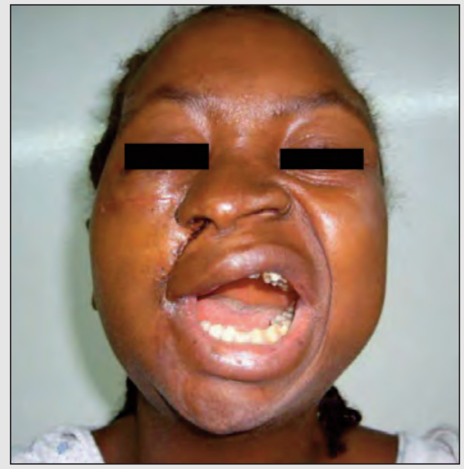

Fig. 35

Pre operative ankylosis and flattening of cheek: coronoidectomy to release ankylosis and temporalis flap (blue arrow) and calvarial bone graft (green arrow) used for reconstruction.

reconstructed. This is always necessary for nasal defects. A common method is to use local skin turned over for mucosal closure. If this good skin is available for turnover, it is ideal. If the muscle is used, it will epithelialize over. Skin or fasciocutaneous flaps as the deltopectoral flap can be skin grafted on the inner or future mucosal side. The thin platysma muscle flap from the ipsilateral neck can be used for large defects (see Fig. 38).

Closure

Any local flap may be used as seen with the rhomboid flap (seen in Figs. 7 and 8) and the cervical and Abbé Estlander flaps (in Figs. 20-22). Regional flaps may be necessary, such as the forehead, deltopectoral, pectoralis major myocutaneous, temporalis muscle, submental perforator flap, visor (see Fig. 32), or supraclavicular flap. Microvascular flaps give an outstanding reconstruction if one has expertise in microvascular surgery.

Fig. 36

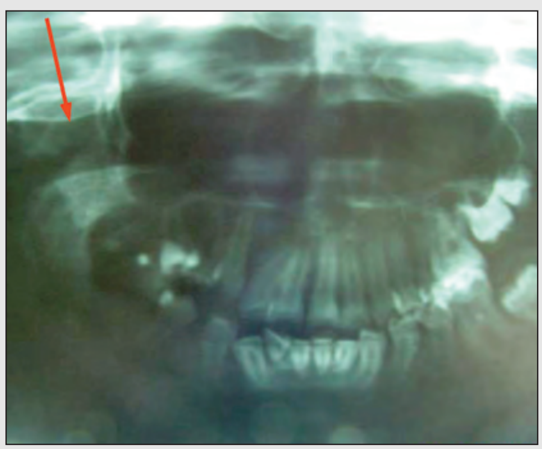

Fig. 37

Fig. 38

This patient with right cheek noma and trismus required nasotracheal intubation with a fiberoptic scope, removal of the bone block (red arrow in Fig. 37) between maxilla and mandible, and TMJ release through bilateral preauricular incisions. The mucosa was reconstructed with a platysma flap (see Fig. 38: donor defect green arrow, and flap prior to insetting blue arrow) and the cheek reconstructed with a deltopectoral flap. The challenging fiber-optic nasotracheal intubation by a pediatric anesthesiologist took 2 hours because of bleeding, and the removal of bony block another 2 hours.

Fig. 39 **Fig. 40**

Same patient as in Figs. 36-38, with flaps in place Fig. 39 and post-op in Fig. 40 with 20 mm of mouth opening.

The **forehead flap** based on the superficial temporal artery is an excellent flap for reconstructing the mid-face. The color match is perfect. Unfortunately, the donor defect deformity is significant. In cultures where head coverings or turbans are worn, the defect would not be conspicuous. The case seen in Figs. 28-29 was a hemangioma in a young girl. She came from a thousand kilometers away for treatment. There was uncertainty about her return, and a high likelihood she would wear a head covering in adulthood based the culture in her home country. This shows how a forehead flap can provide excellent reconstruction, and it has been used extensively in noma treatment.

The **visor flap** can be used for large defects. This is a bilateral superficial temporal artery flap turned down, as a visor, to reconstruct upper and lower lips. Lip mucosa can be reconstructed with **cheek turnover flaps** that should be delayed twice in most cases. In such a case, the surgeon raises a portion of the flaps at the first stage. At the second stage, the full flap is raised but sutured back into place. Finally, the flap is turned over to reconstruct the lip mucosa, and the forehead flap is used to reconstruct the skin of the upper and lower lips. In the case below, the forehead was expanded with hopes that the hair-bearing skin would create the upper lip, and hairless forehead skin would be for the lower lip.

The patient in Figs. 41-42 came from a refugee camp. At the first procedure, a deltopectoral flap was used for mucosal lining and a pectoralis major flap was used for external reconstruction. The ectropion was repaired but recurred due to the heavy pectoralis major flap. The ectropion was repaired on her second and last visit. Other flaps could have been used as the forehead flap, platysma flap, etc. for lining and external reconstruction. Further reconstruction was planned if the patient had returned.

Other defects—Nose

As mentioned earlier, nasal lining is critical with any nasal reconstruction. Bone grafts from the dorsum are taken from the calvarium, rib or iliac crest. In the chapter 6 on facial trauma and reconstruction, there are guidelines for nasal reconstruction. Mucosal lining for the nose may

Fig. 41 **Fig. 42**

Large noma involving cheek, eyelid, and ear with trismus.

Fig. 43

Fig. 44

Noma with nasal loss. Nose reconstructed with a turnover midline forehead flap for mucosal lining, calvarial bone graft for nasal dorsum, right lateral forehead flap based on contralateral superficial temporal artery, Mustardé cheek flaps to reconstruct cheek, and then lateral lip advancement. The maxilla was not reconstructed. Secondary division and inset of lateral forehead flap. The patient lived far away and did not return for further reconstruction.

be obtained by local turnover flaps from the cheek (within the nasal labial fold), nasolabial flaps, or forehead flaps. In some cases, the forehead flaps used for external reconstruction may be skin grafted as the first step and then turned down in the second stage for both mucosal and external reconstruction. Cartilaginous reconstruction for the alar rim and columella are harvested from the ear or nasal septum. After the forehead flap is turned down for external reconstruction, a second stage in a week to ten days is done to defat the flap to give a better cosmetic result. This is done before the flap is divided. Please refer to chapter 6 or to a chapter on nasal reconstruction in a plastic surgery or ENT text.

Summary

Noma deformities are some of the most challenging plastic surgery problems in Africa. The disease process begins in childhood, but the patients present later in childhood or even as young adults. Most victims of noma die during the acute phase of the disease, not having access to adequate medical care. Those who do survive are left with these severe facial deformities. When the patient with chronic sequelae understands his condition and when the surgeon feels the patient and family will be compliant, then operative treatment may be considered. Ideally, reconstruction would be completed prior to school age and socialization. Delayed presentation, however, usually precludes this possibility. Microsurgical flaps, as the radial forearm flap, have been used by microsurgical teams to give an excellent reconstruction. As seen in chapter 12 on burn reconstruction, pedicled radial forearm fasciocutaneous flaps can be used in compliant patients. The use of the pedicled radial forearm flap is the old Tagliacozzi technique and it provides thin skin for reconstruction in selected cases.

Sources

The Surgical Treatment of Noma by Kurt Bos and Klaas Marck. (Kurt Bos and Klaas Marck, founder and President of Dutch Noma Foundation, have written this publication aimed at surgeons and anesthetists working with Noma as part of a surgical aid programme. The book offers a very in-depth description of the procedures used in the reconstructive surgery.)

The authors would like to thank Dr. Gary Parker for his contributions to this chapter.

Chapter 17

Pressure Ulcers

Peter M. Nthumba

Introduction

Pressure ulcers develop as a result of tissue loss primarily from pressure. Decubitus ulcers occur in areas with underlying bony prominences when the patient is lying down (sacrum, trochanter, heel, etc.). Other pressure ulcers occur in the seated position (ischial tuberosities).

Pressure ulcers are an ancient problem, reported in Egyptian mummies. Data from developed countries indicates that between three percent and five percent of all hospitalized patients will develop a pressure sore at some time during their hospitalization. The incidence of spinal cord injuries and pressure ulcers in Sub-Saharan Africa is not known. With the recent exponential increase in the number of accident victims from industrial and motor vehicle accidents, as well as with the flood of motorcycles on Sub-Saharan African roads, the number of critically injured and spinal injured patients have seen a similar increase. It is likely that there will be an attendant increase in patients with pressure ulcers. Further, a growing number of children/adults with spina bifida also contribute to this difficult problem. Children who previously had no chance of survival now grow to adulthood as a result of improved focused care. A favorable pressure ulcer prevalence of 4.2% in Kenya's premier referral hospital was reported, while the National spinal injury hospital had a pressure ulcer prevalence of 68% in a study in 2003. Nang'ole identified trauma (42.4%), HIV/AIDS (27.4%), tuberculosis of the spine (8%), diabetes mellitus (4%), cerebrovascular accidents (4%), and others (14.2%) as the predisposing factors to the development of pressure ulcers in 113 patients in a Nairobi hospital in 2003. The patients had a total of 321 pressure ulcers.

Pressure ulcer prevention in Spinal Cord Injury (SCI) patients in resource-constrained environments is difficult, and the management, once pressure ulcers occur, is complex. Pressure ulcers are associated with increased mortality, morbidity, hospital stay, and cost. Non-monetary ("hidden") costs of pressure ulcer care include the emotional and physical impact of these ulcers on the patient and their caregivers. The surgeon must, therefore, be prepared either to manage or help prevent pressure

Table 1

Grade	Lesion	Management
I.	Non-blanchable erythema (redness) of intact skin. Discoloration of the skin, warmth, edema, induration or hardness may also be used as indicators, particularly in individuals with darker skin.	Institute preventive nursing measures: avoid moisture, friction, and pressure on body part at risk,
II.	Partial thickness skin loss involving epidermis, dermis, or both. The ulcer is superficial and presents clinically as an abrasion or blister,	Avoidance of pressure and wound care. Surgical debridement of any dead skin. Rarely, skin graft.
III.	Full thickness skin loss, involving damage to or necrosis of subcutaneous tissue that may extend down to, but not through, underlying fascia.	Surgical debridement and wound closure, with random skin flap often sufficient.
IV.	Extensive destruction, tissue necrosis, or damage to muscle, bone, or supporting structures with or without full thickness skin loss	Excision of the ulcer as described in this text, with VAC or rotational flap, depending on the site.

Pressure ulcer grading, based on standards of the European Pressure Ulcer Advisory Panel.

ulcers, especially considering that Physical Medicine and Rehabilitation specialists are largely lacking in most of sub-Saharan Africa.

The European Pressure Ulcer Advisory Panel (EPUAP) has graded pressure ulcers to assist with decision-making and intervention (Table 1). It is important to note that the descriptions given are largely applicable to Caucasians and Asians; however, the type of care recommended for each grade, and the need for prevention, are universal.

Independence, social acceptance, freedom from discomfort, and a feeling of adequacy have been identified as the most important desires of patients with Spinal cord injuries (SCI). A causal relationship between pressure ulcer development and a combination of both environmental/extrinsic and systemic/intrinsic factors is accepted. Environmental and extrinsic factors include pressure, shear, and frictional forces. Systemic and intrinsic factors include neurological impairment, age, weight, and misture (fecal/urinary incontinence).

The recognition that pressure ulcer development is a very complex process has led to the formulation of a number of theories over the years, including:

1 **The neuropathic theory (Munro)** proposes an increased susceptibility of skin to pressure necrosis resulting from an interruption of autonomic reflex arcs and loss of circulatory reflex responses following spinal cord injury.

2 **The pressure-induced ischemia theory** states that constant pressures exerted on soft tissues for a sufficiently long time will result in pressure ulcers. The exerted pressure must be sustained, and must exceed 32 mmHg. A notable exception is in cerebral palsy patients, who do not develop pressure ulcers, even when placed in wheelchairs for long periods of time.

3 **The theory of differential pressure tolerance** is derived from the observation that different parts of the body bear different amounts of pressure, depending on the position taken by an individual, whether seated, standing, or lying down.

4 **The multifactorial hypothesis** involves a direct effect by one or more extrinsic (primary) factors, and potentiated and modified by a number of intrinsic (secondary) factors. This is the currently most accepted mechanism.

Identified risk factors for the development of pressure ulcers are primarily **environmental/extrinsic** (pressure, shearing forces and frictional forces) and **systemic/intrinsic** (neurological impairment, age, weight, moisture from fecal/urinary incontinence), predisposing conditions, etc).

The complexity of pressure ulcer evolution is further evidenced by the lack of agreement on their pathophysiology. There is the **deep tissue injury** theory, favored by most workers, holds that pressure ulcers initially develop around bone, and then progress outwards, to the skin. Then there is the **'top-to-bottom'** model suggests that tissue injury starts from the skin and progresses into deeper tissue. The deep tissue injury theory explains the reason for extensive muscle and subcutaneous tissue damage, with minimal skin involvement, lending weight to the expression 'tip of the iceberg,' which aptly describes most pressure ulcers.

The prevention of pressure ulcers is better than their cure, with basic skin care and adequate pressure dispersion as the primary tenets of prevention.

Pre-requisites for Surgical Intervention

Bladder care should be taught, with an emphasis on clean, intermittent self-catheterization (CISC). Condom catheters are fraught with complications, especially urethral fistulae. Indwelling catheters are only used in the post-operative period, until the patient can perform CISC again. Supra-pubic cystostomy is only performed after an urethroplasty or in a patient where pressure has destroyed the penis/penile urethra.

Bowel care is more difficult, as the anus is less accessible, and constant soiling contributes in a large part to wound infection, dehiscence, and recurrence. A colostomy is performed only in the uncooperative patient who permits constant soiling and pressure leading to either dehiscence or an early recurrence in the postoperative period. A colostomy may be required initially, as a lifesaving procedure in the septic patient. Some patients have noted such improvement in their ability to manage their toileting, that they have requested their colostomies be permanent.

The most important question facing the surgeon in the care of the paraplegic with pressure ulcers is whether to operate or not—and if not, when, if ever. The decision not to operate may be based on a number of factors, and most (in the opinion of the author) are patient idiosyncrasies. Surgical intervention must fulfill more than one of the above-stated goals of pressure ulcer care. While each patient with pressure ulcer(s) must be evaluated and managed individually, **some general principles are helpful in the decision-making process, especially in resource-constrained environments.**

Non-surgical management of pressure ulcers depends on the following predisposing cause(s):

1 Paralysis and level of paralysis.
2 Presence or absence of fecal and/or urine incontinence.
3 Severity of the ulcer (grade).
4 Patient idiosyncrasies (e.g. depression, family support).
5 Quality of nursing care (hospital and at home).
6 Financial endowment and equipment.

Upon completing the evaluation of a patient with pressure ulcers, it may become evident that, while surgery may improve a patient's body image in the short term by removing the ulcer along with its foul smell, the risk of recurrence is too high, and therefore would not be useful. The decision not to operate may be based on a number of factors, most of which are patient/care-taker related. ***The decision not to operate is not equivalent to denial of care***. Rather, it gives the clinicians, patients, and relatives the opportunity to re-evaluate the goals of care, motivation, and expectations, and thus enhance the outcome of the reconstruction.

Aggressive surgery is contraindicated in patients placed under palliative care in which the main goal is comfort, and **the following may be considered relative contraindications**:

1 Acutely injured patients who develop pressure ulcers in the first two months post-trauma. Most of these are in the process of dealing with the stress of status change, from an independent, mobile 'bread winner', to one who is dependent, compounded by the physical disability.

2 Depressed patients: these are often uncooperative, or unable to perform basic self-care.

3 Patients whose relatives/guardians are unavailable or unwilling to provide supportive care at home.

4 Patients who are yet to learn basic self-care tasks including bed to chair transfers, and turning.

5 Patients who have no reason to get better, no goals in life.

However, while patient support (both financial and family) may be poor or inadequate, patient motivation, goals in life, and demonstrated level of self-care may be sufficient to justify an aggressive surgical approach. The goal of surgery is to further improving the patient's degree of independence, self-image and social acceptability.

Tips

1 The patient must be able and willing to lie prone. Patients who object will usually be uncooperative. It is best to hold off surgical intervention until the patient is willing and able to lie prone. This is a position that the patient will ideally rest in for the most of the three months following surgical reconstruction. Patients who follow this regimen tend to have few recurrences. Care-takers/parents must likewise be willing to ensure child/patient positioning.

2 Dressing changes should be done with **each** bowel movement, to avoid soiling of incisions, leading to infection and wound breakdown.

3 If possible to measure, serum albumin levels should ideally be above 2.5 g/dL to ensure optimal wound healing.

4 Nutritional support with a local diet that ensures delivery of a high protein intake is essential for optimal wound healing.

Goals of Surgical Pressure Ulcer Therapy

1 Reduction of protein loss through the wound.
2 Prevention of progressive osteomyelitis and sepsis.
3 Avoidance of progressive secondary amyloidosis and renal failure.
4 Improvement of patient hygiene and appearance.
5 Avert future Marjolin's ulcer.
6 Lowering of the cost of rehabilitation.
7 To aid nursing care.

Aggressive efforts at adequate nutrition, infection control, physical therapy and surgery are warranted in patients with potentially reversible underlying causes of pressure ulcers. In chronically ill or palliative care patients, however, the goal of care is the provision of comfort only.

The principles underlying pressure ulcer surgical excision, established by Conway and Griffith in 1956, have not changed, and remain pertinent to date; these include:

1 Excision of the ulcer and surrounding scar, underlying bursa, and soft tissue (heterotopic) calcification, if any.
2 Radical removal of the underlying bone.
3 Padding of bone stumps, filling the dead space with fascia or muscle flaps.
4 Resurfacing defect with large regional pedicled flap.
5 Grafting the donor site of the flap with thick split skin, if needed.

Surgical Technique

Under general anesthesia, the patient is first catheterized and then turned prone. After draping the patient, the ulcer(s) is then painted with gentian violet, and the ulcer excised, along the principles outlined by Conway and Griffith. After surgical preparation, the wound is painted with sterile gentian violet solution (cheaper, and more readily available in Kenya than methylene blue). This maps out the ulcer margins along with any associated bursae and sinuses. A 3% hydrogen peroxide solution may be used to wash off excess gentian violet. The ulcer, surrounding scar, and any heterotopic bone are excised with a small cuff of normal tissue. An **excision less than this** will likely lead to a wound infection and dehiscence. Bone that is either prominent or infected should be excised and smoothed out with a rasp. It is important to ensure that the ostectomy does not lead to an imbalance between the two sides. This would lead to increased pressure and pressure ulcers on the contralateral side. The bone should then be padded and any dead space filled with flap tissue. A myocutaneous flap is ideal, if available, as this also provides skin resurfacing. If a myocutaneous flap is not available, then a fasciocutaneous flap can be used. Muscle does not prevent recurrence. Only the care as outlined above will prevent recurrence.

Common post-operative complications include hematomas, infections, wound dehiscence, recurrence, and heterotopic ossification of muscle flaps.

Independence, social acceptance, freedom from discomfort and a feeling of adequacy have been identified as the most important desires of patients with SCI. The recognition that pressure ulcer development is a very complex process has led to the formulation of a number of theories over the years, including:

1 The prevention of pressure ulcers is better than their cure.

2 Basic skin care and adequate pressure dispersion are the primary tenets of prevention.

3 The burden, both social and financial, that spinal cord injuries place on Sub-Saharan economies is enormous.

4 Patients with SCI face an even greater task in this environment.

Table 2

Pressure Ulcer	Primary Option	Secondary Option	Tertiary Option
Ischial ulcer	Inferior Gluteus Maximus Island Flap	Inferior Gluteal Thigh Flap	V-Y Hamstring Flap
Sacral ulcer	Y-V Gluteus Maximus Flap	Buttocks Rotation (fasciocutaneous) Flap	
Trochanteric ulcer	TFL	Vastus Lateralis Muscle	
Heel Ulcer	Medial Plantar Flap	Delayed Reverse Sural Artery Flap	Cross Leg Flap

Traditional flaps for repair of given pressure ulcers.

Fig. 1

Fig. 2

Fig. 3

Ischial Ulcer, treated with debridement and hamstring (biceps femoris) myocutaneous flap

5 Since rehabilitation is largely unavailable, since patients with SCI shift from independence to dependence on others, and because these patients lack the necessary tools to adjust to a completely new and physically irreversible social status, **many slide into depression**.

The social, healthcare, and transportation infrastructure in most of Sub-Saharan Africa is poorly adjusted to the physically challenged. With little or no government support, the family is forced to take financial responsibility for the care of the SCI patients.

Clinical Cases

1) A 30-year-old male, father of 4, a cobbler by profession. Spinal cord injury 12 years prior to current admission. Two previous admissions elsewhere for pressure ulcer care. Motivated, supporting his own family, but wheelchair bound. After discussion, and understanding of the process of treatment, wound excised and closed with a local flap. (See table 2, Figs. 1-3).

2) A 4 year-old girl with spina bifida and hydrocephalus. Ventriculo-peritoneal shunt placed at age four months. Child left with other children to permit mother go out and work. She developed bilateral trochanteric pressure ulcers, with septic hip joint arthritis and chronic osteomyelitis of both heads/necks of the femurs. Initial evaluation showed an albumin 1.4 g/dL. Wound debridement and nutritional support provided, albumin levels raised

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Figures 4-7: Trochanteric ulcer, bilateral—treated with soft tissue debridement, bilateral ostectomy, with right side Girdlestone and left side bony debridement only, and TFL flaps (Girdlestone procedure—removal of hip and trochanter).

to 2.5 g/dL. Discharged home for further nutritional support and wound care, pending definitive treatment. Review at 1 month, child malnourished, wounds infected, and albumin 1.5 g/dL. Child was re-admitted for nutritional support. Upon attainment of 3.0 g/dL, right Girdlestone and left debridement, with right tensor fascia lata flap. Left wound closed by secondary intention. Subsequent visits, child healthy, wounds completely healed (see Figs. 4-7).

3) Large chronic sacral ulcer secondary to irradiation. Debridement and large transverse back flaps with small hamstring flap to cover left side. Small breakdown on right side was treated with another hamstring flap (Figs. 8-11).

Fig. 8

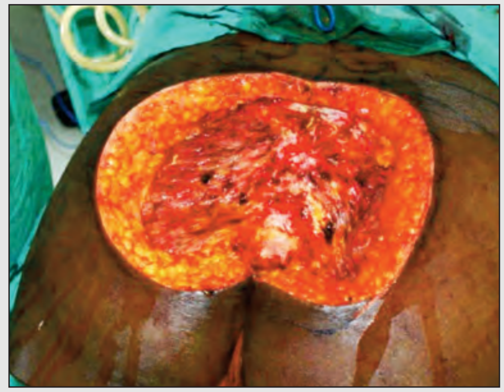

Fig. 9

Fig. 10

Fig. 11

Large sacral pressure ulcer was secondary to irradiation. Wide debridement and closure with large transverse back flaps was performed in one stage. These are perforator flaps.

(**Editor's Summary**: This is an excellent chapter with very specific guidelines for performing pressure sore, decubitus ulcer surgery anywhere in the world. Vacuum Assisted Closure (VAC) may be used if available to help prepare wounds for closure by flaps. In most cases, the flaps will not be sensate. Therefore, patients must be warned of this preoperatively so that they can continue diligent care of these areas post-op.)

Chapter 18

Abdominal Wall Catastrophes: Management and Reconstruction

Michael L. Cheatham and Joseph A. Ibrahim

(**Editors' Note**: We would like to thank Drs. Blair Summitt and Rick Miller for their contribution in the first edition.)

Introduction

Uncomplicated ventral hernia repair is a daily procedure for any surgeon. Complex abdominal wall reconstruction following an abdominal catastrophe, however, represents a difficult challenge and can be a burden upon both surgeon and hospital, especially in resource-limited settings. Chronic incisional hernias due to critical illness and/or malnutrition, damage control laparotomy for traumatic injury or abdominal compartment syndrome (ACS), loss of abdominal wall muscle and fascia due to infection or ischemia, exposed viscera due to fascial dehiscence, and enteric fistulae can all lead to significant patient morbidity and mortality. Perhaps most importantly, these processes can result in significant functional disability, inability to resume gainful work or employment, long-term attendant care from family members, and a financial burden upon both patient and family alike. While abdominal wall catastrophes should be prevented wherever possible, rapid functional resolution of these potentially devastating and life-threatening injuries should always be the surgeon's goal. This chapter will address the most commonly encountered abdominal wall catastrophes and present a variety of techniques for their management and reconstruction.

Principles of Abdominal Wall Closure

The avoidance of complex abdominal wall defects should always be a primary goal for any surgeon. This requires precise surgical technique, careful post-operative resuscitation and nutritional support, meticulous attention to wound care, and a high index of suspicion leading to early diagnosis and intervention when abdominal wall catastrophes occur. Unfortunately, critical illness and injury may result in events over which the surgeon has little or no control. He/she must therefore reconstruct the abdominal wall using whatever anatomic resources are available, supplemented by experience and ingenuity.

The basic principles of successful abdominal wall management are the same no matter what the cause:

- Tension-free apposition of tissue edges.
- Avoidance of ischemia.
- Careful placement of abdominal drains, tubes, and ostomies to facilitate subsequent abdominal wall closure.

Fig. 1

Fig. 2

1) Complex closure of a massive incisional hernia using component separation technique (CST), performed with excessive tension.

2) Subsequent necrosis of anterior abdominal wall with underlying fascial dehiscence due to high intra-abdominal pressure (IAP) and inadequate perfusion of both skin flaps and rectus sheath. The resulting abdominal wall fascia loss required complex free flap and rotational flap repair.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

- Early recognition and treatment of elevated intra-abdominal pressure (IAP).

The avoidance of abdominal wall complications commonly begins at the time of initial laparotomy closure. Care should be taken to avoid closing the patient's fascia under excessive tension. After performing a prolonged and complex intra-abdominal procedure, the natural tendency of the young surgeon is to rapidly (and perhaps inattentively) close the abdominal fascia while reveling in the satisfaction of having completed another "great case". This enthusiasm wanes, however, on post-operative day four or five when the nursing staff informs the surgeon that the patient has just coughed and eviscerated on the ward. Tissue anastomoses subjected to strain are commonly made ischemic, dooming the repair to anastomotic breakdown or subsequent hernia formation (Figs. 1 and 2). With experience, a surgeon of excellence comes to recognize the importance of meticulous, tension-free fascial closure in avoiding subsequent fascial complications.

While running vs. interrupted abdominal wall closure has been found to be equivalent in several randomized clinical trials, the method by which these two closure methods are employed is what is key (Figs. 1-2). When a running closure technique is utilized, sutures should be placed at least 1 centimeter apart and 1 centimeter back from the fascial edge taking care to "reapproximate, but not strangulate" the fascial edges. Tearing of a running suture through ischemic fascia serves to loosen the entire abdominal wall closure and predispose patients to subsequent incisional hernia formation. This likelihood is increased in the presence of systemic hypotension, sepsis, abdominal wall ischemia, or elevated IAP where blood flow through the rectus sheath can be reduced by up to 80%.[3] Interrupted fascial closure can also result in ischemia if the sutures are tied too tightly. Fascial tearing at one or two of these interrupted closures, however, does not have the same impact upon the entire abdominal closure as in a running closure. Interrupted closure should be strongly considered in patients at risk for fascial failure such as previous dehiscence, critical illness, or malnutrition.

Many of the abdominal wall reconstruction techniques described below are dependent upon the anatomy of the abdominal wall musculature and fascial layers for success. While prosthetic mesh (either permanent or biologic) is commonly utilized, it may not be available in the developing world and is associated with both increased cost and the attendant risks of infection and surgical adhesions. In the majority of patients with complex abdominal wall issues, prosthetic mesh can be avoided through careful use of the patient's own tissues. The patient's abdominal wall should therefore be preserved as much as possible to facilitate subsequent definitive fascial closure. Indiscriminate insertion of transabdominal drains, feeding tubes, and ostomies at the time of initial laparotomy may interfere with subsequent use of these tissues to achieve a definitive abdominal closure.

Perhaps the greatest failure is the patient whose abdomen was "a little tight" at the time of closure and who demonstrates anuria and respiratory insufficiency or failure on the morning following surgery. Elevated IAP, caused by visceral edema, hemoperitoneum, or retroperitoneal hemorrhage reduces both visceral and abdominal wall blood flow and significantly increases the risk of abdominal wall catastrophes as well as patient mortality.[3-8] Over the past two decades, the management of complex abdominal processes has significantly evolved with the recognition that, in some critically ill patients, it is not a question of whether the abdomen should be closed, but rather whether the abdomen should be left open. Closure of a patient's abdomen under tension with resultant increases in IAP is a significant cause for many of the abdominal wall catastrophes that will be addressed in this chapter. Avoiding such injuries thus begins with how the abdomen is managed during the initial laparotomy.

Simple Incisional Hernia Repair

Depending upon the procedure performed, 2-20% of all laparotomies will result in an incisional hernia. The reasons for hernia formation are multiple, but include technical failure, critical illness, malnutrition, obesity, or early strenuous activity among others. Depending upon the size, location, and complexity of the hernia defect, primary suture repair may be appropriate, but is associated with a recurrence rate of up to 50%. As a result, incisional hernia repair using prosthetic mesh has become common as it is associated with a low recurrence rate less than 5%. Mesh may not be available in the developing world or in resource-limited settings, necessitating the use of the patient's own tissue for incisional hernia repair.

When the fascial defect is small and the fascial edges can be reapproximated without tension, primary repair can be performed using well-placed Fig. of eight interrupted monofilament sutures. Attenuated or non-viable fascia should be debrided to ensure that healthy tissues are used in the repair. Sutures should be placed at least 1 cm back from the fascial edge and should be tied without causing ischemia to the tissues. Care should be taken to dissect any viscera away from the posterior rectus sheath so that adequate placement of fascial sutures can be performed.

When a tension-free primary closure of the patient's fascia cannot be achieved, one of the simplest techniques for achieving fascial closure in the presence of a fascial defect less than 10 cm in width is to perform bilateral relaxing incisions in the anterior rectus sheath. Skin and subcutaneous tissue flaps are raised bilaterally, exposing the anterior rectus sheath. The anterior rectus sheath is incised with electrocautery allowing the fascia and rectus muscles to move medially. The size of the fascial defect determines where the rectus sheath is incised: small fascial deficits can be repaired by incising the anterior rectus sheath in the midline of the rectus muscle, while larger defects require incising the rectus sheath just medial to lateral edge of the rectus muscle. The cut lateral edges of the anterior rectus sheath are then sewn together in the midline bridging the fascial defect without tension. The skin and subcutaneous tissue flaps are then closed over closed suction drains in the normal fashion. This effectively provides visceral coverage and definitive closure of small to moderate fascial defects that cannot be safely closed using direct fascia-to-fascia apposition. Prosthetic mesh is usually not necessary, but can be sewn to the cut edges of the anterior rectus sheath to reinforce the repair if available.

If available, prosthetic mesh is useful in the repair of abdominal wall hernias and does significantly reduce the recurrence rate of such hernias. Mesh repair can be complicated by infection, mesh extrusion, and enteric fistula formation (Figs. 3-4). Further, mesh should not be used in a contaminated or infected field. Placing peritoneum or omentum between the mesh and intestine reduces adhesions and fistula formation, but is not always possible. Intraperitoneal placement of polypropylene mesh products should be avoided at

Fig. 3

Fig. 4

3) Exposed infected prosthetic mesh placed in a previous incisional hernia repair.

4) Viscera adherent to the infected mesh requiring a complex abdominal wall reconstruction and significant risk for intestinal injury and enteric fistula formation

(Pictures courtesy of Dr. Rick Miller, Vanderbilt Medical Center, Nashville, Tennessee) all costs due to a high rate of enteric fistula formation and intestinal obstruction.

Complex Incisional Hernia Repair

Repair of the large or multi-loculated incisional hernia represents a significant challenge, especially in the presence of previous abdominal wall tissue loss, extensive abdominal adhesions, or the presence of an ostomy. Chronic hernias are typically associated with significant lateralization of the fascia such that tension-free primary reapproximation of the fascial edges is not possible. The use of fascial relaxing incisions, prosthetic mesh, and component separation techniques therefore becomes essential to successful repair.

When planning definitive hernia repair, there are multiple issues to consider. These factors include the size of fascial defect, the presence of an ostomy or enteric fistula, the patient's nutritional status, abdominal wall integrity, immunosuppression, use of high dose steroids, and other comorbidities.

The **component separation technique (CST)**, as originally described by Ramirez et al., is commonly used to repair large midline abdominal hernias.[9] It is a myofascial release that separates the components of the abdominal wall, allowing their medial mobilization to allow closure of fascial defects. Classic CST involves releasing the rectus muscle from its posterior sheath and releasing the aponeurosis of the external oblique muscle along the lateral side of the rectus, allowing the rectus muscle to slide toward the midline with its attached internal oblique and anterior rectus fascia. Fascial defects up to 10 cm wide at the upper abdomen, 20 cm at the waistline, and 6 cm at the suprapubic region may be closed using this method. CST allows safe closure of abdominal wall defects even if patients have concurrent bowel surgery, contaminated wounds, or stomas. It offers dynamic support that increases torso strength by 40% and relieves back pain.

The following steps outline the classic CST procedure:

1 Through a laparotomy incision, the posterior rectus sheath is cleared bilaterally of any attachments to the viscera through careful lysis of adhesions. Care should be taken to not rush through this dissection, as any resulting enterotomies may result in an enteric fistula that will cause failure of the repair.

2 The rectus muscle is loosely attached to its posterior sheath, and can be freed from the posterior sheath as originally described by Ramirez. In our experience, this step is necessary only when one is faced with very large hernias. Freeing the rectus muscle from its' posterior sheath allows advancement of this muscle by 3

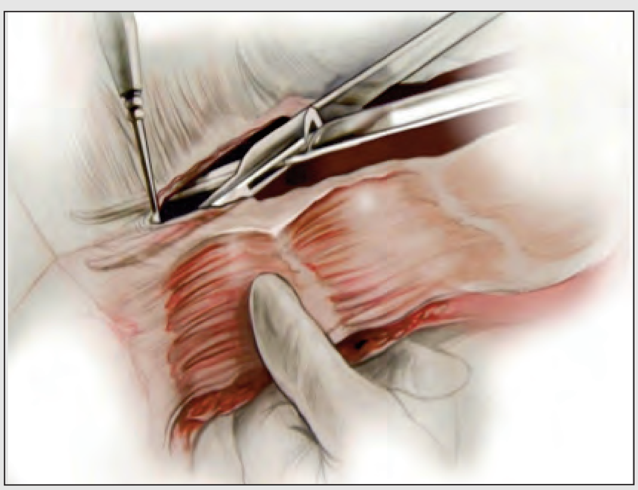

Fig. 5

Fig. 6

5) Incision of external oblique aponeurosis lateral to rectus sheath.

6) Dissection of avascular plane between the external and internal oblique aponeuroses.

(Pictures courtesy of Dr. Rick Miller, Vanderbilt Medical Center, Nashville, Tennessee, and Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida) cm in the upper third, 5 cm in the middle third, and 3 cm in the lower third.

3 Elevate the skin and subcutaneous tissues from the anterior rectus sheath using electrocautery. Develop this plane until about 2 cm beyond the lateral edge of the rectus sheath (linea semilunaris). Further lateral dissection in thin patients with limited subcutaneous tissue may place the resulting skin flaps at risk for ischemia and failure, resulting in a large soft tissue defect that will require split-thickness skin grafting.

4 Carefully incise the external oblique aponeurosis 1 to 2 cm lateral to the lateral edge of the rectus sheath (Fig. 5). Extend this incision parallel to the rectus muscle, superiorly advancing at least 5 to 7 cm above the costal margin, and inferiorly down to the suprapubic region. The plane between the external and internal oblique aponeuroses is relatively avascular, and should be bluntly dissected free down to the mid to posterior axillary line (Fig. 6).

5 These maneuvers should allow the rectus muscle to slide toward the midline to bridge the fascial gap. The medial edges are sewn together, as in a standard laparotomy closure, with interrupted monofilament suture. Drains are placed in the subcutaneous space, and the skin and subcutaneous flaps are closed in the usual manner (Figs. 7 and 8).

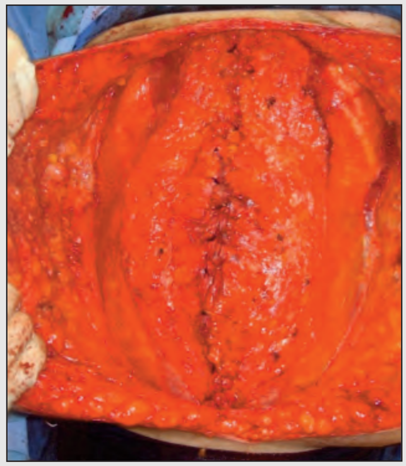

Fig. 7

Fig. 8

7) Completed CST with tension-free closure of fascial edges. Note the separation of the external oblique aponeurosis allowing medial mobilization of the fascia.

8) Closure of the skin and subcutaneous tissues with two closed-suction drains beneath the flaps to avoid seroma formation.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

Important points to improve the success of the CST procedure are:

- Avoid dissecting too deeply laterally when releasing the external oblique, as this can cause injury to the internal oblique and result in herniation or even rupture of the abdomen in this area.

- Most hernia recurrences following CST occur in the epigastric region, so it is very important to perform adequate detachment of the lateral aspect of the rectus muscle above the costal margin, preserving the continuity of the rectus with the pectoral muscle and their contiguous fascia, so that the upper rectus can be mobilized to fill in the epigastric region. This is an area of natural tension due to elevation of the costal margins during respiration.

- Closure of the abdominal cavity in the presence of significant loss of abdominal domain can acutely elevate the IAP and interfere with diaphragmatic excursion. If respiration is compromised, ensure full release such as releasing the posterior rectus sheath. Close attention should be paid to the patient's mean airway pressure on the anesthesia machine. If mean airway pressures rise significantly, there may be too much tension on the fascial closure. Either a staged repair of the patient's abdomen or use of mesh or autologous tissue to bridge the fascial gap may be required for safe closure.

The most common complications following CST are wound infections and hernia recurrence, affecting 20-50% of patients. A randomized controlled trial comparing CST with prosthetic mesh repair for giant abdominal wall hernias found that wound infections in patients after CST have only minor consequences in most cases, but wound infection following prosthetic placement has major consequences, such

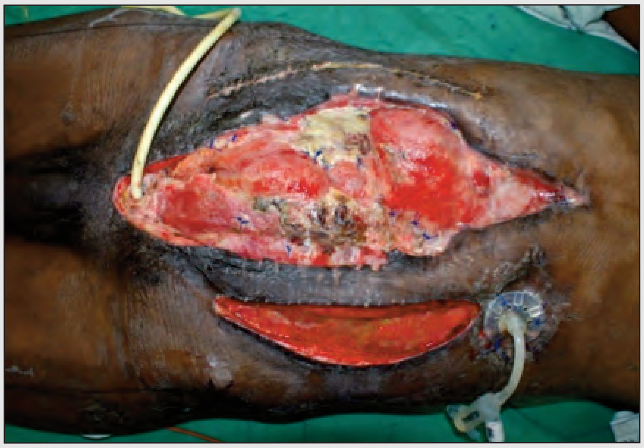

Fig. 9

Fig. 10

An anterior abdominal wall defect after a failed CST. Pedicled ALT was used to reconstruct this defect successfully (Photos courtesy of Dr. Bill Rhodes).

as requiring removal of the prosthetic in 39% of cases. Recurrent hernias following CST are generally small, located in the midline of the upper abdomen and relatively asymptomatic.

When CST is not possible due to tissue loss or the defect exceeds the capability of CST, more complex repairs using autologous tissue may be necessary. This includes the use of both rotational and free muscle flaps. The fascia lata graft, which uses the strong, dense fascia at the lateral side of the upper leg, can be used as a free transplant or as a pedicled flap (the tensor fascia lata flap). This flap can reach infraumbilical abdominal wall defects. The posterior condensation of the iliotibial tract is not taken during the fascial harvest in order to minimize lateral knee instability. The rectus femoris muscle flap has been used pedicled on the lateral circumflex artery and tunneled subcutaneously, or as a free flap, but is associated with significant loss of muscle strength in knee extension. The latissimus dorsi, fed principally by the thoracodorsal artery, can similarly be used as a pedicled or free flap. The pedicled anterolateral thigh flap is excellent for the reconstruction of extensive full-thickness abdominal wall defects, including skin and fascia, with minimal donor site morbidity. The use of pedicled and free flaps is recommended for complicated abdominal wall defects that have failed other approaches, but CST is preferred for the initial management of abdominal wall hernias as it is simpler, not associated with donor site morbidity, and results in a dynamic abdominal wall repair (Figs. 9 and 10).

Definitive Abdominal Wall Closure Following the Open Abdomen

Definitive closure of the abdomen which has been left open as part of a damage control laparotomy can be performed using a number of methods including delayed primary fascial closure, component separation, prosthetic mesh bridge closure, skin only closure, and split thickness skin graft (STSG) closure.[8] Each of these techniques has an appropriate role, depending upon the needs of the patient and the origin of the hernia. With regard to damage control laparotomy, recent evidence suggests that the goal should be to obtain tissue coverage of the viscera within fourteen days of initial laparotomy by whichever of the above methods is possible. Two key factors to achieving successful abdominal closure are 1) a protocolized approach to managing the open abdomen, and 2) the commitment of a single surgeon to facilitate consistent attempts at abdominal closure.[6,8,10]

Primary fascial closure should always be the goal in repairing any open abdomen as it is associated with the lowest mortality, enteric fistula rate, length of hospital stay, and hospital cost.[11] Primary repair is also associated with the highest functional recovery. This is typically achievable in an average of five days following initial damage control laparotomy when the resuscitative principles outlined above are followed. The success of this approach has steadily increased over the years as the standardized approach to damage control and the open abdomen has evolved.[8] Start considering your options for abdominal closure beginning with the initial laparotomy. Don't wait until the patient's abdomen is "frozen" and hostile; at that point, split thickness skin grafting is usually the only option. Aggressively work to avoid lateralization of the fascia, loss of abdominal domain, and fixation of the viscera to the abdominal wall. In doing so, you will greatly improve the changes of achieving definitive fascial closure and reducing your patient's long-term morbidity and mortality.

In our practice, we perform primary fascial closure by approximating the patient's fascia using interrupted monofilament Figure-of-eight sutures. These patients are at risk for fascial dehiscence, and tolerate this closure technique with less risk for evisceration or chronic incisional hernia formation, as opposed to a running closure. In the presence of multiple risk factors for dehiscence (malnutrition, immunosuppression, malignancy, tobacco use, steroid use), we also employ retention sutures leaving these in place for at least four to six weeks. These involve placing a suture through the skin, soft tissue, and fascia with the suture passed through a catheter to decrease the pressure of the suture on the abdominal wall skin. While such sutures do not prevent hernia formation, they do reduce the incidence of evisceration should the fascial closure begin to fail.

A decade ago, virtually all patients who underwent damage-control laparotomy and temporary abdominal closure required the component separation technique to achieve fascial closure. With improved resuscitation and management, true component separation is now reserved solely for the most complex abdominal wall repairs. It also should not be used early in the patient's abdominal wall closure process, but rather used as the final definitive approach to avoid damaging the patient's fascia for long-term repair.

Prosthetic mesh "bridge" closures of abdominal wall fascial defects used to be commonplace, but have less of a role with improved patient management and resuscitation (Figs. 11 and 12). They should not be considered a definitive repair, but rather a temporary repair of an incisional hernia that will need to be addressed at a later point in time. Such a technique is appropriate in the patient who has a hostile abdomen that precludes definitive fascial repair, and in whom there is concern for ongoing lateralization of the fascia. An absorbable mesh is sewn to the fascia circumferentially "bridging" the defect and preventing evisceration. Either split thickness skin grafting of the mesh, once granulated, or closure of skin and subcutaneous tissue flaps over the mesh achieves abdominal closure. As the mesh is reabsorbed over the following months, a large incisional hernia will develop which can be definitely repaired once the patient has recovered from their critical illness and their nutritional state and healing have been optimized. At no point should permanent prosthetic mesh be placed in contact with the viscera, as this will lead to adhesions (requiring laparotomy for bowel obstruction) or enterocutaneous fistula (ECF) formation.

Skin-only closure is just as it sounds. One should consider this when the abdomen has been open nearly two weeks and tissue coverage of exposed abdominal viscera is necessary so as to decrease the risk of fistula formation. This typically requires suturing of the subcutaneous tissues using absorbable suture and closure of the skin using monofilament nylon. This obviously results in

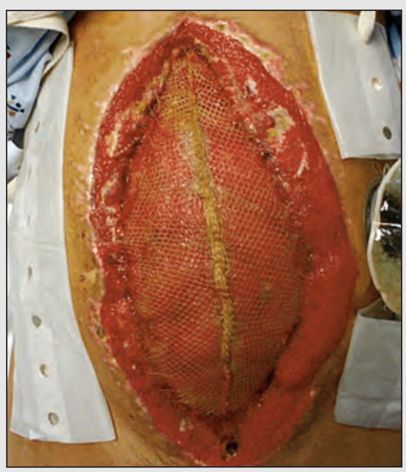

Fig. 11

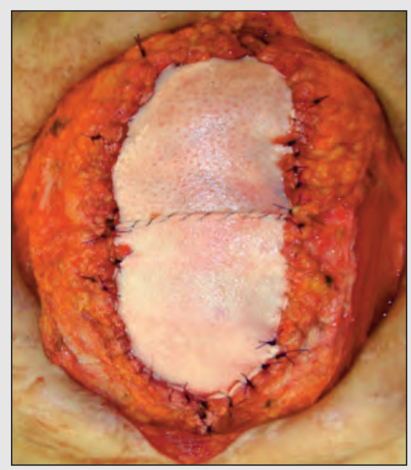

Fig. 12

11) Absorbable mesh interposition graft in a patient with loss of abdominal domain and an ostomy that precludes CST repair. Following granulation of the mesh, a split thickness skin graft was placed with subsequent CST 9-12 months later.

12) Porcine bioprosthetic mesh interposition graft in a patient with loss of domain and inability to tolerate fascial closure due to respiratory insufficiency.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

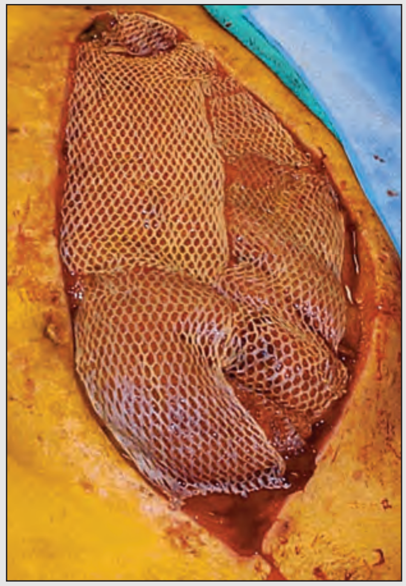

Fig. 13 **Fig. 14**

13) Granulated abdominal viscera and a hostile abdomen that cannot be closed.

14) Meshed split thickness skin graft over granulated viscera.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

formation of a large abdominal wall hernia that can be addressed once the patient is more stable and risk factors have been optimized. Such closures are also useful in the critically ill elderly patient, who physiologically might not tolerate fascial closure and is unlikely to do heavy lifting following recovery.

Finally, one can perform a **split thickness skin graft (STSG)** to provide tissue coverage over the abdominal viscera (Figs. 13 and 14). Quite commonly performed a decade ago, this is now rarely necessary and is associated with the highest cost, length of stay, and patient morbidity. A skin-only closure is preferable to STSG if at all possible. It is possible to place a STSG on exposed viscera, but the success is increased by allowing sufficient time for adequate granulation tissue to form on the exposed intestine. This creates a planned ventral hernia that can be repaired 9-12 months in the future once the STSG has separated from the underlying viscera and the patient has recovered sufficiently from their critical illness.

Temporary Abdominal Closure Techniques

Damage control laparotomy and the "open abdomen" are now the method of choice for managing patients who are at the highest risk for abdominal wall catastrophe. While potentially life-saving, the decision to leave a patient's abdomen open and apply a temporary abdominal closure is one that should not be undertaken lightly, as successful use of this technique requires a concerted team approach led by surgeons and supported by nurses, respiratory therapists, nutritionists, and enterostomal therapists when available.

A temporary abdominal closure technique should be considered whenever the patient demonstrates signs of the "deadly triad": hypothermia, acidosis, and coagulopathy. Such patients are at marked risk for intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) due to visceral edema and elevated IAP. Such techniques should also be considered in the patient with severe intra-abdominal sepsis or peritoneal contamination, where relaparotomy and washout within 48 hours is indicated. Patients whose abdomen is left open in this manner can usually be successfully closed through delayed primary fascial closure within several days of initial laparotomy and have a significantly decreased risk of IAH/ACS and organ dysfunction/failure, as can occur with patients whose abdomen is closed under tension.

Leaving the patient's abdomen open and exposing the viscera to the external environment does place them at risk for visceral injury and subsequent "entero-atmospheric" fistula (EAF) formation. "Temporary abdominal closure" dressings protect the viscera from injury, minimize heat and evaporative fluid loss, and greatly simplify patient care. A variety of temporary abdominal closure techniques have been described.[8-16] While commercially available temporary abdominal closure dressings may not be available in the developing world, they can be effectively replicated with supplies commonly available in most operating theatres. A key principle to use of temporary abdominal closures is that they should avoid use of the fascia as this will only serve to damage the fascia prior to its subsequent use in definitive reconstruction.

Early methods for temporary abdominal closure included the use of surgical towel clips or running suture to rapidly close the patient's skin (Fig. 16). While covering the viscera and preserving the fascia intact, these methods are the least compliant of the temporary abdominal closures, and tend to increase IAP and place the patient at risk for IAH / ACS as well as acute renal and respiratory failure. They should likely be avoided in favor of one of the temporary abdominal closure methods described below.

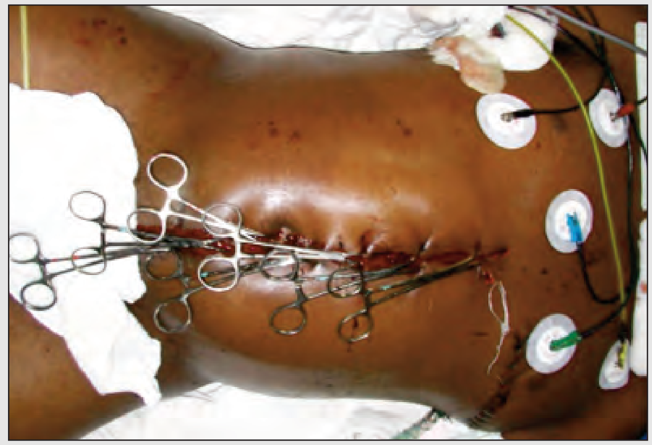

Fig. 15

A temporary abdominal closure using surgical towel clips to rapidly close the abdomen.

(Picture courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

Perhaps the simplest temporary abdominal closure is the so-called "Bógota Bag", named for the Colombian surgeons who initially described its use. A three-liter genitourinary irrigation bag is emptied and opened on three sides to create a strong, non-adherent prosthesis which can be sewn to the skin edges with heavy gauge suture (Figs. 17 and 18). It is essential to use only the skin for this closure, preserving fascial integrity for later definitive repair. The Bógota Bag technique is inexpensive and easy to perform, but does not allow for collection of intra-abdominal fluid. An additional advantage is that it allows the surgeon to visualize the viscera at the bedside and assess for the presence of intestinal ischemia. While a sterile plastic bag is preferable, clinical experience has shown that any clean non-sterile plastic drape may be substituted without significantly increasing the risk of intra-abdominal infection.

The most commonly utilized temporary abdominal closure used worldwide is the so-called "Barker vacuum-pack" dressing.[15,16] This dressing consists of a fenestrated / pie-crusted non-adherent plastic drape placed over the viscera and tucked well under the fascial edges of the wound. Gauze or surgical towels are placed over the plastic drape along with one or two nasogastric tubes or surgical drains (Figs. 18 and 19). The entire dressing is secured to the abdomen with a large adhesive dressing. The drains are then connected to a vacuum source to collect intra-abdominal fluid. The Barker dressing is inexpensive, allows control and quantification of peritoneal fluid

Fig. 16

Fig. 17

16) A plastic intravenous bag is emptied and opened on three sides to create a strong, nonadherent prosthesis that can be sewn to the patient's skin in an abdomen that cannot be safely closed following damage control laparotomy. This technique is inexpensive, easy to perform, and uses materials that are readily available in any hospital.

17) A similar "Bógota Bag"; note the significant visceral distention that prevents safe abdominal closure.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

Fig. 18

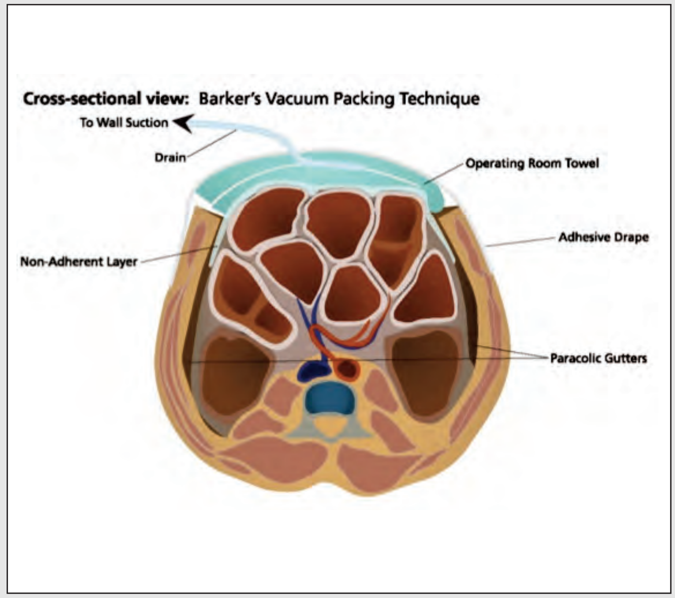

Fig. 19

18) Barker's "vacuum-pack" temporary abdominal closure dressing. A non-adherent plastic bag or drape is "pie-crusted" to allow passage of fluids. This is placed over the viscera, tucking it under the fascial edges of the wound. This helps to prevent adherence of the viscera to the abdominal wall, thus limiting subsequent closure of the abdomen. A moist surgical towel or gauze is applied over the drape. Two large closed-suction drains are placed over the towel and the entire dressing is covered with a large adherent plastic drape. The drains are then placed on continuous suction.

19) Cross-sectional view of Barker's dressing.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

losses, and avoids damage to the fascia.

Negative pressure wound therapy (NPWT) dressings are increasingly being utilized to manage complex wounds in both the developed and developing world.[13,14,16] Commercial NPWT temporary abdominal closure dressings are available and have been demonstrated to significantly increase patient survival following damage control laparotomy.[13] The key principles to successful use of these dressings are interposition of a large plastic sheet between the polyurethrane foam and viscera (to avoid EAF formation) and tucking the plastic sheet well back into the abdominal gutters bilaterally to both facilitate removal of pro-inflammatory, cytokine-rich intra-peritoneal fluid and prevent visceral adherence to the abdominal wall allowing subsequent delayed primary fascial closure.

Common Abdominal Wall Catastrophes

Abdominal Compartment Syndrome

The physiologic impact of IAP on abdominal organ perfusion and function has been recognized for almost 200 years.[4-7] Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS), the pathophysiologic implications of elevated IAP, have detrimental effects on all organ systems and are associated with significant morbidity and mortality. One of the most important aspects of abdominal wall management is recognizing the patient's risk for developing IAH/ACS. Serial measurements of IAP are essential to this endeavor. IAP is most easily measured by transducing the pressure of the urine within the bladder (Fig. 21). Normal IAP is less than 5 mmHg.[4] Following uncomplicated laparotomy, a patient can be expected to have an IAP of 10-15 mmHg. IAH is defined as an IAP ≥ 12 mmHg. ACS is defined as an IAP > 20 mmHg with associated organ dysfunction (hypotension, oliguria refractory to volume resuscitation, refractory acidosis, hypercarbia, hypoxemia refractory to oxygen administration, high peak inspiratory pressures).[7,10]

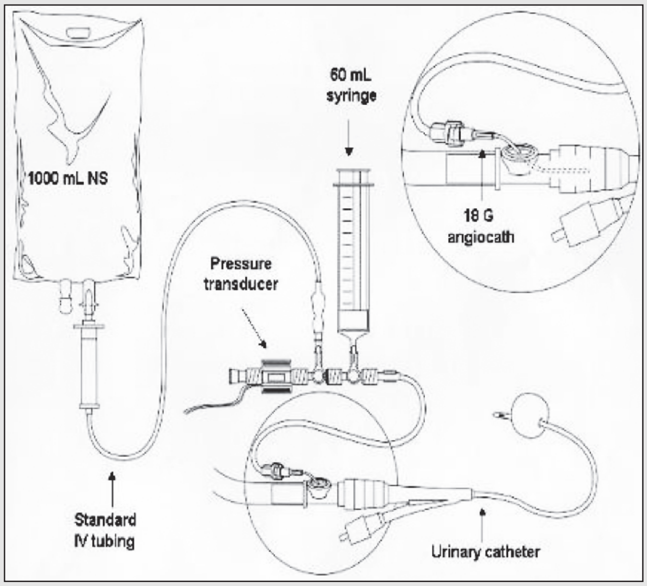

Fig. 20

A closed, needle-free system for IAP measurement. Normal saline, a 60-mL Luer lock syringe, and a segment of pressure tubing are attached to a pressure transducer connected to two stopcocks. An 18-gauge angiocatheter is inserted into the culture aspiration port of the urinary drainage tubing and the needle removed, leaving the plastic infusion catheter in place. The infusion catheter is connected to the pressure tubing and the system flushed with normal saline. The drainage tubing is clamped, 25 mL of saline is instilled into the bladder, and the patient's IAP is measured. The clamp is removed and the saline is allowed to drain from the bladder.

(Picture courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

The management of patients with IAH / ACS has evolved dramatically in recent years, resulting in significant improvements in abdominal closure rate, resource utilization, and, most importantly, patient survival.[8] These improvements appear to be temporally related to the application of a multi-modality management strategy that is based upon four general principles: 1) serial IAP monitoring, 2) institution of medical interventions to reduce IAP and the end-organ consequences of IAH/ACS, 3) prompt surgical decompression for IAH/ACS refractory to the above therapeutic interventions, and 4) early abdominal closure following resolution of the patient's critical illness.[7]

The key to managing ACS is prevention. First, avoid excessive fluid resuscitation. To accomplish this goal, monitor the patient's urinary output and blood pressure closely so that the intravenous fluid choice (0.9% normal saline or Lactated Ringer's solution) and rate are optimized to the patient's needs. The appropriate intravenous fluid choice and the chosen rate of administration play a vital role in a patient's risk for ACS as well as other complications. In the presence of hemorrhagic shock, early transfusion of whole blood or blood products in a 1:1:1 ratio for packed red blood cells, plasma, and platelets further decreases the need for crystalloid. This goal-directed therapy has been advantageous in decreasing multiple complications, including ACS.

Once IAH or ACS have been identified, there are multiple non-surgical options to consider initially (Fig. 22). First, adequate analgesia and sedation should be administered, as a patient in pain tightens the abdominal wall musculature, thus increasing the IAP and reducing intra-abdominal blood flow. Second, appropriate nasogastric and or rectal decompression should be initiated to decompress the viscera. Third, judicious fluid resuscitation and removal should be implemented. Fourth, percutaneous drainage of intra-abdominal fluid collections identified via ultrasound or other imaging modalities can effectively reduce IAP and treat IAH. If the patient progresses to ACS, early decompressive laparotomy should be performed with maintenance of an open abdomen until the patient's critical illness is improving.

Loss of Abdominal Domain

In patients with an open abdomen, lateralization of the fascial edges, and evisceration of the abdominal contents through the fascial defect, definitive repair and return of the visceral contents to the abdominal cavity can have detrimental effects upon the patient's pulmonary status (due to cephalad elevation of the diaphragm) and intra-abdominal organ function (due to acute increases in IAP and decreased

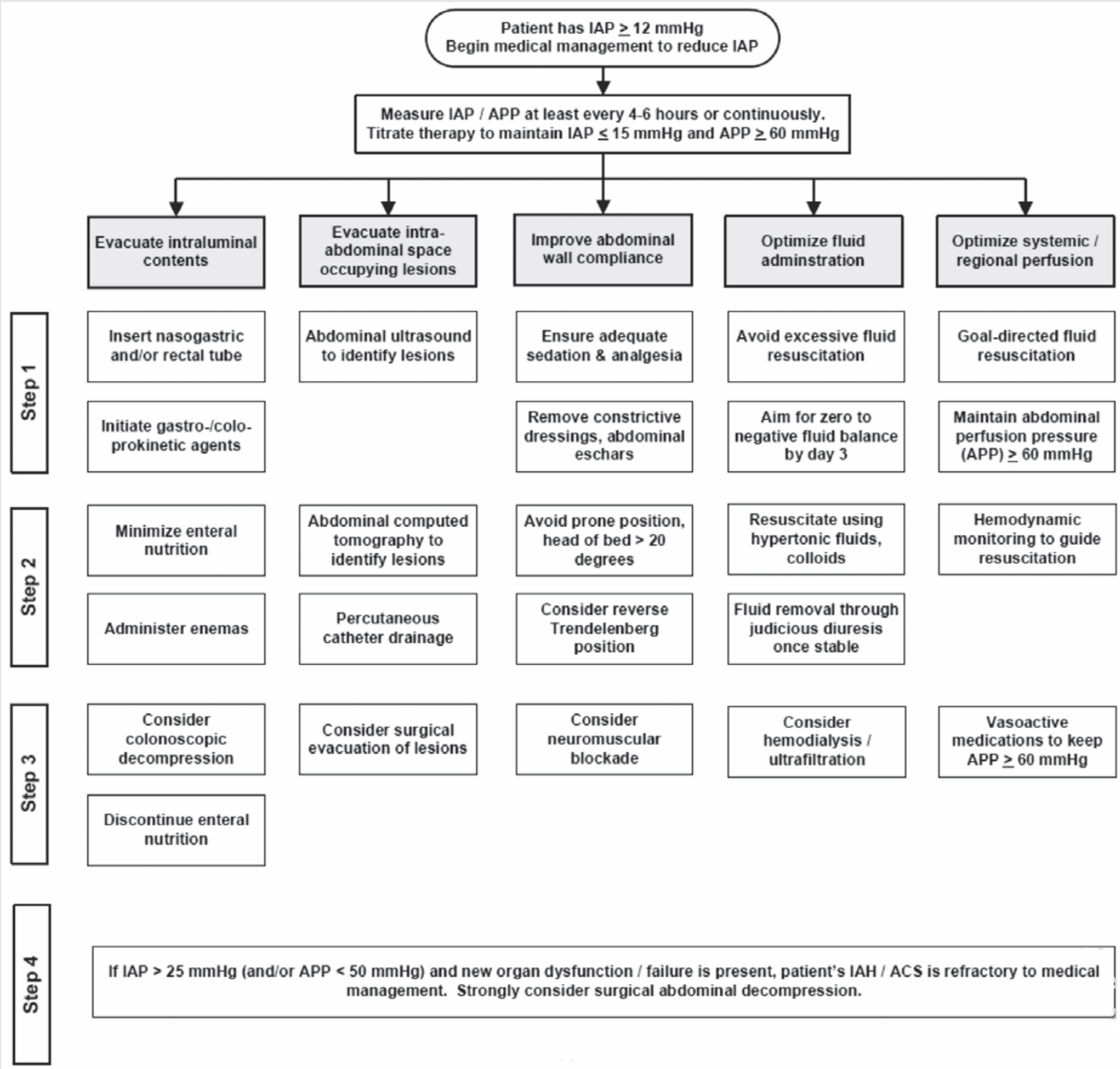

Fig. 21

IAH / ACS medical management algorithm. The interventions should be applied in a stepwise fashion until the patient's IAP decreases. If there is no response to a particular intervention, therapy should be escalated to the next step in the algorithm.

(Picture courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida).

organ perfusion). It is therefore essential that careful attention to IAP, peak airway pressures, and urinary output be maintained during attempts to close a patient's abdomen. In patients with loss of abdominal domain who cannot be safely closed in a single procedure, we utilize a technique called "progressive abdominal closure". Transabdominal retention sutures are placed and serially tightened over a period of days to weeks to slowly approximate the fascia as tolerated by the patient's pulmonary and renal function.

In patients with large chronic hernia defects, repair of the hernia and return of the hernia contents to the abdominal cavity for similar reasons can also have detrimental effects upon organ function. As a result, such patients must be carefully evaluated pre-operatively to determine whether hernia repair might actually be harmful. We have a number of patients in our practice with massive incisional hernias and loss of abdominal domain that, after careful evaluation of their cardiopulmonary status, we have chosen to follow closely with non-operative management as the potential benefits of hernia repair outweigh the risks of perioperative morbidity and mortality. Such hernias can generally be managed quite effectively with an abdominal binder or women's girdle allowing the patient to work and resume a productive lifestyle.

Loss of Abdominal Wall Muscle and Fascia

Loss of abdominal wall tissue as a result of necrotizing fasciitis or ischemia presents a special problem, as the normal anatomic components available for reconstruction have potentially been lost. While one of the most unusual of the abdominal wall catastrophes, it is perhaps the most challenging. Initial management relies upon the principles of the open abdomen to protect the exposed viscera and prevent heat and evaporative loss. Our preference would be to apply either a Barker vacuum pack or NPWT dressing as a plan for definitive management is developed. Once the infection or ischemia is controlled, tissue coverage should be pursued as rapidly as possible to decrease the risk of enteric fistula development. If the tissue loss is primarily fascial, skin and subcutaneous tissue flaps can be raised and approximated over the viscera. If available, tissue expanders can be used over time to generate additional skin for coverage. If skin loss is significant, rotational or free vascular flaps from the thigh can be employed to obtain visceral coverage.

Fascial Dehiscence with Exposed Viscera

Fascial dehiscence should always be considered a surgical emergency. Evisceration of the intestinal contents through a small fascial defect can lead to strangulated intestine, perforation, and enteric fistula. These events are most likely to occur 5-14 days post-operatively at a time when re-entering the patient's abdomen can be fraught with difficulty. Nevertheless, the patient should immediately be returned to the operating theatre with careful reduction of the eviscerated tissue and meticulous closure of the fascia to prevent recurrence. If the fascial defect is large, the viscera is not at risk for strangulation, and the abdomen is hostile such that re-entering the abdomen would prevent excessive risk, simply closing the skin and subcutaneous tissue over the exposed

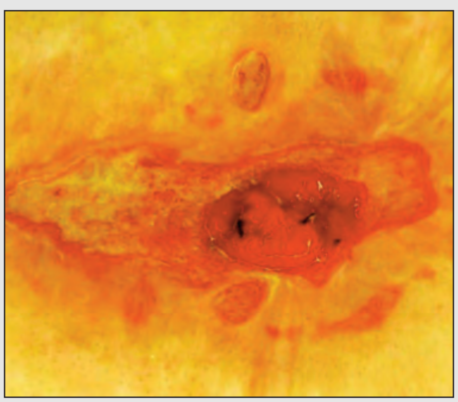

Fig. 22

Fig. 23

Fig. 24

22) Enterocutaneous fistula due to anastomotic dehiscence. Note visible silk sutures which prevent spontaneous closure.

23) Complex open abdominal wall defect with entero-atmospheric fistula arising from granulated viscera.

24) Isolation of entero-atmospheric fistula for long-term management using a skin graft.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

viscera may be the most prudent course of action. The patient's abdomen can then be re-explored in 3-6 months once the patient's adhesions have softened and a definitive operation can be performed.

Enterocutaneous/Entero-atmospheric Fistulae
Perhaps the most dreaded and devastating abdominal wall catastrophe is either an entero-atmospheric fistula (EAF) or enterocutaneous fistula (ECF) (Figs. 22 and 23). Such connections between the intestine and skin are associated with significant morbidity and mortality, especially in resource-limited settings where ostomy supplies are limited to non-existent and resources for treating electrolyte and nutritional deficiencies from high-output fistulas are poor. As a result of the devastating impact of enteric fistulas on both patient and hospital alike, a surgeon should do everything possible to avoid such complications following initial abdominal closure. All intestinal anastomoses should be buried within the adjacent viscera and covered by omentum, if possible.

Enteric fistulas present a surgical challenge for a number of reasons. First, control of the enteric effluent from the fistula can be quite complex, as every fistula is anatomically different and inevitably labor-and-resource-intensive.

Protection of the skin and subcutaneous tissue from the caustic effluent is essential. Chemical dermatitis and fungal superinfections are commonplace. Second, enteric fistulas can significantly impact the patient's nutritional status. Distal fistulas function effectively as would an ileostomy, with the attendant risks of fluid and electrolyte losses. Such patients are generally able to maintain their fluid and nutritional balance with increased oral intake. Proximal fistulas, however, commonly preclude oral intake as an effective route of nutritional support requiring total parenteral nutrition, intravenous fluids, and/or distal feeding tubes to avoid both dehydration and malnutrition. Careful attention to nutritional status in such patients is essential if proper wound healing is to be expected. Third, surgical correction of enteric fistulas typically requires multiple months of supportive care before the surgeon can safely re-enter the abdomen. During this time, the patient can require almost constant wound care, depending upon the severity of the fistula, and may represent a significant burden upon hospital and/or family. This increases costs and lengthens

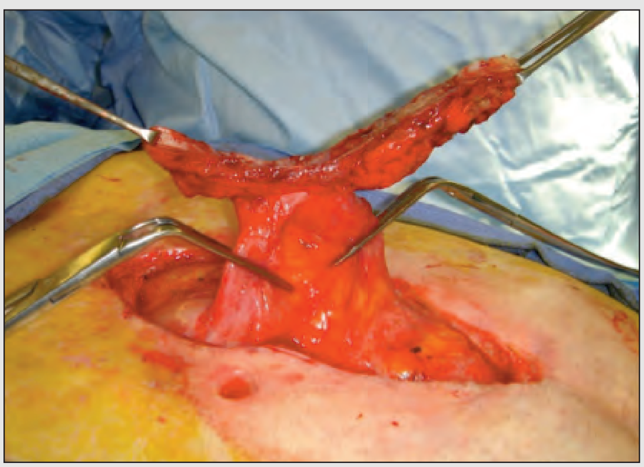

Fig. 25

Fig. 26

25) The non-healing wound and enterocutaneous fistula depicted in Fig. 23 has been excised en bloc, and the underlying intestinal loops dissected free.

26) The enteric fistula and skin are excised, and resection with primary repair is performed. The anastomosis should be covered with omentum, if possible. The abdominal wall is then closed in layers to cover the anastomosis.

(Pictures courtesy of Dr. Michael Cheatham, Orlando Regional Medical Center, Orlando, Florida)

hospital length of stay. Every surgeon should therefore strive to avoid the development of enteric fistulas whenever possible.

The key principles to avoiding enteric fistulas include maintenance of visceral perfusion, meticulous anastomotic techniques, careful application of temporary abdominal closures, and early visceral coverage and fascial closure. When enteric fistulas occur, simple suture repair / closure, while tempting, is rarely successful and often results in a larger fistula than was present to begin with.[17] While placement of a catheter into an ECF in an attempt to control the effluent can be effective, placement into an EAF typically results in a larger fistula. While primary resection of the fistula and renanastomosis is ideal, this is commonly prevented by an edematous, fixed, "hostile" abdomen. Attempts to dissect through the adhesions present inevitably leads to additional fistulas. The adage "there is no problem that an operation cannot make worse" definitely applies to enteric fistulas!

The most effective method for initial management of an EAF is isolation. Catheter drainage while covering the fistula with a skin & subcutaneous tissue flap thereby converts an EAF into an ECF which is both more easily controlled and may permit spontaneous closure.[17] Alternatively, an EAF can be controlled through placement of a surrounding split-thickness skin graft (Fig. 25). This allows eventual placement of an ostomy appliance over the fistula and eventual reoperation to resect the fistula in 9-12 months once the skin graft has separated from the underlying viscera and the abdomen is no longer hostile.

Resection of enteric fistulas is best left for a later date, by which time the patient's nutritional status can be optimized and the intestinal adhesions will be much easier to dissect with less risk of causing further enteric fistulas to form (Figs. 24 and 25).

Long-Term Outcome

Technically successful abdominal closure and survival from critical illness are of little consolation to the patient if achieved at the cost of significant reductions in quality of life or the inability to resume gainful employment. The avoidance of abdominal wall catastrophes through meticulous surgical technique and careful patient management is thus essential. When such catastrophes do occur, early appropriate intervention can frequently make the difference between a complicated repair and good outcome and an impossible repair with permanent disability for the patient. Multiple studies in patients with abdominal wall catastrophes have demonstrated that the vast majority of such patients can be returned to normal physical and mental health

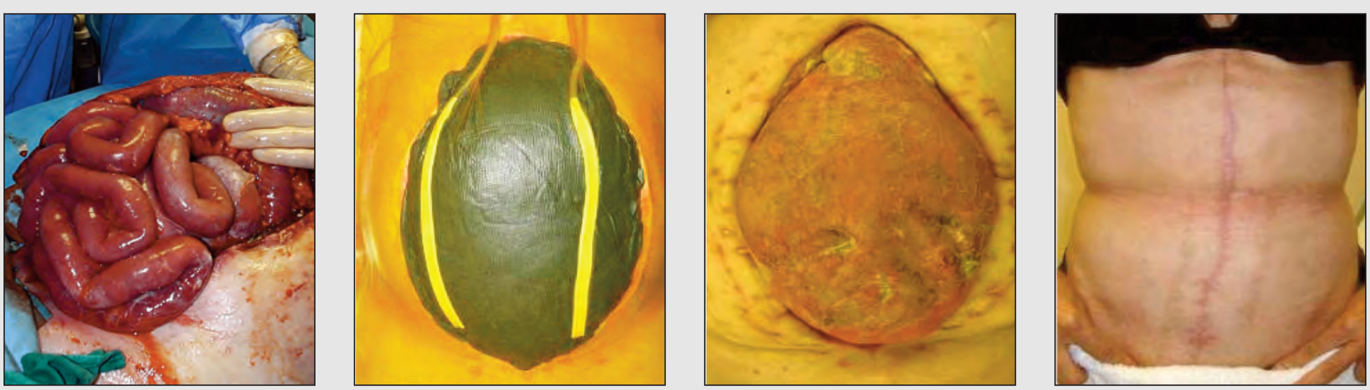

Fig. 27

A young woman was involved in a road traffic accident sustaining a closed head injury and severe hepatic and visceral trauma. She was managed using a Barker vacuum-pack temporary abdominal closure dressing. Continued loss of abdominal domain and critical respiratory failure prevented safe definitive abdominal wall closure. A split-thickness skin graft was placed over her exposed viscera. After rehabilitation and recovery from her closed head injury, she was returned to the operating theatre 14 months later, where her complex abdominal wall defect was repaired using component separation technique. She subsequently resumed her previous employment as a school teacher.

through repair of their abdominal wall defects.[8,11] Further, most patients can be returned to a normal work status and are able to resume gainful employment.

Abdominal wall catastrophes thus represent a significant burden for patient, surgeon, and hospital alike. Through careful surgical technique and patient management, however, both the occurrence and impact of these complex abdominal wall problems can be minimized and patients can be returned to a normal lifestyle (Fig. 27).

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Chapter 19
Fournier's Gangrene

Louis L. Carter, Jr.

Introduction

Fournier's gangrene is a necrotizing fasciitis-like infection of the penis, scrotum, and perineum. It occurs around the world, and especially in immunocompromised patients. The general surgeon is always involved in the acute care of these patients, and without plastic surgeons the general surgeon must also do the necessary reconstruction. For this reason, the treatment of Fournier's is included here.

Description

Fournier's is a polymicrobial infection that occurs in patients with underlying diabetes, HIV/AIDS or other immunodeficiency states. The etiology of the infection is most often due to urethral strictures with periurethral infection and abscesses, and also perianal disease. Th-e infection may spread proximally into the abdominal wall, and must be contained and controlled by a radical initial debridement, repeated "second look" debridements, broad spectrum antibiotics, and delayed closure by methods discussed below. Septic shock is always a potential complication in these patients, and often they present with septic shock.

The infection is usually in the superficial fascia and above the muscles and muscle fascia. It involves Dartos fascia in the penis and Scarpa's fascia in the abdomen and scrotum, as it is a form of necrotizing fasciitis. Culture and sensitivity with or without biopsies may be done, but urgent and wide debridement is necessary soon after admission and before culture reports are back even if they are available. Blood work must be done to rule out diabetes and HIV. Usually, it is obvious if the patient has urinary obstruction. If there is a urethral stricture, catheterization may be attempted; however, if a periurethral abscess is present, it is opened, and suprapubic cystostomy is done to divert the urine. Occasionally a colostomy may be necessary.

Treatment

Appropriate treatment includes daily wound care, radical and repeated debridements, broad spectrum antibiotics, fluid resuscitation, treatment of underlying illnesses, protection of testicles, and reconstruction once the wound is clean and free of infection.

Debridement: Urgent and extensive debridement must be done on admission with careful inspection to ensure the infection has not spread proximally into the abdominal wall. Periurethral abscesses must be opened and drained well. A "second look" procedure is always necessary the following day. The testicles are very vascular and usually are not involved, though covered with exudate. Every

Fig. 1

Fig. 2

Fournier's gangrene secondary to periurethral abscess.

Fig. 3

Fournier's gangrene secondary to perianal infection.

attempt must be made to save the testicles and not debride or excise until one is certain they are necrotic.

Antibiotics and Fluid Resuscitation: This is a polymicrobial infection with aerobic and anaerobic gram positive and gram negative organisms. Ideally, newer antibiotics as ciprofloxacin and clindamycin are used, but most must rely on the older but still effective triple antibiotic therapy with metronidazole (Flagyl®), ampicillin or penicillin/cloxacillin, and gentamycin. When other antibiotics are not available to cover gram-negative infections, chloramphenicol is given. In compromised patients with diabetes, rapid systemic spread of the infection with septic shock is common. Fluid resuscitation must be started immediately even if the patient is not in shock.

Fig. 4

Fig. 5

Fournier's secondary to urethral stricture and periurethral abscess.

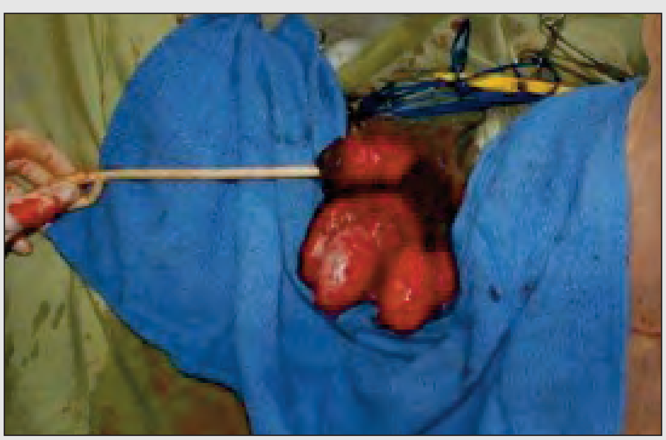

Fig. 6

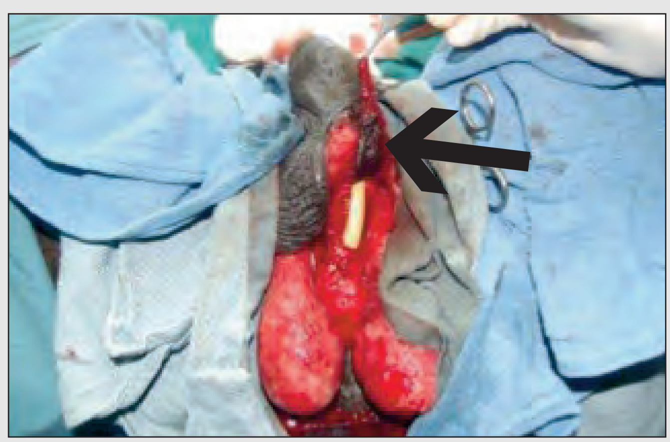

Fig. 7

Same case as Fig. 4-5, after serial debridements and reconstruction of the urethral fistula with a dartos island prepuce flap from the penis. The black arrow points to flap prior to the closure of the fistula. The flap was used as an onlay patch to reconstruct the urethral mucosa.

Treatment of Underlying Illness: History and blood tests should give immediate information regarding diabetes, HIV, or other underlying problems. Diagnosis of urethral stricture with periurethral disease is diagnosed by history, physical and attempted catheterization. A Foley/SP catheter is a must to monitor urine output.

Wound Care and protection of testicles: This gangrenous infection will require repeated debridements for several days to several weeks. Occasionally, the abdominal wall must be opened, and the subcutaneous tissue with the involved Scarpa's fascia excised. It is rare for the deeper muscle muscles or muscle fascia to be involved, but it must be evaluated. Wounds should be kept moist between debridements with wet dressings, honey, silver sulfadiazine as a topical antimicrobial, and possibly a VAC if available (see the chapter 2 on chronic wound management). The testicles must not be allowed to desiccate. Once the testicles are free from overlying infection, they can be placed temporarily in pockets just below the subcutaneous tissue in the upper thigh. The testicles lie loosely in these pockets with the pockets open to allow for drainage. In some cases, the testicles are left in these pockets permanently.

Reconstruction

After adequate debridement, the testicles are often left "hanging" free and independent. If they have been placed temporarily in thigh pockets, they can

Fig. 8

Fig. 9

Shows repair of the urethral defect and elevation and rotation of medial thigh flaps to cover testicles. Donor site skin grafted. (Figures 4-9: Courtesy of Dr. Bill Rhodes)

Fig. 10

Fig. 11

Fournier's Gangrene after multiple debridements and wound care for several weeks: Testicles were covered with island medial thigh flaps that were tunneled to reach the testicles. Remaining wound closed by undermining local perineal skin. This wound could have been closed with a skin graft, but without the good "cosmetic and a near normal" result.

Fig. 12

Fig. 13

Young boy with a diagnosis of Fournier's gangrene. TFL flap used to cover defect and prevent recurrent hip contracture.

be released for scrotal reconstruction. A VAC, if available, may help fill in dead spaces between the testicles and prepare the wound for scrotal reconstruction. The easiest method of scrotal reconstruction is with local tissues if these are available and not excised during debridement. Remaining scrotal, perineal and inner thigh tissues have considerable elasticity and often can be undermined and advanced to cover the testicles and much of the residual defect. Every case is different, and the amount of available tissue remaining for reconstruction varies. Where local flaps are not adequate or when one is unsure how to use these, meshed skin grafts can be used to cover the testicles and perineum. Meshed grafts contour well to the irregular surfaces and these mature over time and give an adequate "scrotum", though sensitive and prone to mechanical trauma. Grafts and local flaps can be used together for coverage. Testicles can be gently sutured together in a vertical direction to close the midline defect and provide a smaller, smoother surface for skin graft coverage.

Flaps available for coverage include the **medial thigh flap**, the **Singapore flap** or **pudendal thigh flap**, and **anterolateral thigh perforator flap**. Superficial **inferior epigastric flaps** can also be turned down from the abdomen. All these flaps are fasciocutaneous and give a good cosmetic reconstruction. The medial thigh flaps can be based proximally in the anteromedial groin, and advance easily into the defect. These are fasciocutaneous flaps based mainly on perforators, and are very vascular and safe to use. The length of the flap can be 2-3 times the width. The anterolateral thigh flap (ALT) is a large flap based off perforators from the lateral circumflex femoral artery. These flaps will be out of the zone of infection. When the residual defect is deep and large and includes the abdominal wall, the ALT flap provides excellent coverage. **Gracilis—muscle-only—flaps** may be used and skin grafted. When the muscle is raised and turned to cover the defect from one side to the other, only one muscle may be necessary. If there is still considerable swelling in the local tissues and testicles, then the gracilis from both sides may be necessary. Grafts are placed on the muscles and open areas around the muscle flaps. The gracilis is an easy muscle to elevate through a longitudinal anterior medial thigh incision from the pubis to the medial femoral condyle. The point of rotation is at 10 cm distal to the inguinal ligament. All flap procedures must be well drained on each side. Suction drains are ideal if available.

Fig. 14

Final result of case in Fig. 12-13.

The author's choice of closure is:

1. First, local tissue from scrotum and medial thigh.
2. Second, unilateral or bilateral medial thigh flap.
3. Third, unilateral or bilateral gracilis muscle transfers with skin grafts.
4. Anterolateral thigh flap.

Meshed but not expanded skin grafts are used for penile reconstruction. Meshed skin is ideal for coverage of the penis. If the entire penis requires grafting, then the penis must be stented in the following manner:

1. Foley catheter, if it is possible, and the catheter taped or sutured to the abdominal wall out of the zone of infection.
2. A suture is placed from the glans to the catheter to hold the penis extended.
3. A non-adherent dressing should be used to cover the skin graft
4. Then a bulky gauze dressing.
5. Followed by a layer of foam rubber that wraps around the penis and underlying dressing to create a chimney-like dressing to hold the penis extended.
6. Sutures: 4-6 long sutures at the corona and also at the penile base are tied over the foam rubber as a stent dressing. (Foam rubber may be obtained from the rubber in the local market that is used in chair cushions.)
7. If available, a small VAC can be placed over the penile graft.
8. Antibiotics are used during the grafting procedure and for several days post-op if extensive flaps have been used.

Post-operative Care

With meshing of the graft, there is no urgency to inspect the graft. The author changes the penile dressing in 10-14 days. Keeping the penis extended and stabilized allows for complete healing. Drains under flaps should be left in place until drainage has ceased, often 5-7 days. The patient is carefully followed and treated for any underlying medical condition.

Summary

Fournier's gangrene is a life-threatening infection that requires urgent and repeated debridements to save the patient's life.

Chapter 20

Hidradenitis Suppurativa

Peter M. Nthumba

Introduction

Hidradenitis suppurativa is a chronic, recurrent, painful inflammatory skin disease, first described in 1833 by a French surgeon. Verneuil, another French surgeon, in 1854 localized the pathology to sweat glands, giving rise to the eponym 'Verneuil's disease' in use to date. In 1922, Schiefferdecker was officially credited with reporting its origins in the apocrine sweat glands. The actual pathogenesis remains unclear to date, with some investigators suggesting that this disease belongs in the realm of folliculitis, and not sweat glands.

Hidradenitis suppurativa is a chronic disease of young and middle-aged people. Clinically, it may be intermittent or continuous in nature. Typically it finally will 'burn out' in time, though it may remain active for many years.

It affects 0.3% to 4% of the population; gender predilection is determined by site affected:

- Axillary disease—female>male
- Perianal disease—male>female

Racial differences are not clear, although it is felt to be higher in those of African descent due to the greater concentration of apocrine sweat glands.

Hidradenitis suppurativa is found in areas of apocrine gland-bearing skin: axilla, scalp, neck, inguinal area (with or without genital involvement), perineum, perianal, labial, and gluteal regions, but it may occur elsewhere in the body as well. Some authors have suggested that extra-axillary hidradenitis suppurativa lesions may be a premalignant state, and, therefore, a radical approach to their treatment from the outset would be justified.

The lesions start as painful inflammatory papules that progress on to pustules, and then develop odiferous draining sinuses, leading to scarring, chronic fibrosis and deformity of involved areas. Scarring can be severe enough to limit range of motion. Most patients have experienced symptoms for 5-10 years prior to initial presentation. This delayed presentation is often due to social embarrassment.

Hurley developed a classification in 1989 that is useful for the management and follow-up of patients. Sartorious et al, proposed a more complex scoring system.

Hidradenitis suppurativa has been reported to occur

Table 1

Stage	Clinical Features	Management
I.	Single or multiple abscesses, without sinus tracts or cicatrization.	Antibiotics
II.	Single or multiple recurrent abscesses, with tract formation and cicatrization, widely separated lesions.	Antibiotics and Surgery
III.	Multiple interconnected abscesses and tracts across entire area, with diffuse or near-diffuse involvement.	Surgery

Hurley's classification of Hidradenitis Suppurativa.

(Modified from Hurley H., *Dermatologic Surgery, Principles and Practice*, New York: Marcel Dekker, 1989; pp. 729–7, used by permission.)

with some other disease processes including:

- Follicular occlusion tetrad (acne conglobata, dissecting cellulitis of the scalp, and pilonidal cyst).
- Acne vulgaris.
- Pyogenic arthritis.
- Pyoderma gangrenosum.
- Synovitis.
- Acne syndrome.
- Hyperostosis.
- Pustulosis.

Complications of hidradenitis suppurativa are numerous, including:

- Scarring and contractures.
- Fistula formation.
- Complex regional pain syndrome.
- Elephantiasis.
- Psychological impairment.
- Malignancy (especially squamous cell carcinoma, most commonly in perianal and gluteal lesions).

Pathogenesis

Although still controversial, current thinking on pathogenesis is that hidradenitis suppurativa is a follicular occlusion disease: hyperkeratosis with obstruction of follicular ducts leads to ductal dilatation and bacterial superinfection, resulting in rupture, inflammation and abscess formation throughout the subcutaneous plane. Sinus track formation and scarring are the end results of this process.

Hidradenitis (apocrine gland inflammation) is currently thought to be a secondary event. It is possible that these glands secrete a substance that triggers a cascade of events leading to hidradenitis suppurativa.

Also thought to contribute to the disease are genetic, immunologic, hormonal (as it rarely occurs prior to puberty and after menopause), infective, and host factors. Smoking has been suggested to inhibit glandular function and may be a predisposing factor. Diabetes, obesity and a tendency to develop acne have been identified as risk factors for the development of hidradenitis suppurativa. The actual roles that these factors play in the evolution of hidradenitis suppurativa are still unclear.

Bacteriology

As noted above, the role of bacteria in the causation of hidradenitis suppurativa is unclear. Sartorius et al., in a study on the bacteriology of hidradenitis suppurativa, found Coagulase negative staphylococci in all their patients; ***Corynobacteria spp.*** were the next most common bacteria isolated. As in other studies, ***Staphylococcus aureus*** was **not** identified in this study. In all, gram positive cocci were the most commonly identified bacteria. ***Staphylococcus aureus*** has been identified in axillary hidradenitis suppurativa lesions in other studies, as have gram negative bacteria in perineal lesions.

Fig. 1
Hurley's Stage I

Medical Treatment

Medical treatment is reserved for Hurley's stage I (as seen in Fig. 1) and early stage II. Topical and systemic antibiotic use has not shown any difference in outcomes, and despite widespread use of antibiotics, few studies have shown proof of their efficacy. Recurrence is almost certain, even when antibiotic use has resulted in relief.

Some studies have shown results suggesting that

Fig. 2
Hurley's Stage III

Table 2		
Method of Defect Reconstruction	**Recurrence Rates**	**Comments**
Primary Skin Closure	2.5% - 80%	May compromise wound margins.
Local Flap	18%	Requires some knowledge on flaps.
Skin Graft	13%	May give poor aesthetic results
Secondary Healing	0 - 50%	Requires prolonged follow-up and wound care (up to 30 weeks).
Defect reconstruction.		

hormonal therapy (with anti-androgens) may be superior to the use of antibiotics.

Surgical Treatment

Surgical excision offers the only possibility of cure for hidradenitis suppurativa. Surgical treatment options are guided by Hurley's stage at presentation, with stage III (shown in Fig. 2) and late stage II benefitting the most. Surgery may range from incision and drainage, de-roofing and marsupialization, local excision to radical wide excision, as dictated by the stage of presentation and the area affected. Where multiple areas are affected, the area with the most debilitating disease is treated first, followed by the other areas.

Incision and drainage may be performed in acute settings, with fluctuant abscesses. A plan should be made to excise the involved tissue due to high recurrence rates following incision and drainage. De-roofing and marsupialization involve complete exposure of sinus tracts, leaving wounds that heal by secondary intention. Excellent outcomes have been reported.

Radical wide excision of all involved skin is the only mode for cure; skin and subcutaneous tissue are excised down to deep fascia, with a margin of 1-2 cm. to ensure against recurrence.

Table 3	
Region	**Recurrence Rates**
Perianal	0%
Axillary	3%
Inguinal/perineal	37%
Submammary	50%
Recurrence rates	

Fig. 3

Perianal: Excised with gluteal advancement flaps (Courtesy Dr. Blair Summitt).

Depending on the size of the defect, and the area involved (hence the need to ensure a cosmetically acceptable reconstruction), primary closure, skin grafting and/or the use of local flaps may be used.

Recurrence rates after wide excision differ; may be related to higher densities of apocrine glands in areas with higher recurrence rates.

Other Treatment Modalities

Radiation therapy has been used to treat patients with hidradenitis suppurativa. There is concern about the possibility of developing malignancy following radiation therapy, and therefore, its use is not recommended. In patients with recalcitrant hidradenitis suppurativa, radiation may give good results.

Lasers and **Photodynamic Therapy** have also been used with some degree of success, as have many other treatment modalities.

Chapter 21

Neurofibromatosis

Peter M. Nthumba and Louis L. Carter, Jr.

Introduction

Neurofibromatosis is frequently seen in Africa. This is a genetic disorder of the nervous system causing tumors on nerves. It occurs in three different types: Types 1 and 2 and Schwannomatosis. In this latter, rare type, there are multiple schwannomas all over the body. Simply put, Type 1 is mainly peripheral and Type 2 is central, though there is some overlap.

Type 1 (NF1), also known as von Recklinghausen's disease, causes skin changes, peripheral neurofibromas, and bone deformities. It begins at birth and will usually be evident by ten years of age. The NF1 gene is located on chromosome 17. This type will be discussed in this chapter.

Type 2 (NF2) is associated with hearing loss, ringing in ears, poor balance, and acoustic neuromas. It begins in the teenage years. The NF2 gene is located on gene 22. This is rarely recognized in the district hospital.

Many inherit neurofibromatosis, but 30-50% of new cases arise spontaneously through mutation. These mutations may be passed on to succeeding generations.

Symptoms/Indications of NF1

- Café–au-lait spots—brown spots in the skin; 6 or more >5 mm. are diagnostic.
- Freckling in axilla or groin.
- Skin nodules—neurofibroma; 2 or more are diagnostic of NF1.
- Plexiform neurofibroma involves many nerves and may be painful.
- Lisch nodules—neurofibromas in the iris of the eye; 2 or more are diagnostic.
- Abnormal spine development—scoliosis, kyphosis, and boy defects of skull and tibia.
- Tumor on optic nerve—optic nerve glioma.
- A parent or sibling with NF1.

Prognosis

- Often these patients have a normal life expectancy, but the findings are usually progressive.
- Neurofibromas will often continue to grow.
- Plexiform neurofibroma may become massive, significantly impairing quality of life, and may lead to psychological problems.
- Children have a higher than average risk for learning disorders.
- Malignant change is rare, <10% of patients.
- Hypertension is also seen in NF1.
- There is no cure for neurofibromatosis, and nothing will limit the growth of the neurofibromas.
- Surgery rarely removes the entire tumor, and after surgery, recurrence is common.

Treatment

- Many different types of treatment have been tried, but nothing has been found that is curative.
- Radiation and chemotherapy have been tried, but without success.
- Gene therapy if/when available will be the ultimate solution.
- Only surgery has been found helpful, and even that with only limited success.
- Pre-operative embolization has promise in major centers.
- Multiple small lesions may be treated with electrocautery.

Fig. 1

Localized mass which was able to be completely excised.

Fig. 2 **Fig. 3** **Fig. 4**

Scalp was expanded with a tissue expander over several weeks. The expanded skin was used to cover the large defect that remained after the excision of the neurofibroma.

Fig. 5 **Fig. 6**

Neurofibroma originating from supraorbital nerve Required several debulking procedures and though residual tumor still remains, the patient was pleased.

Surgery

Often patients want small-to-medium-sized neurofibromas, skin nodules, and tags, removed because of location when on the face or neck, belt or bra line, etc. Usually, these can be easily removed under local anesthesia with or without the use of electrodessication.

- Surgery may be done for large disabling and cosmetically embarrassing tumors.
- Most large lesions cannot be completely removed but only debulked.
- **Neurofibromas are very vascular, and hemorrhage may be a significant problem.**
- This surgery requires excellent anesthesia and availability of blood.

Fig. 7 **Fig. 8**

Eye involvement in neurofibromatosis is common—often these require enucleation.

Fig. 9

Fig. 10

Fig. 11

Neurofibroma involving eyelid without damage to eye: a debulking procedure was done.

Fig. 12

Infiltrating neurofibroma.
Patient would have been ideal for mesh.

- The large neurofibromas (plexiform neurofibromas) **cannot be "shelled" out** as they infiltrate the overlying skin, cross tissue boundaries and invade surrounding tissue.

- The skin often must be removed with the underlying subcutaneous tissue and the resulting defect closed with by mobilization of surrounding tissue, use of flaps or even skin grafts.

- Pre-op expansion of surrounding normal skin is possible before the excision of the neurofibromatosis, as in the case shown in Figs. 2-4.

- When neurofibromatosis involves the face, the only way to remove the mass is with **near total removal of the facial skin** and possible muscle and parotid excision. **This will require flap coverage**. If microvascular surgery is possible, distant tissue may be used for reconstruction. Still the resulting defect may be as disfiguring as the original mass. Obviously this may lead to significant psychological issues.

- Often the neurofibroma will come out of the orbit through the supraorbital nerve. If this is the case, then the mass can be debulked with a fair result as the case shown in Figs. 5-6. When performing surgery around the face, lidocaine with adrenaline should be used to reduce hemorrhage. One must be careful to dilute the lidocaine to ½% so as not to give an overdose (maximum amount is 7 mg/kg of lidocaine with adrenaline). The only way to potentially remove all the neurofibromatosis in this case would be to perform a craniotomy and remove the roof of the orbit—not practical where the surgery was performed. Even then, it may not be possible to remove it all. Secondary procedures are often necessary to remove residual or recurrent tumors. The patient in Figs. 5-6 had three procedures.

- Facial neurofibromas can be difficult to manage.
  - With orbital involvement, there is often proptosis, pulsatile eye, and corneal damage secondary to exposure.
  - Enucleation is the most reasonable procedure.
  - Debulking may be done when one eyelid is involved, but if both are involved and there is corneal damage, enucleation is the best procedure as was done for the cases shown in Figs. 7-8.
  - If only the eyelid is involved and the cornea is not damaged, debulking may be done with a good result. Repeat surgery may be necessary. See Figs. 5-6 and Figs. 9-11

Fig. 13

Fig. 14

Fig. 15

After neurofibroma was excised, mesh was inserted and anchored to deep fascia and bone around the mass (Courtesy Peter M. Nthumba).

Fig. 16

Plexiform neurofibromatosis.

- A relatively new technique uses mesh that is used for hernia repairs. This has been shown to control the growth of disfiguring neurofibromas seen in the cheek as the case seen in Fig. 12. This **"netting" procedure**, first described by Park from South Korea, uses mesh to control recurrence of the residual mass and prevent re-drooping of the face after the initial radical, but likely only palliative, surgery.

  The mesh provides a tight net to prevent the bulging and drooping that occurs with the force of gravity. In cases where the patient has enough normal skin that can be saved and used after wide excision of the neurofibroma, the mesh can preserve the underlying muscles of facial expression and nerves.

- The mesh is anchored to the dermal layer of the corner of the mouth, the upper lip, eyebrow, zygomatic arch, and laterally to the deep temporal fascia. This gives a tight "net" around the residual tissue.

- In some patients with recurrent disease, the neurofibroma often involves the skin. These patients may need radical removal of the neurofibroma as well as much of the overlying skin. These will need flap reconstruction with deltopectoral, supraclavicular flaps (see chapter 29 on perforator flaps), expanded tissue (flaps), or free microvascular flaps.

- Mesh can also be used under the flaps in these cases. An example of the netting procedure is seen in Figs. 13-15, the same as the eye case in Fig. 12.

- With massive neurofibromatosis, excision will not be easy because of the extent of the mass and significant hemorrhage. Just a debulking procedure on the patient's arm in Fig. 16 had to be terminated due to massive bleeding.

- When the neurofibromatosis is limited to one nerve or one side of the extremity, debulking may be possible. The neurofibromatosis in the young girl shown in Figs. 17-18 involved branches of the ulnar nerve. It was resected after a long and tedious dissection under tourniquet control in order to save the nerve.

- When the neurofibromatosis in one extremity is

Fig. 17

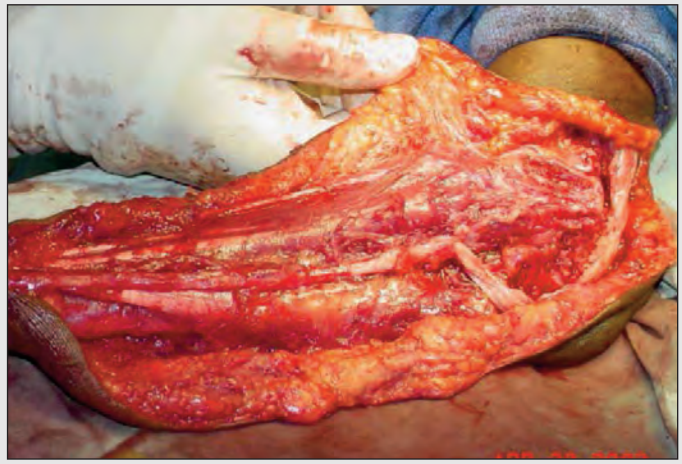

Fig. 18

Neurofibroma in forearm and hand, along ulnar nerve, was removed first and bleeding controlled. Then, tourniquet was removed and remainder of the mass in the arm removed. This is the same patient as seen in Figure 1 where the neurofibroma of earlobe was "completely" removed.

Fig. 19

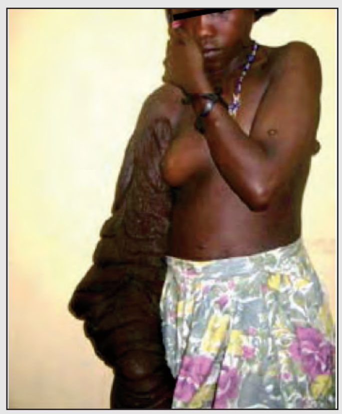

Fig. 20

Fig. 21

Amputation was recommended in these cases.

massive, as in the cases shown in Figs. 19-21, amputation unfortunately may be the best solution.

- **Complications**
  - Inadequate removal but with prolonged improved quality of life.
  - Hemorrhage.
  - **Postoperative edema** is often severe and resolves very slowly. Initially, family members often wonder whether or not surgery was actually performed. This edema can occlude the airway.

Summary

Neurofibromatosis can be a very disfiguring and debilitating disease in Africa. The stigma must be unbearable to the unfortunate ones afflicted with this disease. It is always a very vascular growth, causing many difficulties for removal. By the time these patients consult a surgeon, the disease is often far beyond easy removal. Often, a few neurofibromas on the face and neck can be removed easily without significant bleeding. The use of mesh to prevent late drooping is a new treatment that shows great promise for the grotesque facial masses. Complete removal of large facial masses may require both a neurosurgeon and an ophthalmologist. Even then it will be difficult to completely remove the mass.

Chapter 22

Urethral Stricture Disease

Peter M. Nthumba

The term ‘**urethral stricture**’ generally refers to anterior urethral disease or ***spongiofibrosis***; the fibrosis may extent into adjacent tissues. **Posterior urethral stricture**, on the other hand, is an **obliterative process** in the posterior urethra resulting in fibrosis, usually due to some form of trauma.

The anterior urethra consists of the **navicular**, **pendulous penile**, and **bulbous** urethra; this part of the urethra is surrounded by the corpus spongiosus. The posterior urethra is made up of the relatively fixed **membraneous** urethra and the **prostatic** urethra. The posterior urethra does not have a corpus spongiosus (See Fig. 1).

There is no single treatment modality for all urethral strictures. Nevertheless, the end-point in treatment should encompass the following:

- A good voiding stream.
- Continence and potency.
- Return to normal activity.

These end-points are fairly elusive, especially in low- and middle-income countries (LMIC), and are compounded by factors such as the inability to afford the proffered treatment modalities, age, co-morbidities, and the wide breadth of different causes of urethral stricture disease.

Lack of money, equipment, and the technical skills limit the number of patients who can hope to get a “cure” for this disabling disease, sometimes leading to the “urethral stricture cripple”—the patient who spends a lifetime with catheters, only freed intermittently during catheter changes.

Peno-Scrotal Anatomy

The anatomy of the penis and scrotum is unique in that the subdermal plexus continues to maintain the viability of the donor site's covering skin once a flap has been transferred with the entire dartos fascia. The entire dartos fascial layer of the external genitalia has a robust interconnecting circulation from the deep and superficial external pudendal vessels that anastomose freely with the internal pudendal circulation through the scrotum (Fig. 2).

Location of Urethral Strictures

- Bulbar strictures—most common (50%).
- Penile strictures—(30%).
- Navicular fossa—(20%).
- Posterior urethra strictures—result either from traumatic urethral rupture or radiotherapy for prostate cancer.

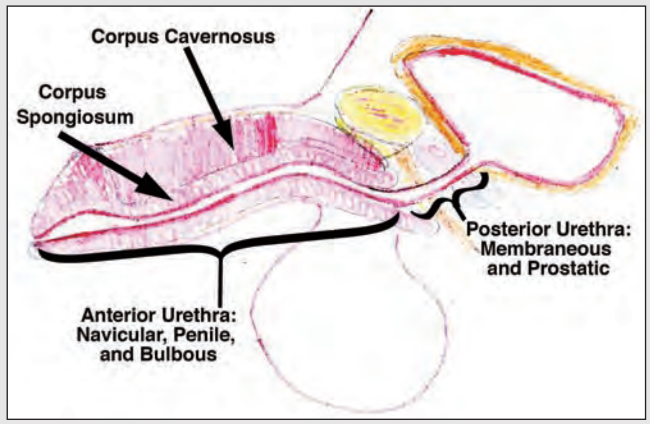

Fig. 1
The anterior and posterior urethra.

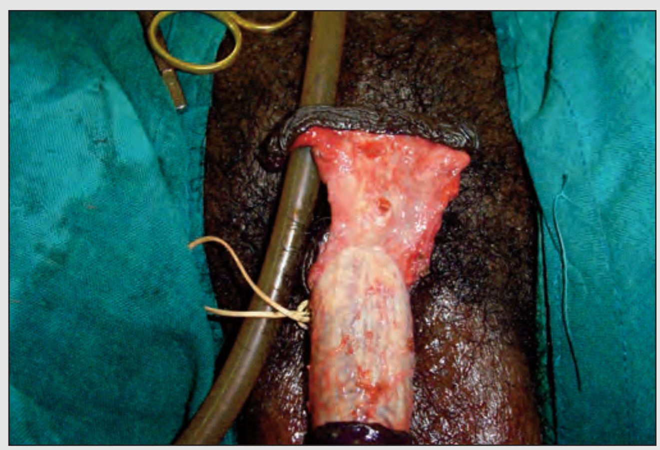

Fig. 2
Penile skin flap harvested and raised on the dartos fascia. The remaining skin flap will survive on the subdermal vascular plexus.

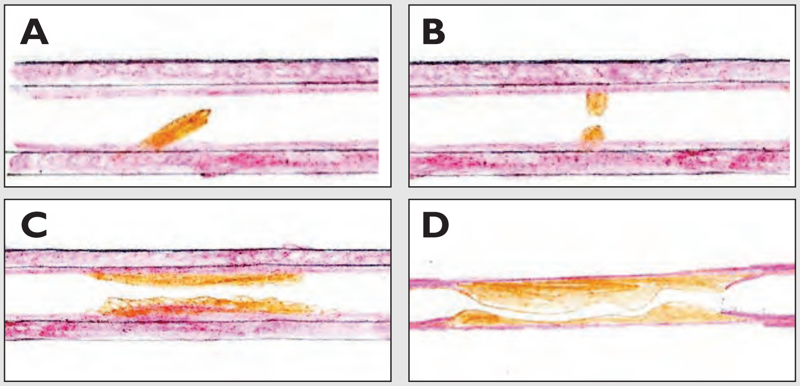

Fig. 3

A) Mucosal fold; B) Iris constriction; C) Full-thickness involvement with minimal fibrosis in the spongy tissue; D) Full-thickness spongiofibrosis.

Anatomy Of Anterior Urethral Stricture

Jordan in 1987 divided progressively worsening spongiofibrosis into six groups (A to F) as follows (See Figs. 3-6):

A. Mucosal fold.
B. Iris constriction.
C. Full-thickness involvement with minimal fibrosis in the spongy tissue.
D. Full-thickness spongiofibrosis.
E. Inflammation and fibrosis involving tissues outside the corpus spongiosum.
F. Complex stricture complicated by a fistula.

Causes of Urethral Strictures

1 Trauma.

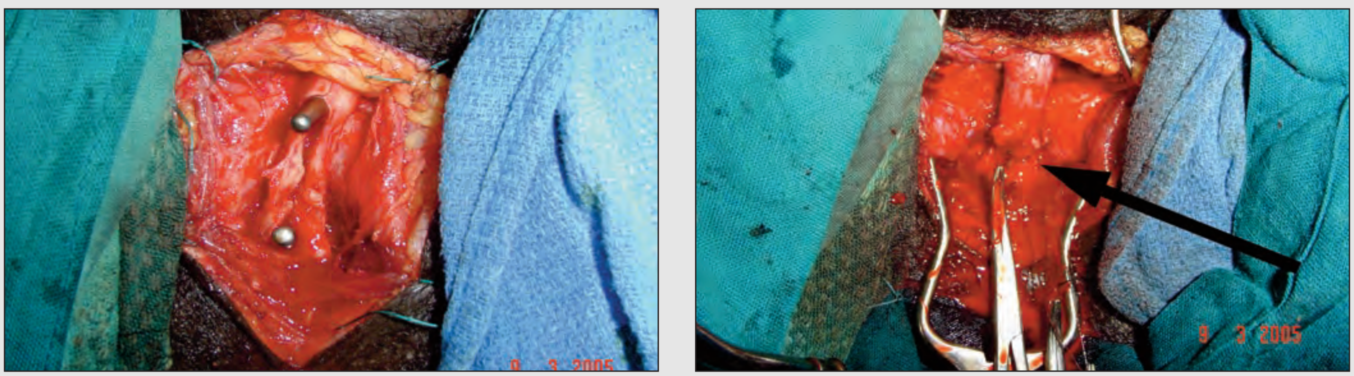

Fig. 4

Note full thickness spongiofibrosis with no involvement of surrounding tissue. (L-R) Full-thickness spongiofibrosis; End-to-end anastomosis.

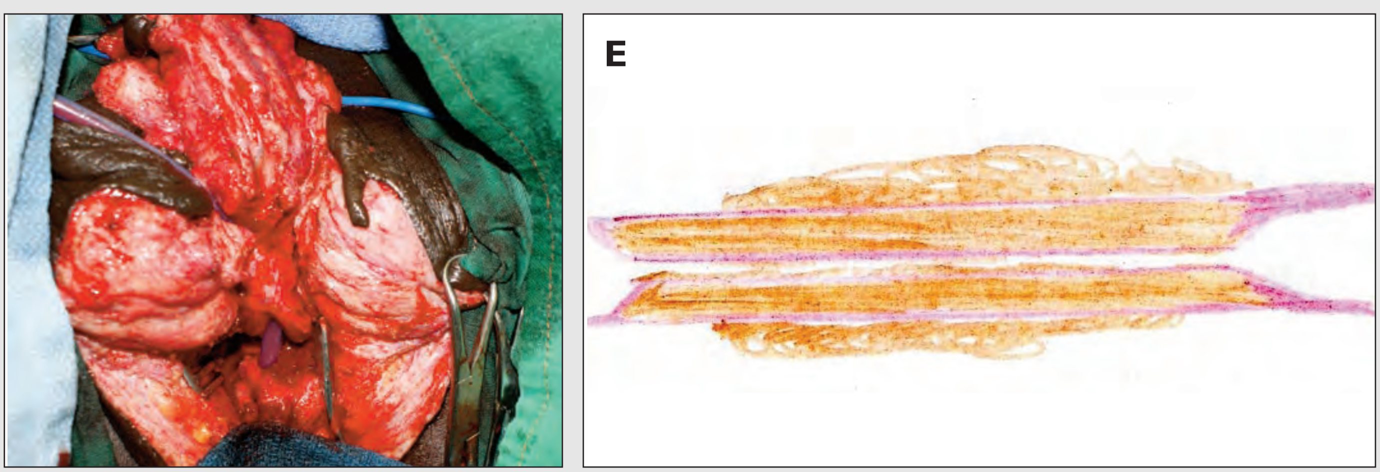

Fig. 5

Thickened corpus spongiosum and urethra with extensive fibrosis. Fibrosis extends into surrounding tissue, especially the cavernosal bodies. In this picture, the entire length of the anterior urethra is involved in the fibrosis, with a segment (peno-scrotal and bulbous urethra) requiring excision because of complete occlusion. The sketch (E) conveys the extensive nature of the fibrosis with areas of complete urethral obstruction.

- Iatrogenic—from urethral manipulation—may account for up to 45% of all strictures. May include: traumatic indwelling catheter, transurethral interventions (e.g. urethral dilation and other instrumentation), correction of hypospadias, circumcision, prostatectomy, and brachytherapy. Urethral strictures develop in 3% to 5% of patients undergoing transurethral resection of the prostate (TURP).
- Non-iatrogenic—Traumatic urethral rupture following pelvic fracture, falls (astride), etc

2 Infection: Bacterial urethritis, associated most commonly with gonorrhea.

3 Tumors: e.g. Kaposi's sarcoma.

4 Inflammatory.
- Latex allergy: reaction to latex catheters.
- Balanitis xerotica obliterans (BXO)—a chronic inflammatory disease of unknown etiology, that may be a variant of lichen sclerosis et atrophicus in the male. Early circumcision may prevent or protect from its development. Phimosis has been associated with the development of BXO.

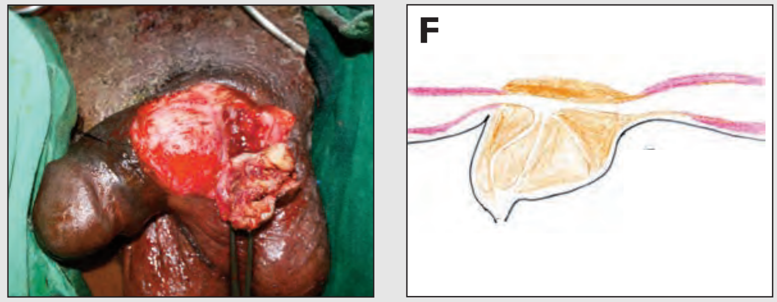

Fig. 6

Inflammatory urethral mass requiring extensive resection of the urethra. F is a drawing of the complex stricture complicated by fistulae. The fistulae may be associated with abscess formation, and may open through the skin (as in the case depicted here) or rectum. Staged urethroplasty with perineal urethrostomy was performed.

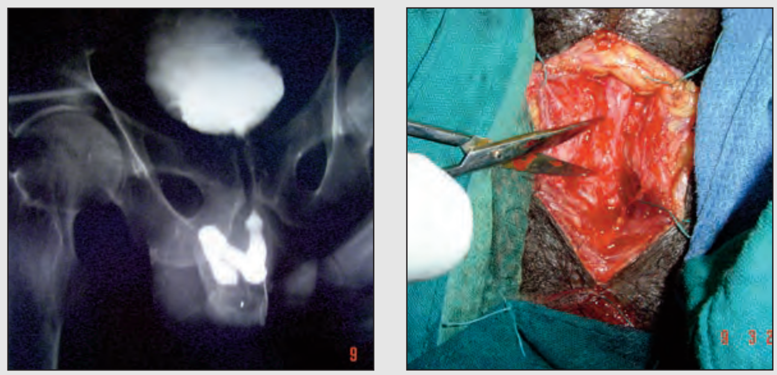

Fig. 7

Length of bulbo-membraneous stricture on a radiograph, and the following dissection.

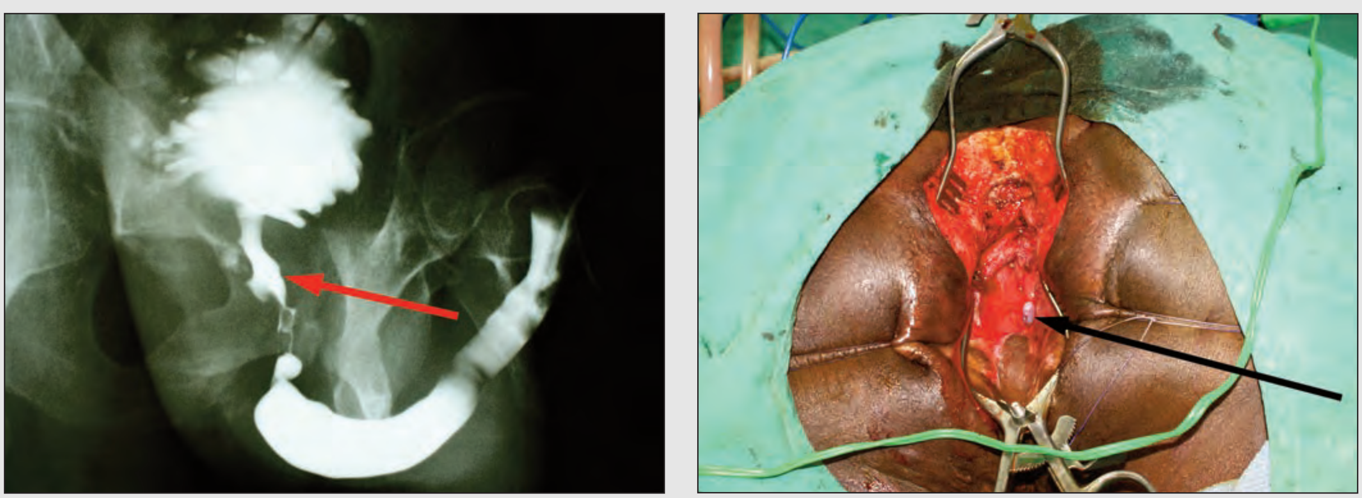

Fig. 8

Prostato-rectal fistula. The red arrow shows fistula location on radiograph. Black arrow shows tip of catheter in fistula.

5 Others: e.g. urethral stones

6 Idiopathic—up to 30% of all strictures have no identifiable cause or risk factor.

Management of Urethral Strictures

Investigations:

- Urinalysis and urine culture.
- Creatinine.
- Imaging provides a road map for the surgeon.
    - **Urethrogram**—Plain radiographs are more available in LMIC than any other imaging modality; it is also the cheapest imaging modality: where these are available, ascending and descending cysto-urethrograms should be possible. While the real-time images may give a fairly accurate stricture length and caliber, the films given may sometimes be difficult to interpret. The urethrogram gives the following information on the stricture:

Fig. 9

Patient with extensive proximal urethral stricture. Note large bladder stone on a scout film. Cystolithotomy and urethroplasty performed in a single sitting.

Fig. 10

Complex urethral stricture with urethral stones (black arrow).

        - The inability to pass contrast either way defines the presence of a stricture.
        - The anatomic location of the stricture (**reasonably accurate**).
        - The length of the stricture (**not always accurate**).
        - Presence of false passages or fistulae (does not rule out the presence of these).
        - Presence of stone disease—a scout film, usually taken before contrast is given, may show the presence of bladder or urethral stones.
        - Associated bladder pathology, including stones, bladder diverticuli, etc.
    - **Ultrasonography** is slowly becoming ubiquitous in Sub-Saharan African hospitals—primarily for obstetric patients, and now gradually for trauma. Ultrasonography is operator-dependent, but is superior to plain radiography. Ultrasonography can tell:
        - The exact anatomic position of the

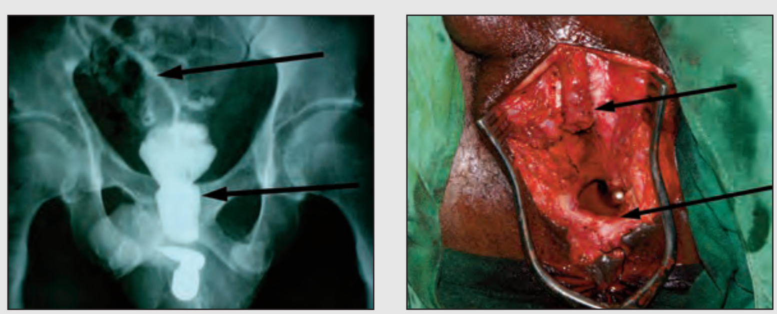

Fig. 11

Proximal urethral dilation. (L) Top arrow shows dye; bottom arrow shows dilation. (R) Top arrow indicates distal position; bottom arrow shows dilation.

stricture; multiple strictures.
  - The type of stricture—the thickness and degree of fibrosis.
  - Any associated pathologies (urethra and bladder).
- **MRI** may be used, but would be too expensive, and is certainly not available to the majority of hospitals in Sub-Saharan Africa.

Treatment Options

1 Endo-urological procedures.
- Urethral dilation/Bougienage or U/D.
- Direct Visual or Internal Urethrotomy (DVU).

2 Open urethroplasty.
- Stricture resection and end-to-end/bulboprostatic anastomosis.
- Urethroplasty with a free graft (e.g. skin graft, buccal mucosa, etc).
- Urethroplasty with pedicled flap (e.g. Quartey flap).
- Perineal urethrostomy/staged urethroplasty.

Table 1

Type	Management		
Jordan	U/D	DVIU	Urethroplasty
A	✓	✓	X
B	✓	✓	X
C	X	✓(<2cm)	✓
D	X	X	✓
E	X	X	✓
F	X	X	✓

Treatment options.

Urethral Dilation/Bougienage (U/D)

Passage of urethral sounds or bougienage of the urethral stricture is the oldest form of treatment and was used even in the pre-Christian era. Bougienage stretches the spongiofibrosis, producing innumerable microlesions in the scar tissue, thus leading to further scarring. The normal adult urethral caliber is 24 to 26 FG at the meatus, widens up to 36 FG in the bulb urethra, and then narrows again in the membraneous urethra.

One may also use graduated filiforms and followers: small filiforms are blindly guided into the bladder through the urethra, past the stricture. Once a flexible filiform has been successfully guided into the bladder, a follower is coupled on to it and gently pushed into the bladder. The filiform is left in the bladder until the desired size of a dilator can comfortably be pushed into the bladder. The filiform is then withdrawn, and a catheter placed.

When this treatment modality is used alone, it only provides temporary relief; the stricture may be expected to recur after 4 to 6 weeks. Thus, the patient must return every month for repeat procedures. The introduction of a self-clean intermittent catheterization program may help prevent or forestall this recurrence.

Ideally, it should be used only in patients who refuse surgical treatment or who are unsuited for surgery for other reasons.

Urethral dilatation ideally should not be used as primary treatment for urethral strictures, as this may create a vicious cycle with longer and thicker strictures, especially if this procedure is left to the most junior member of the team, as is often the case. If used, an appropriately done urethral dilatation should not lead to any urethral bleeding at the end of the procedure. The surgeon must avoid using the largest dilator (to get the urethra as wide as possible), as this causes maximal trauma. Rather, use the smallest, but safest, dilator and gradually increase the size, aiming for a size 16 or 18 FG. If urethral patency is maintained at this size, function is normal.

Although regional (spinal) or general anesthesia may be administered, local anesthesia (xylocaine gel, or lidocaine mixed with a lubricant) is put into a 20 cc syringe and then instilled gently into the urethra. The glans is grasped firmly with using a piece of wet gauze to ensure that the local administered remains within the urethra for about two minutes for the lubrication and anesthetic to take effect, after which the grasp is relaxed. If most of the gel exudes from the meatus, there is a tight urethral stricture that may be difficult to dilate; if, on the other hand, little or no anesthetic gel exudes, there may be either no stricture or a very loose stricture easy to manage with gently urethral dilation.

Always record on the patient chart the state of erectile function prior to surgery, as some patients blame the surgery for their erectile dysfunction or expect their pre-existing ED to recover fully following the surgery. A long discussion, preferably with the wife in attendance, explaining what can be expected is a critical part of the success of the surgery.

Following a urethroplasty in a cooperative patient where the risk of recurrence is high, the patient is taught ‘clean intermittent self-catheterization’ (CISC) once a week for six weeks, then every 14 days for three months, and then monthly for six months. The CISC can often be discontinued at this point.

Direct Visual Urethrotomy (DVU)

Visual internal urethrotomy is probably a better modality for the treatment of strictures usually managed with regular dilations. Both procedures are regarded as simple and straightforward—they, however, carry a significant risk of complications. Several recent studies, (including a prospective randomized study), have concluded that DVU and urethral dilation are equivalent in their outcomes. For example, either procedure will cure 50% of short bulbourethral strictures as the first procedure. If the DVU has to be repeated, it is rarely curative. DVU is not an effective a treatment option in strictures other than in the bulbar urethra.

Stricture recurrence most commonly occurs within the first two years; recurrences are often managed by repeated instrumentation. Such patients can only be cured by a urethroplasty. Other options include the use of a laser for DVU, indwelling urethral stents and CISC. CISC is the only useful alternative; when possible, urethroplasty should be recommended and performed.

Stricture scar is incised with a knife endoscopically to widen the lumen. The resulting wound margins expand. Healing is by secondary intention, leading to scar formation, hence high recurrence rates. Recurrence is expected in 50% to 60% of cases. Recurrence depends on:

- Length of the stricture; better results if short (<1.5 cm).
- First-time strictures of the bulbar urethra have up to 75% success.
- Healthy tissue proximal and distal to the stricture has to be incised; this makes the lesion longer, and therefore, the recurrent stricture is always longer than the original one. Complete healing cannot be expected if recurrence occurs, following a DVU. A CSIC program may help obviate recurrence, if rigorously adhered to.
- The number of urethrotomies performed is a negative predictive factor for failure of a subsequent urethroplasty.
- Attempts have been made to minimize recurrence rates by using lasers instead of cold steel, but none of these has been shown to be superior.

Open Urethroplasty

Principles (Bulbar strictures)

Mobilize the urethra as much as possible and utilize its elasticity to obtain maximum length, and therefore achieve end-to-end anastomosis.

Straighten the natural curvature of the bulbar urethra by any of the following means:

- Separate the crura at the base of the penis.
- Wedge pubectomy of the inferior pubic arch.
- Re-route the urethra around the shaft of the

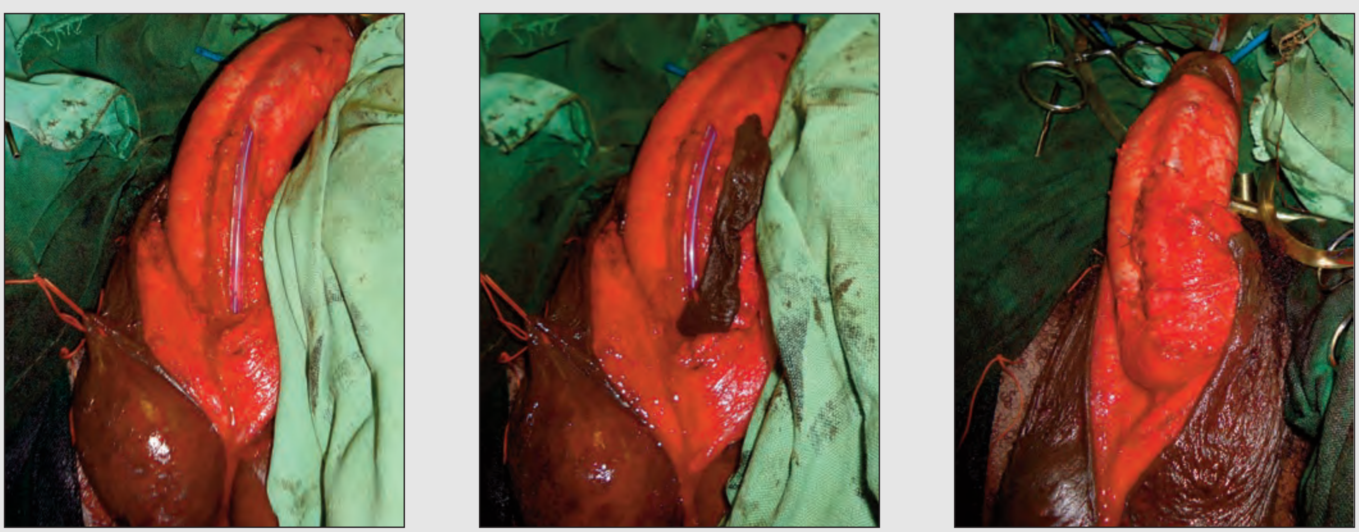

Fig. 12

Stricturoplasty and patch urethroplasty using a pedicled penile skin flap.

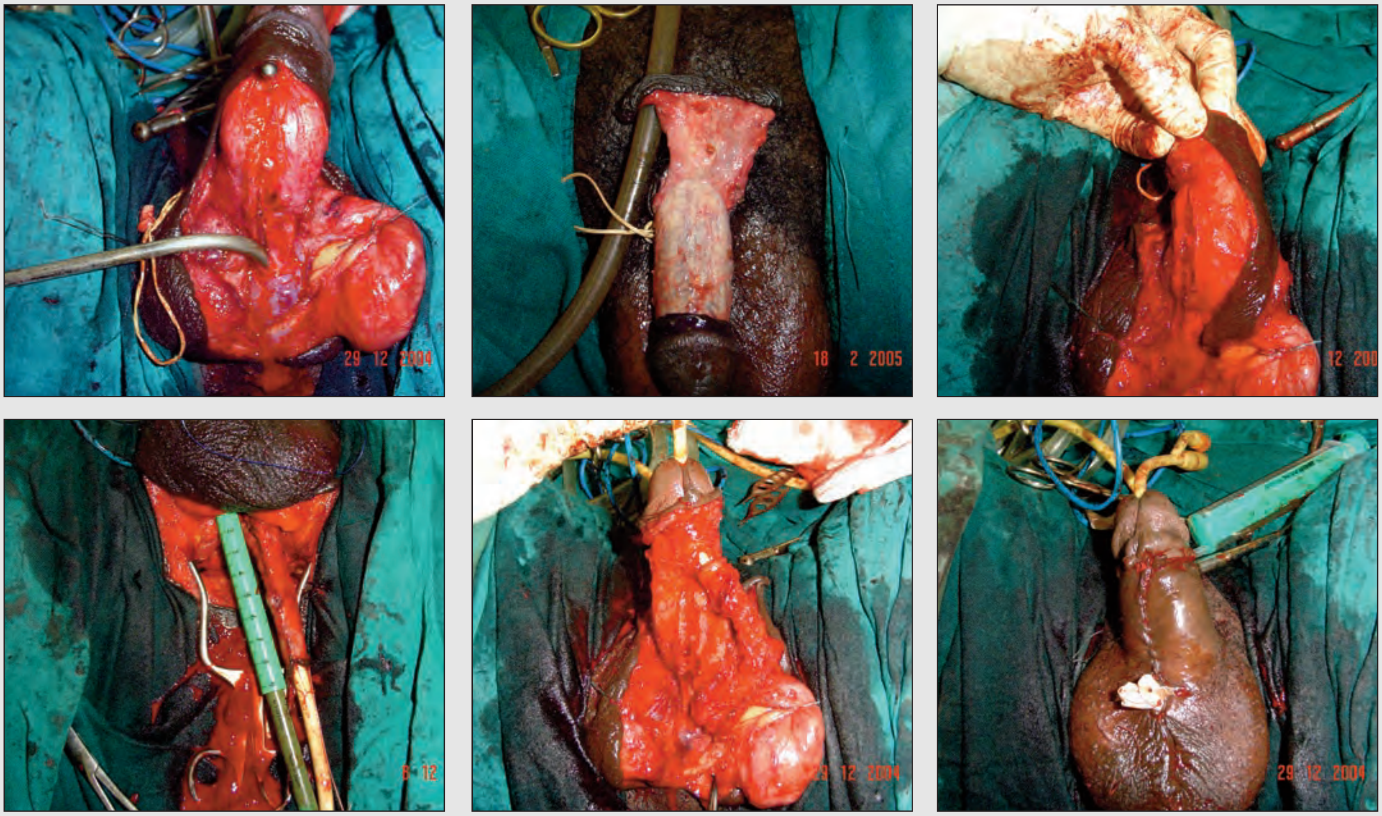

Fig. 13

Circumferential replacement of a long segment of the urethra using pedicled skin flaps—the Quartey flap.

penis until this course is a straight line, rather than a curve.

- The best results are obtained with short (<2.5 cm) strictures of the bulbar urethra with stricture resection and end-to-end anastomosis.

Through a perineal approach, the urethra is dissected out, the stricture identified and completely excised; with mobilization, spatulation of the ends, and a tension-free end-to-end anastomosis. Long-term success rates are above 90%.

Substitution Urethroplasty

Longer strictures, and almost all penile (pendulous) urethral strictures, require substitution urethroplasty (**Attempts to get end-to-end anastomosis for penile urethral strictures may lead to severe chordee deformity.**):

1 Penile foreskin.
2 Buccal mucosa.
3 Thigh/groin.
4 Bladder/colonic mucosa.

Substitution urethroplasty should only be used when end-to-end anastomosis is not feasible. Stricturoplasty and patch urethroplasty (Fig. 12) have better outcomes than stricture excision and circumferential replacement of native urethra (Fig. 13).

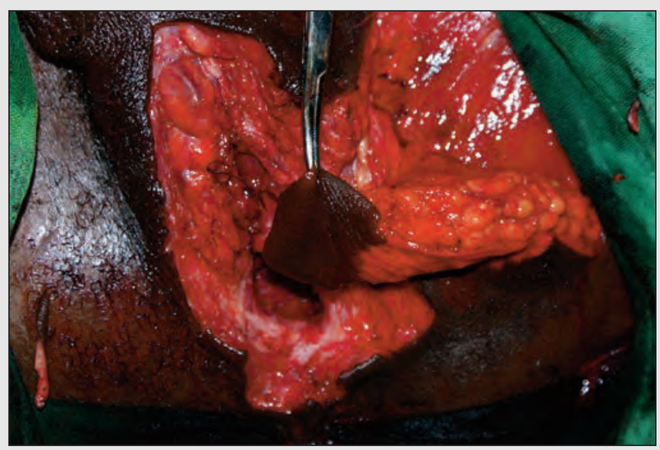

Fig. 14

Singapore flap urethroplasty.

A pedicled skin flap (penile shaft skin on underlying dartos fascia) is raised and used to replace mucosa over the open urethra. These require long operative times, and are associated with increased complication rates (skin necrosis in about 15%, fistula formation in about 5%). They are technically more challenging than other repair methods.

The Singapore flap (Fig. 14) was popularized for use in the treatment of vesicovaginal fistulae. Although bulky, it is an excellent local flap for long peno-bulbous or membraneous strictures (See Chapter 27).

Perineal urethrostomy—Boutonnière procedure—bulbar urethra is sutured directly into the perineal skin beneath the scrotum as a first stage.

Membraneous urethral strictures occur in association with pelvic fractures. The urethra is torn off, either directly above or directly below the urogenital diaphragm (supra-diaphragmatic vs. infra-diaphragmatic urethral rupture). This leads to scarring of the defect, with complete obstruction of the urethral lumen. Treatment consists of complete excision of the scar tissue and anastomosis between the bulbar urethra and the prostate apex.

In **supradiaphragmatic rupture** (30%), the continence mechanism may be damaged, as part of it may be excised with the dense scar tissue during dissection.

Indications for Surgery

- Any strictures that have failed attempted treatment using either the urethral dilators or DVU.
- Patients with Jordan types D, E and F urethral strictures (see above).
- Any patient who has failed previously attempted urethroplasty repair.

Surgical Technique

The urethrogram should be displayed in the operating room, as a guide to:

- The site of surgery.
- Patient positioning—**penile urethral strictures** can be repaired with the patient lying prone, while peno-scrotal to prostatic strictures require the patient to be positioned with stirrups to permit access to the urethra through the perineum.

The majority of patients with Jordan Classification types D, E, and F will have a suprapubic catheter. Patients without a suprapubic catheter make it difficult to delineate the proximal end of the stricture. The suprapubic catheter is an important part of the management of the patient with a urethral stricture.

- With the patient positioned appropriately, fill the bladder with a dilute povidone-iodine solution, of about 200 to 300 ml. This helps evaluate the volume of the bladder, confirms fistula presence, and completeness of the obstruction. Bladder content (dilute betadine) noted to egress from the penile meatus indicates urethral continuity, and may therefore be relatively easy to reconstruct

- The patient is positioned appropriately for the urethroplasty, prepped and draped.

- The urethra is lubricated by squirting lubricant

Fig. 8
Perineal urethrostomy

Fig. 16

Fig. 17

Two urethral sounds are used to determine the position and length of the urethral stricture. A skin incision is made over the entire length of the determined stricture. The 'V' incisions at either end help in protecting one from getting scrotal contents into the area of surgery superiorly, and from inadvertent injury of the anal sphincter/rectum inferiorly.

gel into the meatus. A size FG 16 urethral sound/dilator is lubricated and gently directed through the penile meatus into the urethra, allowing only the weight of the dilator to drive it through the well-lubricated urethra until resistance is met at the expected point. Another dilator (FG 18 or 20) is directed through the suprapubic cystostomy into the bladder-neck and prostatic urethra, into the bulbar urethra, as far as it will go, or until it meets resistance. The distance between the tips of the two dilators marks the length and position of the stricture.

In the perineum, one may inject lidocaine with epinephrine carefully into the area of the stricture. A longitudinal incision on the skin exposes the bulbospongiosus muscle. Use cautery to expose the corpus spongiosum. Note that the corpus spongiosum will bleed easily if traumatized. This bleeding is difficult to control: the surgeon should dissect gently, especially in cases where the fibrosis is extensive.

- Identify the stricture and resect it to healthy looking urethral mucosa.
- Clamp the bleeding edge(s) of the urethra with a vascular clamp (non-crushing).
- Identify the midline and gently use the cautery to separate the corporal bodies from about 4 cm distal to the divided urethral edge to the pubis.

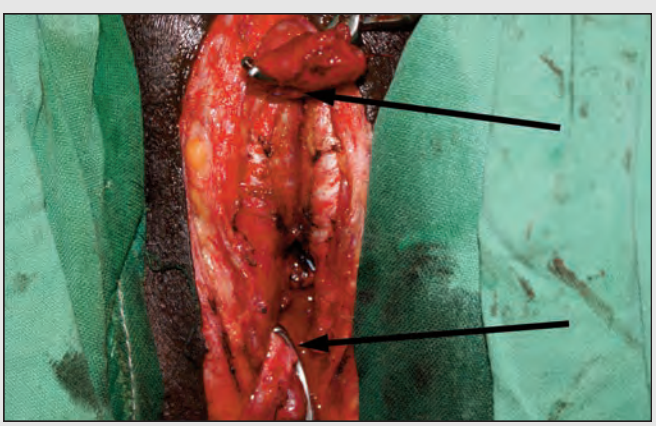

Fig. 18

Vessel clamps on corpus spongiosum.

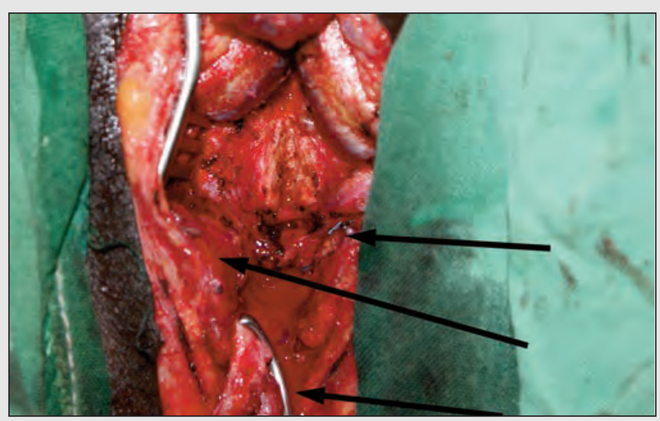

Fig. 19

Top arrows: cavernosal bodies separated and splayed out using a self-retaining retractor. Bottom arrow: Pubic symphysis.

End-to-end anastomosis should be easy to perform without tension following this maneuver, in defects of 4 to 6 cm. Excising some tissue from below the pubic symphysis will allow tensionless end-to-end anastomosis of even longer defects, by shortening the distance/ route that the urethra traverses.

Once the corporal bodies have been separated completely, the extra-anatomical anastomosis is made.

The anastomosis is tensionless, but a note is made that the urethra is now extra-anatomic for purposes of future instrumentation.

Fig. 20

End-to-end urethral anastomosis.

Summary of Surgical Techniques

H-M strictureplasty—It is possible to do Heineke-Mikulicz-like strictureplasty for relatively short strictures, as these do not lead to chordee even on the pendulous penile urethra.

Non-Anatomic Repair±—after determining that the defect is too long to permit primary anastomotic urethroplasty, the corpora cavernosa bodies are separated in the midline all the way to the pubic symphysis, and proximally to the pelvic diaphragm. It is then often possible to place the urethra in between the corporal bodies and perform the anastomosis. This non-anatomic position will make instrumentation of the urethra difficult in future, but affords a tensionless repair.

Prostatic Urethral Strictures—long prostatic urethral strictures are frequently the result of some iatrogenic

Table 2

Anatomic Part	Anastomotic Urethroplasty		Penile Skin Flap	Tubularized Penile Skin Flap	
		Maximum Defect	Longer Defect	Non-circumferential defects	Circumferential Defects
Meatus	Meatoplasty	N/A	X		✓
Glanular	Glanuloplasty	N/A	X		✓
Coronal	Short Strictures	N/A	X	✓	✓
Penile (shaft)					
Distal	H-M stricturoplasty	10 mm	X	✓	✓
Mid	H-M stricturoplasty	10 mm	X	✓	✓
Proximal	H-M stricturoplasty	10 mm	X	✓	✓
Bulbar	H-M stricturoplasty	25 mm	Non-anatomical	✓	✓
Membraneous		(Normal Bulbar Urethra)	✓	✓	✓
Prostatic	X	N/A	✓	✓	✓

Summary of Surgical Techniques.

process: trans-urethral prostatectomy or open prostatectomy, leading to complete fibrosis and obliteration of the urethra and bladder neck. The approach to these complicated strictures may be transvesical or transperineal. The transperineal route has a lower morbidity and is thus the approach of choice by the author. After determining the urethra that one will use to bring to the bladder-neck, that urethra is anchored to the tip of the urethral catheter using 3.0 or 4.0 absorbable suture such as Vicryl®. The tip of this catheter is then tied to the tip of the supra-pubic catheter by use of a 1.0 Prolene® suture and pulled into the bladder. Both catheters must be 100% silicone. The balloon of the urethral catheter is inflated and confirmed to be in the bladder. The supra-pubic catheter is then pushed back into the bladder and inflated as well.

The catheters are kept in place for 12 weeks, both deflated, and then one gently pulls on the supra-pubic catheter until the Prolene® suture is visualized and cut, to allow removal of both catheters. Any Vicryl® sutures noted to still be on the catheter are similarly cut, and the urethral catheter is gently pulled out of the bladder. The supra-pubic catheter is replaced for another two weeks. The patient is instructed to void only via his urethra, after a successful trial of voiding.

Fig. 21

Cysto-ureteral reflux.

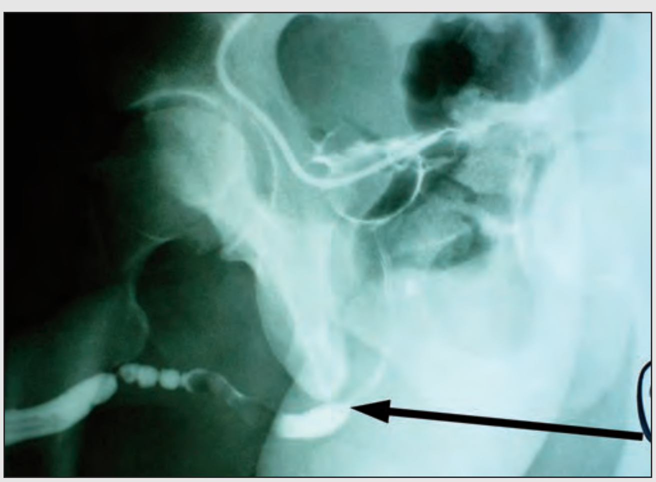

Fig. 22

Bulbo-urethral stricture leading to the reflux noted above.

Complications of Urethral Strictures

- Reflux.
- Urosepsis.
- Urethral/ bladder diverticuli.
- Renal failure.
- Fistula.
- Fournier's gangrene.
- Death.

Complications of Urethroplasty

- Penile curvature.
- Impaired ejaculation.
- Frequency.
- Skin necrosis.
- Fistula formation.
- Incontinence.
- Impaired glans sensitivity.
- Recurrence.

Fig. 23

Post-Quartey urethroplasty—skin necrosis. The wound healed without need for any intervention. Very rarely, one may need to skin graft the resulting ulcer. The reported incidence of this complication is up to 15%.

Recurrence

Recurrence is a difficult problem in this group of patients, as many of them will have spent many years with a catheter.

After removal of the urethral catheter and trial of voiding, the suprapubic catheter is kept spigotted for at least two weeks after which this last catheter is removed.

The patient is counseled about urinary frequency, and a reduction in the stream force (the need to push need urine against resistance), as early warning symptoms of a recurrence, and hence the need to return for review.

'Small Bladders'

Patients who have had their bladders drained for long periods of time with the use of suprapubic catheters have relatively small bladders, and rehabilitation following urethroplasty can be troublesome, as the volume of the bladder is easily filled by the two catheter balloons, and bladder spasms can be a problem. Further, upon removal of the catheter, the patient may continue to experience frequency because of a small bladder.

The catheter(s) should be spigotted, once the repair is deemed healed, and bladder training initiated, initially with relief every 3 hours, until the patient can hold urine for at least 6 hours.

Further Reading

1 PM Nthumba. The Management of Urethral Stricture Disease in a Rural Setting: A Personal Experience. *East and Central African Journal of Surgery 2005*;10(2):70-76.
2 Jordan GH: Management of anterior urethral stricture disease. *Probl Urol 1987*;1:199–225.

Chapter 23
Genitourinary Fistulae

Andy M. Norman

Author's Comments: Dedication to Dr. Brian Hancock

Dr. Hancock's publications have helped me immensely in teaching beginners about Vesico-vaginal fistula (VVF) surgery. He graciously allowed me to use his *First Steps in Vesico-Vaginal Fistula Repair* to provide order to this chapter and also allowed me to use his illustrations. Most of the figures in the article are his. I will credit them with the letters BH at the end of each narrative. In some instances, I may reword or add my own comments to the narrative, but the picture will be his which I borrowed with permission.

Editors' Comments

This chapter on VVF surgery is included since many general surgeons in remote areas will see these unfortunate and desperate women in their practice. Some may not have fistulae surgeons nearby to care for these patients. Like other conditions discussed in this book, cleft palate and hypospadias, it is not recommended that a surgeon attempt the repair a VVF without some knowledge and experience. Certainly one can make the condition considerably worse by poor surgery. So this chapter is a review for those who have some experience in VVF surgery and who are called upon to help these women when "experts" are not close by.

Genitourinary Fistulae

A Vesico-Vaginal fistula (VVF) is not a common occurrence in developed countries. When one does occur, it is usually a complication of abdominal or laparoscopic hysterectomy; VVF can also occur as a complication of pelvic cancers or in patients who have had pelvic radiation therapy for such cancers. Most fistulae in underdeveloped countries, especially those in Sub-Saharan Africa, occur as a consequence of prolonged obstructed labor. The soft tissues of the bladder and vagina are entrapped between the bones of the baby's head and the back of the maternal symphysis pubis. Prolonged pressure results in a necrotic injury that may be small and localized or may be quite extensive. In 1991, the World Health Organization said the following:

> *Obstetric fistula lies along a continuum of problems affecting women's reproductive health, starting with genital infections and finishing with maternal mortality. Because of the disabling nature and dire consequences–social, physical, and psychological–it is the single most dramatic aftermath of neglected childbirth.*

Women who get a fistula are generally the poorest of the poor. They tend to be short and young. They live in countries where the medical care is poor and not readily accessible. Their labors are most often not managed or monitored by skilled attendants. They

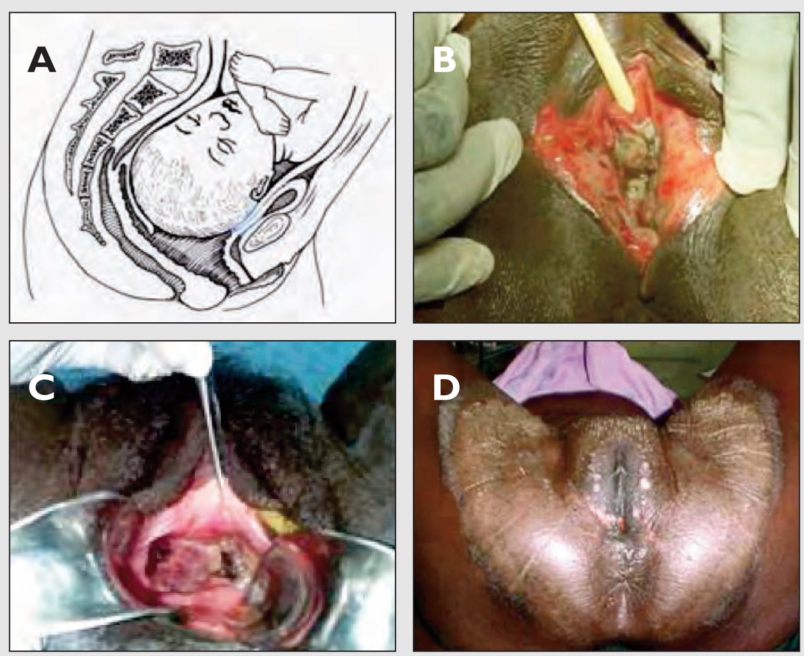

Fig. 1

A) The area in blue is first to undergo ischemic necrosis; B) A few days after a vaginal delivery, necrosis is extensive, extending almost to distal urethra; C) Necrosis involves much of the upper vagina, perhaps even extending into the bladder base; D) Vulvar contact or ammonia dermatitis from urine drainage. This needs prolonged gravity drainage. (BH) labor at home or under the care of traditional birth attendants and only seek care in a hospital after they have been in labor for a full day or much longer. Whether after days of unrelieved labor or after delivery at home, they often arrive at a hospital tired, dehydrated, anemic, and leaking urine or stool or both. Many of them have a foot drop. Depending on the interval between delivery and presenting at the hospital, the patient may even have pressure ulcers or limb contractures. Most of the time, they don't have money for preadmission deposits if such advance payments are required for in hospital care and surgery.

Among the first issues to face the medical/surgical staff at the hospital where such a patient presents is determining how to care for the patient and who can provide the best care. If there is a VVF program that is reachable by the patient and her family, it may be better to send the patient there. Most of these programs have some type of subsidy for the surgical care and a hostel where the patient can wait for surgery or recover after surgery. Many of these patients will be divorced and have injuries that preclude future childbearing and sometimes even comfortable sexual function. VVF programs or centers often offer some vocational rehabilitation during the recovery period. Most long-standing programs have surgeons who have had considerable experience with such fistulae. Many have said that the best chance of successful surgery is the first attempt.

Having said that, fistula surgeons are certainly not all gynecologists. I have personally known very good fistula surgeons who are general surgeons, urologists, and African general medical practitioners. Anyone with good basic surgical skills and especially anyone with some vaginal surgical experience can learn to do VVF's. About 25% of presenting VVF's are fairly easy to repair. Discerning which ones are easy and which ones are potentially very difficult can be a bit of a challenge.

Interviewing or "Clerking" a Patient

History is important though sometimes it is hard to get a detailed one because of a language barrier or because the patient doesn't know what was done to her.

- History of Urine or Stool Leakage:
  - Urinary Leakage: The history of the urinary leakage is important. Does the patient leak all of her urine all the time? Does she wet the bed at night? Does she still feel an urge and urinate spontaneously?
  - Fecal Incontinence: Does the patient have accidental leakage of stool? Does this occur all the time or just when she has diarrhea or liquid stools? Can she hold gas?

- Age: Patient's age if known. How old is her youngest child? How long has she been married?

- Obstetric History: How many pregnancies? How many deliveries? Any miscarriages or abortions?

- Duration of Urinary Incontinence: Did it start after a delivery?

- Type of Delivery in the "Index" Pregnancy (the last pregnancy):
  - Did she deliver vaginally or by C. section?
  - Was the delivery at home, at a health center, or at a hospital?
  - Was any operative delivery done (such as forceps, vacuum, or destructive delivery)?
  - Had the uterus ruptured?
  - Was a hysterectomy done?
  - Did the child survive? 90+ % of babies in these cases are stillborn or die soon after birth, especially if the delivery was vaginal. Nowadays, many patients get C. sections; many of these are done for babies that are already dead.

- Menstrual/ Personal History: Does she still have menstrual periods? Are they regular? When was the last menstrual period? Some patients don't menstruate after these deliveries. If a C. section was done, and the patient no longer menstruates, perhaps a C. hysterectomy was done for a ruptured uterus. Many patients are not told that they had a hysterectomy.

- Does the patient still live with her husband? Are they still sexually active? Who helps or takes care of her (if she is separated or divorced)?

- Previous Repair Attempts: When and where were previous repairs attempted?

Even with a real effort, taking this history is a challenge. Sometimes patients hide information about previous failed repairs. History does not make a lot of difference when the VVF is simple, but some historical details can have prognostic implications concerning the severity.

- History of a foot drop even if it has mostly resolved.
- Rectovaginal fistula, except for broken down episioproctotomies, are usually associated with a severe injury.
- Fistulae after a C. section for prolonged obstruction are often in the area of the cervix. These can be more complex and harder to access.
- Fistulae after a ruptured uterus with C. hysterectomy can be vault VVFs, but are not infrequently ureterovaginal fistulae.

Physical Assessment

- General: Observe the patient's gait. Does she look debilitated? Is she pale (pull down an eyelid and look at the conjunctivae)?

- Abdomen: Are any scars present? Any masses? Any hernias?

- Pelvic Exam: This can be done in dorsal lithotomy position or the Sims position (patient lying on her side with someone holding top leg up).

- Inspection: Is there an odor? Is there obvious urinary leakage? Is there vulvar dermatitis?

- Vaginal exam: Look to see if the urethral orifice is present and normal. Gently palpate digitally along the urethra and anterior vaginal wall. Is there scarring? Can a defect or fistula be palpated? Is the vagina normal in length and caliber? Is the cervix palpable?

- Use a Sims or Deaver retractor to pull the posterior vaginal wall away from the anterior vaginal wall (use it to elevate the posterior vaginal wall if patient examined in Sims position). Is a fistula visible? Sometimes a small defect can be confirmed to be a fistula by passing a metal catheter or 5 mm Hegar dilator through the urethra and out into the vagina through the fistula. If no fistula is clearly seen, do a Dye Test. Just insert a catheter through the urethra and fill the bladder with a dye solution made with sterile water or saline and a few drops of Gentian Violet, Methylene Blue, or Indigo Carmine. Watch for leakage into the vagina. Sometimes one must hold pressure on the distal urethra around the catheter to control leakage around the catheter. It might help to have the patient cough if the defect is small. Most of the time, one has to inject only 50-60 cc, but occasionally small fistulae only leak when a larger volume is injected.

- If no leakage is observed, consider doing a "Tampon Test". This is especially useful in a patient who leaks continuously day and night but also feels an urge and voids several times a day. For this, put a tampon or some gauze in the vagina. Give 100-200 mg of Pyridium (phenazopyridine) orally and ask the patient to drink lots of water or give Indigo Carmine or Methylene blue IV. Check the tampon or gauze in a few hours to see if the innermost part is stained. If there is only staining distally, the leakage could be stress incontinence or leakage through the urethra. Sometimes if the diagnosis has not become clear, I simply leave a catheter to bedside drainage overnight. If the patient does not leak with a catheter, urethral leakage is likely. Some patients with inadequate urethras will still leak some even with a catheter in place. This is especially true when the patient moves to an upright position.

- Patients with severe scarring or who cannot tolerate a thorough vaginal exam may require examination under anesthesia.

Conservative Treatment When VVF's Present Early

Patients who have had prolonged obstructed labor, whether they have delivered vaginally or by C. section, should have indwelling Foley catheters until a necrotic injury is ruled out. Rather than routinely leaving catheters for two weeks or more, one can examine the anterior vagina three days post-delivery if the patient is doing well and is ready for discharge. If no ecchymosis or necrosis is seen, the catheter can be removed, and the patient observed for a few hours to be sure she can void adequately (Review Fig. 3).

When patients present early (within two weeks) of delivery with urinary leakage, a Foley catheter should be inserted. If inspection suggests a small fistula whose edges are in close proximity or touching, catheter drainage from 2-4 weeks may result in spontaneous healing. Even patients with large fistulae or necrotic injury may benefit from 2-4 weeks of catheter drainage as the proximal urethra will be kept open or patent. A Foley catheter is not likely to be beneficial if the patient is still leaking at four weeks postpartum.

Description and Classification of Fistulae

Descriptions should be given of fistula location, fistula size, and scarring. The simplest classification system is just to describe the fistula location such as juxtaurethral, midvaginal, or juxtacervical. Some of the juxtaurethral fistulae can be through the urethra and extend all the way to the symphysis pubis. These are called circumferential fistulae. They literally separate the remains of the urethra from the bladder.

Measurement of the length of the urethra that remains and notation of whether it is patent or blocked proximally is important. In the two classification systems in common use, the length of the remaining urethra and the distance of the fistula from the external urethral orifice are used. The size of the fistula in centimeters is documented. The bladder can be sounded with a uterine sound or urethral catheter to determine the distance from the distal urethra to the bladder apex. The presence, location, and severity of scar tissue are also described.

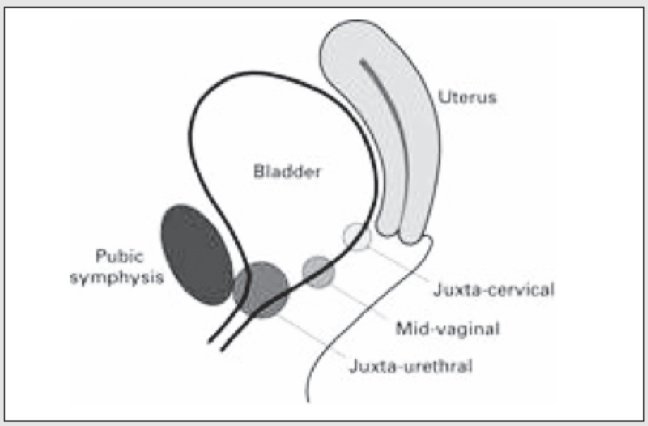

Fig. 2

Necrotic injuries can result in fistulae at any of the pictured locations (BH).

A simple sketch of the fistula is very useful for remembering a particular examination's findings.

The classification systems commonly used were described by Kees Waaldjick and Judith Goh. One can go to the original articles for these or read a summary of them in Brian Hancock's book, Practical Obstetric Fistula Surgery, which is available online (see references).

Determining Which Cases Are Simple and Straightforward

It would be good if anyone thinking of attempting a VVF repair could at least see a few repairs done by an experienced fistula surgeon. Generally, simple midvaginal or juxtaurethral fistulae with normal urethral length and with edges that are soft and free of fixing or distorting scar bands are reasonable for an experienced surgeon, particularly one with some experience operating in the vagina, to attempt.

Pre-Operative Considerations

At most sites in Sub-Saharan Africa, a minimum of preoperative lab assessments are done. At least a blood count (hemoglobin or hematocrit), and HIV screening test, a sickle prep, and a blood smear for malaria parasites are done. It's good to get weak or malnourished patients into better condition before operating.

Some patients, who are brought to the operating room with a full rectum, pass a lot of stool after the

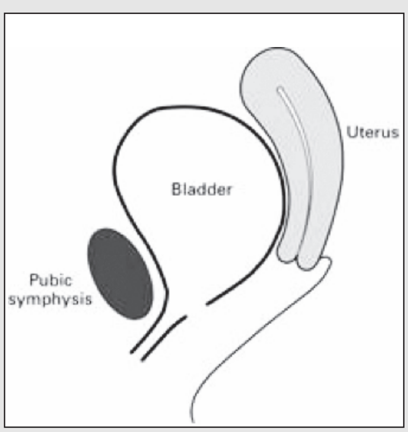

Fig. 3

Fig. 4

Fig. 5

(L to R) Simple juxtaurethral, juxtacervical VVF, and circumferential juxtaurethral VVF. (BH)

Fig. 6 **Fig. 7**

6) Large juxtacervical VVF.

7) Vesicocervical fistula. (BH)

Fig. 8

Ideal position for VVF Surgery.
(Courtesy Jonathan Karshima)

anesthetic is administered. Preoperative enemas or laxatives can be used but are not always beneficial. It would be good to ask the patient to empty her bowel before going to the theatre. We usually attach a sponge or towel to the perineum to divert any stool downward. An **anal purse string suture**, used only for the duration of the repair, may be helpful at times.

In The Operative Room (Theatre)

The importance of a table that can be placed into relatively deep Trendelenburg position and a good light cannot be overemphasized. The patient should be placed in the dorsal lithotomy position with her buttocks hanging just over the edge of the table. The legs should be suspended out of the way with candy cane or other stirrups. **Shoulder supports** or an over-the-shoulder sling attached to the stirrup poles should be used to keep the patient from sliding up the table when the head of the table is lowered.

Anesthesia

A low spinal is adequate for most vaginal VVF repairs. Some are short enough to be done with IV Ketamine alone. General anesthesia is preferred for most abdominal repairs.

Instruments

A minimum number of instruments are needed for simple vaginal repairs. The following are important:

- Posterior Weighted Speculum—those with a short blade of only 5-8 cm work best.
- Needle holder.
- Toothed dissection forceps—7-8 inches in length.

Fig. 9

Instrument set for VVF Surgery. (BH)

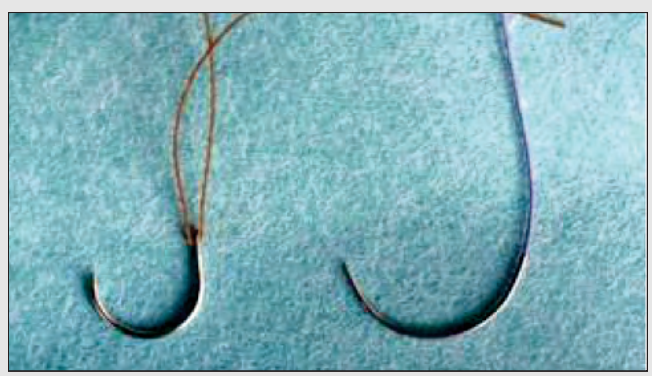

Fig. 10

Needles useful in VVF repair. On the left is an eyed J-shaped needle. On the right is a swaged 25 mm half-circle (UR 6) needle with 2-0 Vicryl®. (BH)

- A few hemostats.
- A few Allis clamps.
- A metal catheter.
- A probe such as a small lacrimal duct probe.
- A small Deaver retractor is sometimes useful.
- Good quality dissecting scissors such as Dean ENT scissors, small curved Metzenbaum scissors, and possibly a pair of Toreck angled scissors for dissecting distally.

Suture
Absorbable suture is preferred. Certainly, permanent sutures should not be put into the bladder as exposed permanent suture can lead to stone formation. Most surgeons prefer polyglycolic acid sutures such as Vicryl®, Polysorb®, or Dexon®. Chromic catgut also works. Urology needles such as UR 6 can be very useful.

Surgical Technique
Over the years, various techniques have been used. The one in common use presently among fistula surgeons is a flat-splitting dissection that perhaps originated with Machenrodt. The vaginal skin is

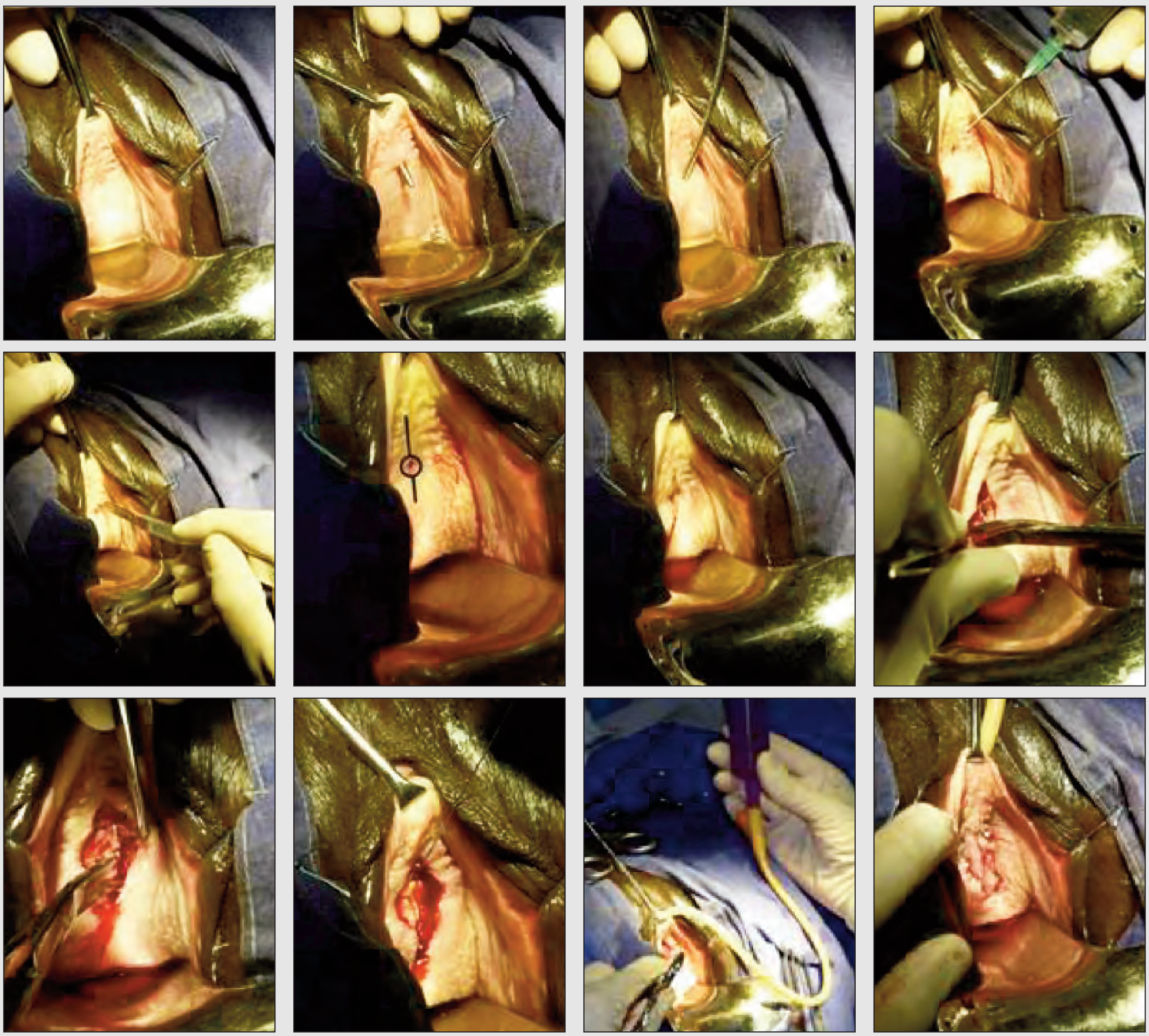

Fig. 11

Technique to close a small mid-vaginal VVF. Note the **injection of dilute adrenaline** (top right), wide dissection of vaginal mucosa, testing of closure with dye, and bladder closure with Vicryl® and vaginal mucosa with chromic.

dissected away from the bladder and pubo-cervical connective tissue. It is essential that dissection be carried out on all sides of the fistula to allow tension-free closure of the bladder defect in one, or sometimes two, layer(s). Most closures are done transversely, but smaller fistulae can be closed vertically. Sister Ann Ward, who has done over 5,000 VVF repairs in SE Nigeria, told me, "I always close VVF's transversely unless the fistula begs to be closed vertically."

Repair of Simple VVFs

A novice fistula surgeon should start with small midvaginal or juxtaurethral fistulae that have soft edges and some pliability. The technique involves an incision through the vaginal skin circumferentially around the fistula and extending a few centimeters either transversely or vertically from the fistula. The vaginal skin is separated from the underlying connective tissue on all sides. If the fistula is small, the remnant of vaginal skin and the fistula tract are excised. If the fistula is a bit larger, this rim of tissue can be turned into the bladder closure. **It is important that no remnants of epithelium from the vagina or bladder be left in the closure.** Closing sutures are taken significantly into the bladder wall

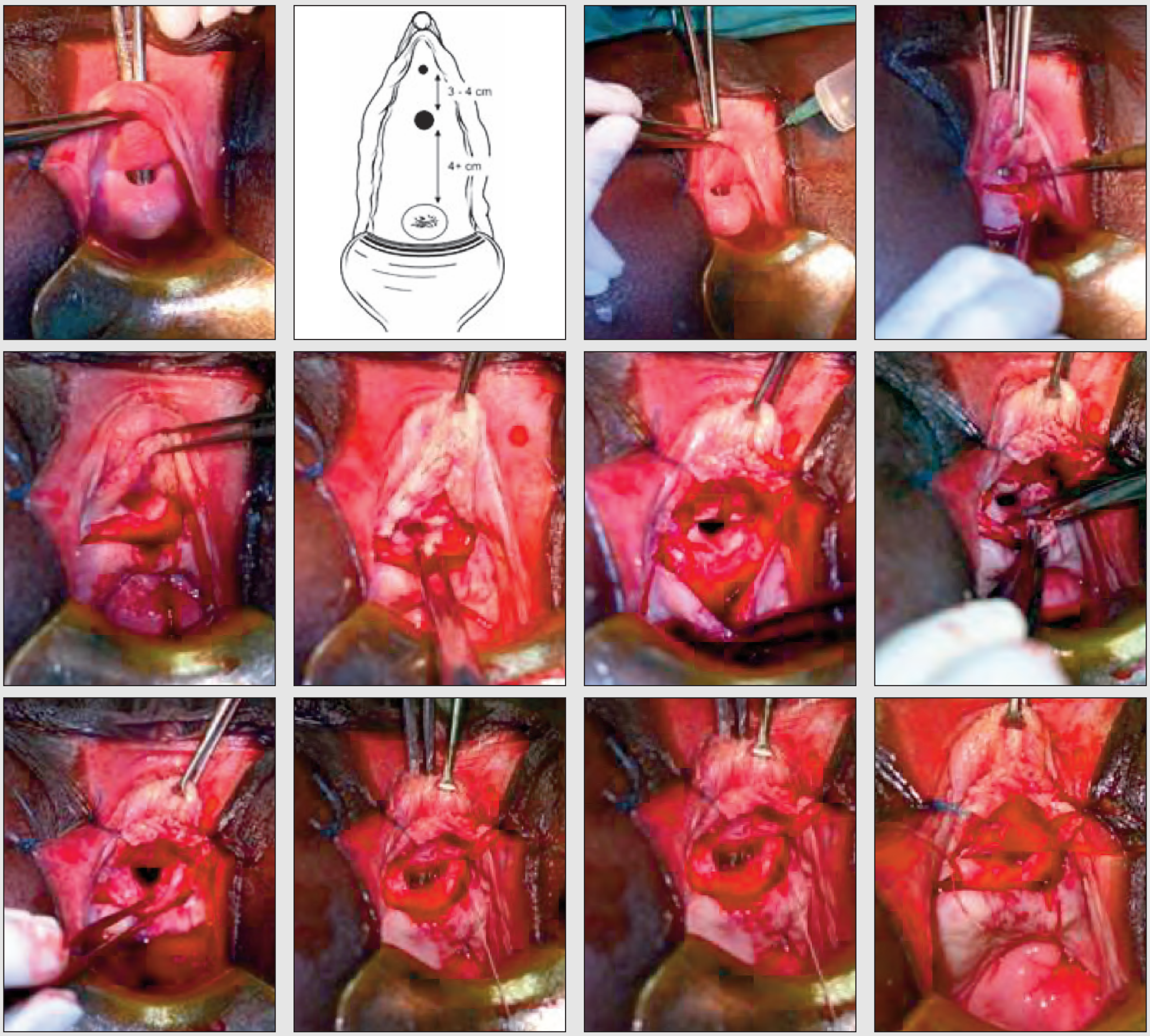

Fig. 12A
Repair of a small juxtaurethral VVF. (BH)

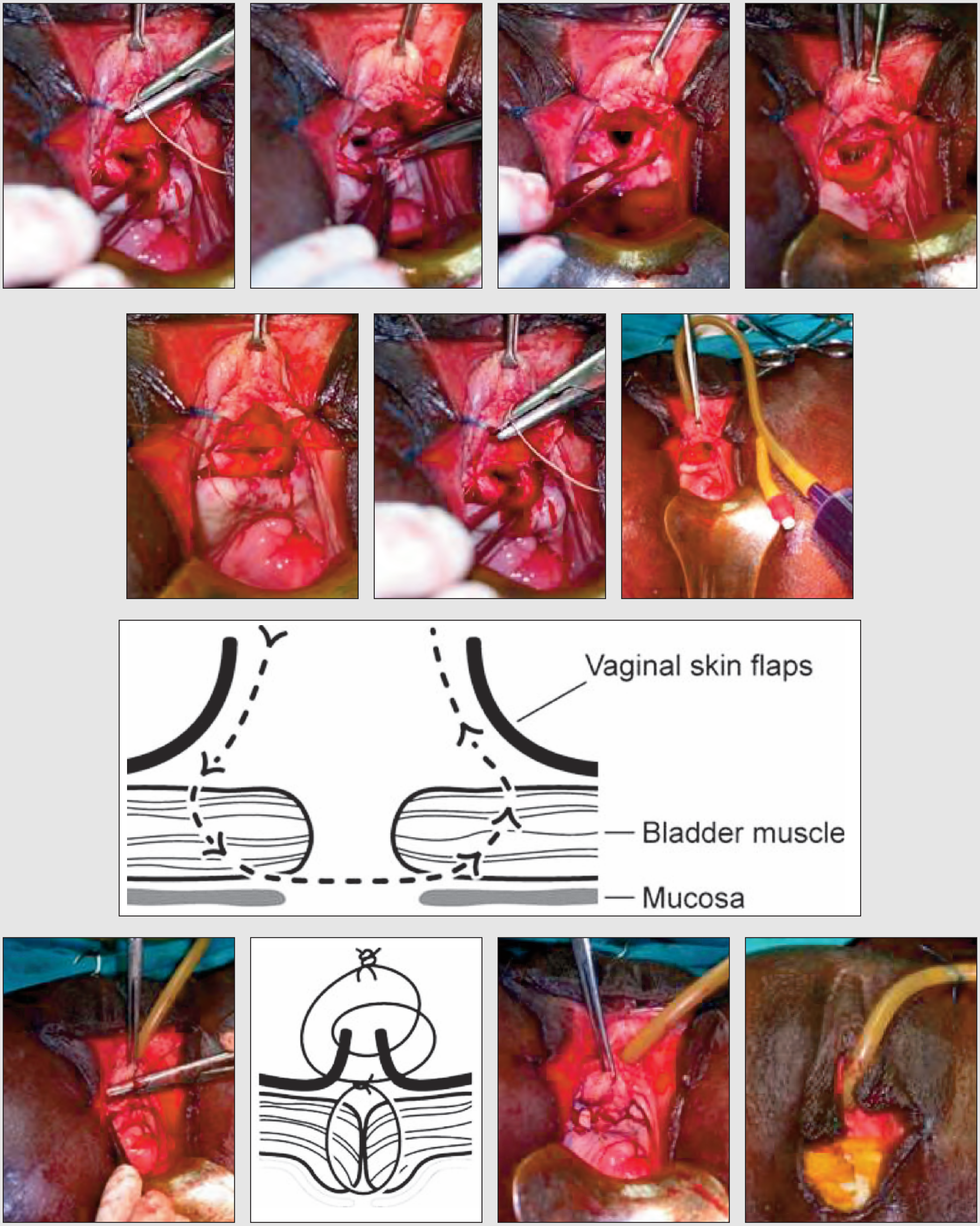

Fig. 12B
Repair of a small juxtaurethral VVF. (BH)

and overlying connective tissue starting at the corners of the repair. These sutures can be interrupted or continuous.

After adequate closure, a dye test is done. Any areas of leakage are additionally sutured. If the closure is neat and dry, the vagina is closed with interrupted, mattress, or continuous sutures.

Repair of a Small Juxtaurethral VVF

(See Fig. 12, courtesy of Brian Hancock)

Editors' note: The following steps are extremely important.

Note suturing of labia minora laterally for better exposure, **injection of dilute Adrenaline solution for hemostasis and ease of dissection**, dissection posteriorly first so blood does not run down on surgical field, etc. See entire description in appendix.

Repair of Intermediate VVF's

Some juxtacervical VVF's can be fairly simple to repair for a surgeon who is used to dissecting the bladder off the cervix and lower uterine segment for vaginal hysterectomies. There are several considerations. Many of these fistulae occur after prolonged obstructed labor and a C. section. Often the anterior cervix is split apart or attenuated. Sometimes the uterus or vaginal apex is adherent and

Fig. 13

Small juxtacervical VVF that is fairly accessible. (BH)

Fig. 14

Juxtacervical VVF one cm in diameter One should identify ureteric orifices. (BH)

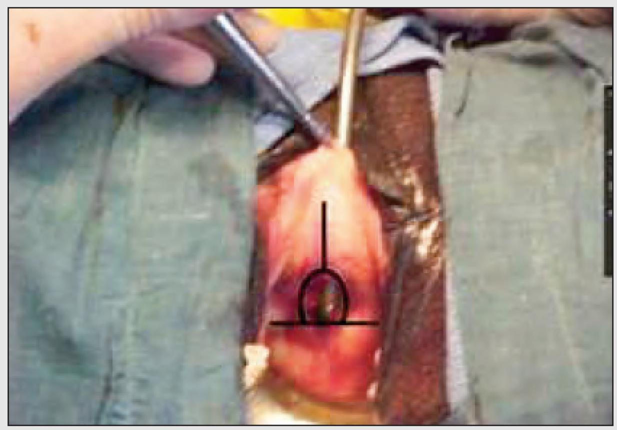

Fig. 15

Mid-vaginal but scarring has pulled the cervix down. Incisions along black lines and dissect bladder away from cervix. (BH)

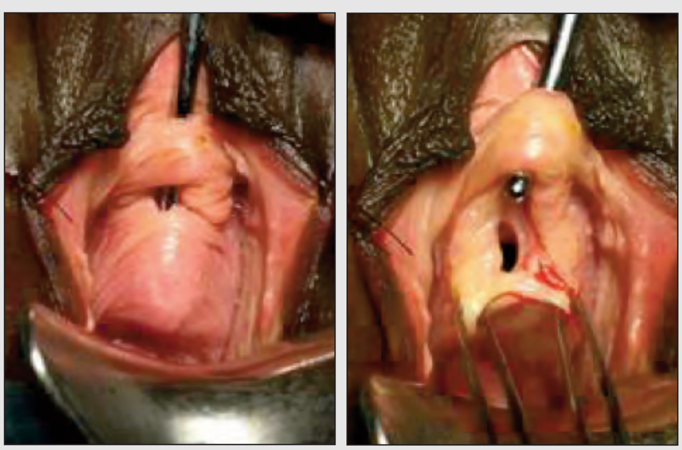

Fig. 16

This looked like an easy juxtaurethral VVF, but when exposed, urethra detached from the bladder. (BH)

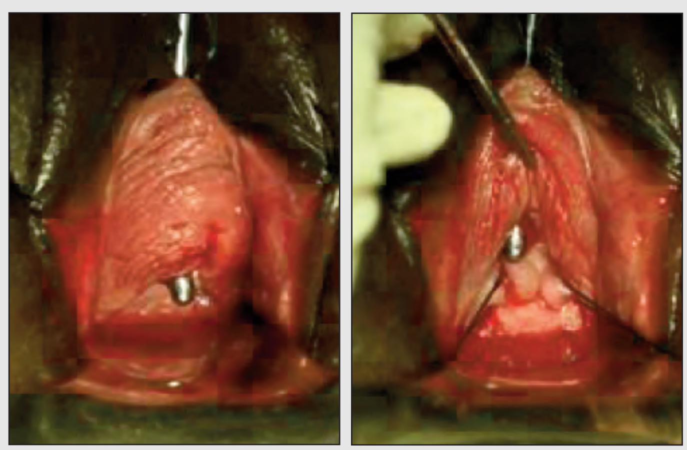

Fig. 17

This is a juxtacervical fistula that extends high into an open cervical canal. The dissection may be difficult. (BH)

Fig. 18

The defect in the anterior vagina is so large the anterior bladder has prolapsed. Only an expert fistula surgeon should attempt this repair. (BH)

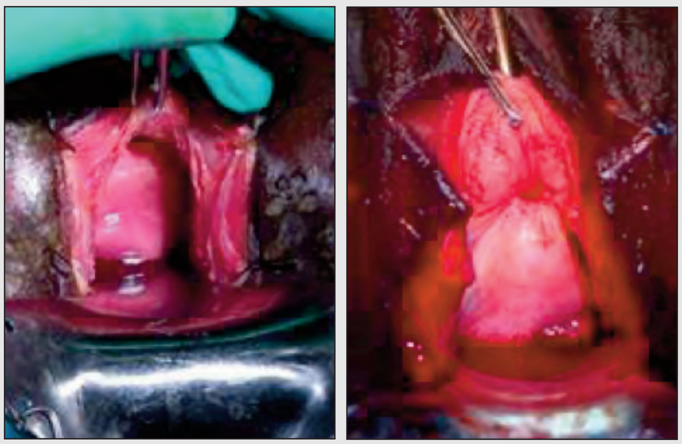

Fig. 19

19a) Small juxtaurethral fistula is hard to visualize because it is pulled up behind the symphysis pubis by scar tissue. Tilting the table and cutting 1 or 2 generous mediolateral episiotomies may help with visualization. 19b) This is a similar juxtaurethral fistula. When a metal catheter was used to rotate the bladder neck downward, and generous bilateral episiotomies were cut, the fistula became accessible. (BH)

does not descend well even with traction. The ureters are close to the edges and easily injured in larger juxtacervical fistulae. Figs. 13-15 show a few juxtacervical fistulae that might prove to be fairly simple.

Larger fistulae and fistulae bound by scar bands require more extensive dissection. Scar bands have to be identified and detached safely from their attachments to bone. Often the attachments of connective tissue and bladder tissue along the pubic rami have to be separated and, as the fistula gets

Fig. 20

This looks like a small fistula, but the vagina is almost completely stenosed beyond the fistula. Generous lateral incisions in the vaginal walls were necessary to gain access. (BH)

Fig. 21

This massive defect was closed on the second attempt, but the patient had urethral incontinence. (BH)

closer to the cervix, the bladder has to be separated from the cervix and lower uterine segment. This dissection can be very similar to that done on a vaginal hysterectomy, but can be more tedious in that the anterior cervix is often split or attenuated, especially in juxtacervical fistulae that occur after C. section and prolonged obstructed labor.

Some fistulae are very difficult even for an experienced fistula surgeon. A surgeon should probably have experience with at least 500 VVF repairs before attempting the very difficult cases such as those shown in Figs. 16-21:

Post-Operative Care

Post-operative care is not complicated but is important for success. We think of Three D's.

- **Drainage**: A Foley catheter is attached to gravity drainage. High-quality bags with long tubes are rarely available. It's hard to find nurses and nursing assistants who will consistently empty urine bags and record urine output. Most fistula surgeons prefer open drainage into a bucket or pan. The nurses and the patient, along with her accompanying caregivers, are asked to take immediate action if drainage ceases. Catheters are frequently checked for kinking, gently irrigated with 20 cc. of saline, and, if necessary, replaced if there is any cessation of drainage. Many fistula surgeons just attach a tube to a bedside bucket or pan and try to keep it dripping.

Fig. 22

Fig. 23

Fig. 24

22) Full hanging urine bag without support. This could easily pull catheter balloon out and damage repair. 23) A free drainage in pan is safer. 24) Drip buckets to hold urine after patients begin ambulating at second day post-op. (BH)

- **Drinking**: The patient is asked to drink 4 liters of water daily. The goal is to keep the urine dilute, uninfected, and continuously dripping.

- **Dry**: The patient's bed should remain dry. Medical staff should be alerted if that is not the case. Sometimes patients will leak some around the catheter from bladder spasms and, not infrequently, they will void around the catheter or leak through the repair if the catheter becomes occluded.

Fig. 25

Fig. 26

25) Normal catheter. 26) Kinked catheter: patients, caregivers and nurses should check for possible complications every hour. (BH)

The catheter is usually left to gravity drainage for 14 days. In simple fistulae, this can be shortened to 10 or even 7 days. If there is a bit of leakage onto the bed, the duration of catheter drainage can be extended up to 28 days. If there is much continuous drainage, do a gentle dye test or inspect the surgical site to see if the repair has failed. Patients might leak some around the catheter from a patulous, damaged urethra or from bladder spasms.

Patients are generally discharged a few days after the catheter is removed. They may need some bladder training and time to get back to a reasonable bladder capacity. They should be warned not to do heavy

Fig. 25

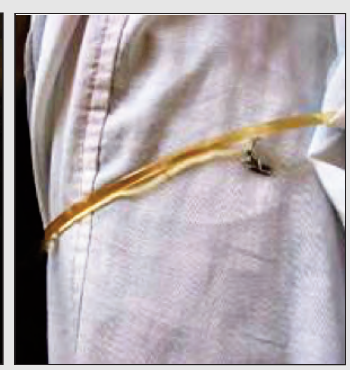

Fig. 26

27) If the patient is drinking enough fluids, then urine should be clear. 28) Urine is too concentrated. (BH)

work or have sexual relations for at least 3 months after the procedure. Were they to get pregnant again, the caregivers should be informed about the previous VVF repair. The patient should be advised to have a C. section prior to the onset of labor or in early labor in most instances.

The Plastic Surgeon as a Consultant in Urogenital Surgery

One of the bad prognostic signs for successful closure and continence is lack of enough vaginal skin to cover the repair and to give a bit of length to the anterior vagina. Some of the larger VVF's can take out most of the vagina between the proximal urethra and the cervix. Various flaps and grafts have been tried, but none have really stood above the rest. Four options are commonly considered.

1 Leave it as it is. Pack the vagina. Hope that the area will stay open and re-epithelize.
2 Cover the bladder repair with a Martius fat graft. Pack the vagina. Hope that the vagina will stay open and epithelialize.
3 Use a labial pedicle, i.e. dissect out the labia minora and cover the repair with thin labial skin.
4 Use more complicated flaps, e.g. medial thigh or buttock flaps.

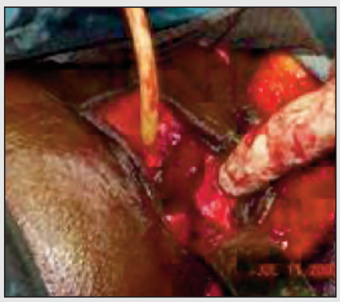

Fig. 29 **Fig. 30**

Pudendal thigh, or Singapore, flap based on the superficial external pudendal artery, and tunneled beneath the labia to cover a large anterior vaginal wall defect after VVF repair. A small transverse section is de-epithelialized to pass under the labia and sutured to the labia.

Fig. 31 **Fig. 32**

Conventional, posteriorly based pudendal thigh or Singapore flap used to reconstruct vaginal wall defect following VVF repair, with scarred contracted vagina. In this case, the labia was split, but ideally, one should tunnel flap beneath the labia. A 6 cm wide flap may be closed.

(**Editor's Note:** Some VVFs do need extra tissue for satisfactory closure. Martius fibro-fatty flaps from the labia are highly vascular and bring vascularized tissue between a scarred vagina and bladder. Though the editor has used these extensively in the past, there has been no assurance that these are helpful, other than bringing in vascularized tissue into a scarred area. They normally **do not include skin**, and so do not help in vaginal reconstruction. Often it is difficult to get the vaginal mucosa closed over these flaps. In the same way, gracilis muscle flaps from the inner thigh have been used to bring in vascularized tissue/muscle, but these can also be bulky. If the distal skin over the gracilis is brought with the muscle, it is not always reliable, especially if it is distal thigh skin.

The pudendal thigh or Singapore flap is a thin fasciocutaneous flap raised off the posterior labial arteries from the pudendal artery posteriorly or the superficial external pudendal artery anteriorly. The flap is raised just lateral to the labia. The adductor muscle fascia should be taken with this flap to preserve blood supply. This flap is thin and can be used to reinforce the vaginal repair. It should be tunneled beneath the labia with a wide tunnel to prevent pressure on the pedicle.

Other perforator flaps show promise as these are thin fasciocutaneous flaps. The medial thigh perforator flap may be used to reconstruct a vagina or even create a new vagina. The perforators are within 5 cm of the perineum, and the flap maybe 9 x 20 cm in size. In addition, the anterior lateral thigh flap may also be used for reconstruction.)

Conclusion

Few surgeries lead to a more profound change in a patient's life and lifestyle than a successful VVF

Fig. 33

repair. Even small VVF's cause a patient to leak her urine all of the time. It has been said that the closure of these defects literally restores women to humanity.

(**Editor's comments**: When one sees a woman in her child bearing years leaving a hospital with a big smile on her face, either they have just delivered a healthy baby or more likely they are now "dry" after experiencing wetness 24/7 for years. See Fig. 33.)

The intent of this chapter is to help surgeons who need to start doing simple VVF repairs. It is imperative that they observe a "master VVF surgeon" perform a few cases before doing their first one. Remember, a botched repair may leave a "fistula cripple" behind. Certainly there are a number of women in Africa with ureter-sigmoid anastomoses secondary to severe VVFs or failed repairs.

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- Valuable reading from the world's most prolific fistula surgeon. More useful for experienced fistula surgeons.
- Available from Teaching Aids at Low Cost (TALC), Box 49, St. Albans, Hertfordshire AL1 5TX, UK <info@talcuk.org>

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- For beginners in VVF surgery.
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- Also available online from www.glowm.com. Search for the book by name. One can download it chapter by chapter.
- This link to the entire book can be copied and pasted into your browser. Downloading the whole book may not work or may take a long time if your server is slow: (http://www.glowm.com/safer_specific_resources/profession/doctor/page/fistula_surgery.html/title/first-steps-in-vesico-vaginal-fistula-repair/resource_doc/4935)

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- Comprehensive VVF surgery text.
- Also available online from www.glowm.com. Search for the book by name. One can download it chapter by chapter.
- This link to the entire book can be copied and pasted into your browser. Downloading the whole book may not work or may take a long time if your server is slow: (http://www.glowm.com/safer_specific_resources/profession/doctor/page/fistula_surgery.html/title/practical-obstetric-fistula-surgery/resource_doc/5435)

Teaching Videos from the Addis Ababa Fistula Hospital:

- Part 1: "Repair of a Simple Vesico-Vaginal Fistula" by Dr. Catherine Hamlin.
- Part 2: "Three More Repairs from the Addis Ababa Fistula Hospital."
- Obtainable from Brian Hancock, 21 Yealand Rd, Yealand Conyers, Lancashire LA5 9SG, UK (brian@yealand.demon.co.uk).
- These videos were made in 1999. Some recommendations have changed. Martius grafts are less commonly used by fistula surgeons now.

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Chapter 24
Hypospadias

Dan Poenaru, Frehun Ayele Asele, and Ronald S. Sutherland

Editors' note: *Hypospadias is included in this text for the sake of the general surgeons working in remote areas where pediatric urologists, urologists or plastic surgeons with hypospadias experience are not nearby. As with cleft palate and VVF, without expert surgical care, these patients may be left as surgical cripples, much worse off than before. It is suggested that these procedures be looked up on the Internet, particularly on YouTube.* ***In addition, the general surgeon should only attempt the distal cases initially***.

Summary
This developmental deformity of the penis requires much from the surgeon who attempts to repair it: knowledge, experience, meticulous technique, fine instrumentation, and humility. Even in the best of hands, the complication rate is high. In many respects, the repair is one of the most complicated urologic reconstructive procedures. Indeed, it is the quintessential urologic plastic surgical challenge.

Definition
Hypospadias is a developmental anomaly characterized by a urethral meatus that opens onto the ventral surface of the penis, proximal to the end of the glans. The meatus may be located anywhere along the shaft of the penis, from the glans to the perineum. Ventral penile curvature, commonly referred to as chordee, occurs variably with hypospadias.

Embryology and Etiology
The penis is normally completely developed by 14 weeks gestation, but arrested development of the urethra may leave the meatus located anywhere along the ventral surface of the penis. Typically, this leads to foreshortening of the ventral aspect of the penis beyond the hypospadiac meatus (chordee) and failure of the prepuce to form circumferentially. A combination of endocrine, environmental and genetic factors determines the potential for developing hypospadias. Current studies suggest a link to environmental endocrine disruptors, but conclusive evidence is lacking.

Incidence
The incidence of hypospadias has been estimated to be between 1 in 1,000 to 1 in 125 live male births. The higher incidence value results from including minor forms of hypospadias.

Anatomy
Understanding the wide variations of hypospadias anatomy (Fig. 1) directly affects the surgical planning, timing, and outcome.

1 The proximal location of the meatus results in ventral deflection of the urinary stream. Boys with minor glanular hypospadias may void normally

2 Ventral curvature (chordee) may be due to shorter ventral corporal bodies (corporal disproportion), deformed spongiosal tissue, scar tissue, or a combination of all. Curvature can lead to painful erections and impaired intercourse.

3 Small penis size (micropenis) may be found in found in boys with hypospadias and disorders of sexual development (DSD).

4 A dorsal, hood-like prepuce results from the ventral deformity. It provides a good source for penile skin coverage or urethroplasty during

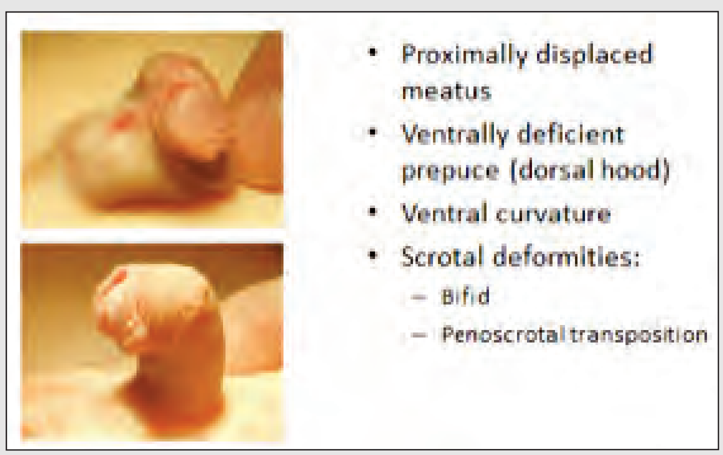


Fig. 1
Hypospadias defined.

repair.

5 The flattened glans results from failure of the glanular urethra to fuse in the midline; hence the "spade or shovel-like" appearance of the glans, which led to the name "hypo**spadias**."

6 Ventral skin deficiency may be difficult to replace once the penis is straightened and the urethroplasty done. In redo surgery, paucity of penile skin is especially challenging.

7 Penoscrotal transposition occurs in severe forms of hypospadias (perineal/scrotal) and is described by the appearance of the scrotal skin above the penis, and the penis is severely curved downward in a more proximal position. These forms are always associated with a bifid scrotum.

8 Megameatus, intact-prepuce (MIP) variant of hypospadias presents with a normal appearing prepuce. A large meatal deformity is discovered at the time of circumcision or retraction of the foreskin (Fig. 2).

9 Chordee without hypospadias usually results from hypoplasia of the overlying urethral spongiosum or failure to correct curvature at the previous attempted hypospadias repair.

10 Meatal stenosis is rarely found in non-operated hypospadias and usually occurs from improper repair. It results in abnormal voiding with dysuria, infection,and breakdown of the more proximal repair.

Fig. 3

Hypospadias and disorder of sexual development (DSD): 5 year old boy with perineal hypospadias and left non-palpable gonad (dysgenetic with fallopian tube). Right iintrascrotal testis with abnormal epididymis. This patient required a three-staged repair.

Associated anomalies

Associated anomalies in boys with **isolated** hypospadias are rare, so further work-up is seldom needed. Inguinal hernia and undescended testes are the most common anomalies associated with hypospadias. However, if proximal hypospadias occurs with cryptorchidism, whether unilateral or bilateral, the possibility of a disorder of sexual development (ambiguous genitalia) has to be considered (Fig. 3).

Fig. 2

Megameatus intact-prepuce (MIP Variant).

Classification

There is no single satisfactory way of classifying hypospadias. Despite obvious limitations, pre-operative meatal position (distal, middle and proximal) remains the most commonly used criterion. The other important consideration is the presence of chordee. In the presence of severe chordee, the meatus may be at the glans, but after correction of the curvature, the meatus may be very proximal. The position of the meatus after repair of the chordee defines the degree of the hypospadias (figure 4).

Based on these factors a simple classification of hypospadias follows.

1 **Distal (anterior) hypospadias**: includes glanular, coronal and sub-coronal forms with the ventral meatus at the level of glans, corona, and sub-coronal level, respectively. Most of these are associated with mild glans curvature (or tilt), which is spontaneously released during repair

and do not require extensive chordee repair. At least 70% of hypospadias are in this category.

2 **Midshaft (penile) hypospadias** with or without chordee: this includes 10% of hypospadias.

3 **Proximal (posterior) hypospadias**; includes perineal, scrotal, and penoscrotal meatus; most of these are associated with severe chordee. Proximal hypospadias forms constitute approximately 20% of hypospadias, but percentage may be higher in referral centers.

Fig. 4
Meatal opening is adjacent to the glans tempting one to treat as a sub-coronal hypospadias. However, when the penis straightened he will be left with a scrotal hypospadias and a long defect to reconstruct.

Surgical management

Hypospadias surgery has developed into a well-defined art and science over the years. Surgeons tackling it should have a detailed understanding of the various basic surgical principles, be experienced in the delicate, precise optically assisted techniques, and maintain a clinical workload that is sufficient to obtain consistently good results. Thus, a key principle of hypospadias repair is selecting which cases can be repaired with local expertise and which ones are left to experts. **There is always a danger of causing irreversible damage** to the patient's penis/urethra if the procedure is done without adequate knowledge and/or expertise. Another well-publicized principle in hypospadias management is the avoidance of newborn circumcision, as most repairs use the preputial skin.

1) **Age of intervention**. Most surgeons who deal routinely with hypospadias prefer to perform the repair when the patient is 6-12 months old. The authors' preferred age is one year, for decreased anesthesia risk and minimal psychological impact. **However, waiting even years for an expert intervention is preferable to early surgery with lasting complications**.

2) **Aims of surgery**. The objectives of hypospadias correction are:

- Complete straightening of the penis (orthoplasty).
- Construct the urethra to be a uniform caliber with the meatus at the tip of the glans (urethroplasty).
- Cover the urethroplasty with a secondary, "waterproofing" layer (see tunica vaginalis flap procedure in Fig. 6).
- Form a symmetric, conically-shaped glans over the repair (glansplasty).
- Cover the repair with penile skin to ensure a satisfactory cosmetic appearance.

(**Editor's note**: Chordee correction. One may ascertain that the chordee has been adequately corrected by injecting saline into the corpora cavernosa through the glans. The erect, taut shaft will easily reveal any uncorrected chordee. There are several techniques to correct the chordee that must take into account penile length, amongst other factors. The details will be available in texts on hypospadias.)

3) **Who should do the surgery?** Because of the wide variation in the anatomic presentation of hypospadias, no single urethroplasty is applicable to every patient. Versatility and experience with all options of surgical treatment are keys to successful management. By recognizing the sometimes subtle details in meatal variation, glans configuration, and curvature character, the experienced surgeon can make the best choice as to the type of repair to use. Thus, hypospadias repair is a procedure, which in the hands of inexperienced surgeons, **can be more harmful than beneficial to the patient**. Some authors claim that a surgeon should perform at least 50 hypospadias repairs per year to maintain the skills necessary to perform this type of surgery. Thus, surgeon knowledge and experience cannot be over-emphasized, particularly for proximal forms.

Options for Each Type of Hypospadias

Anterior Variants

1) **Urethral plate tubularization** involves measuring the urethral plate, making a u-shaped incision, and tubularizing the urethral plate over the catheter in a tension-free manner. This may be done in 3 ways.

- **Glans approximation procedure (GAP)**. The urethral plate is incised along a previously marked "u"-shaped line. The glans is de-epithelialized, rather than deeply incised, as is usually done to create glans wings. The urethral plate is then closed in two-layers. The de-epithelialized glans is then closed over the repair once an intervening vascularized second layer is placed. GAP is useful when a wide-mouthed meatus exists with a deep glans groove (Fig. 5).

- **Tubularized plate (TP) urethroplasty** (also known as Thiersch-Duplay) is similar to the GAP except that the glans is deeply incised to form glans wings to cover the repair. This technique is applicable when the urethral groove is shallower.

- **Tubularized Incised-Plate (TIP) urethroplasty** (Snodgrass) is a modification of the Thiersch-Duplay tubularization. This technique involves a deep longitudinal incision of the urethral plate in the midline. This allows the lateral skin flaps to be mobilized and closed in the midline without tension. After tubularization, it is essential to cover the midline repair with at least one layer of adjacent or preputial dartos tissue prior to closure of the glans wings.

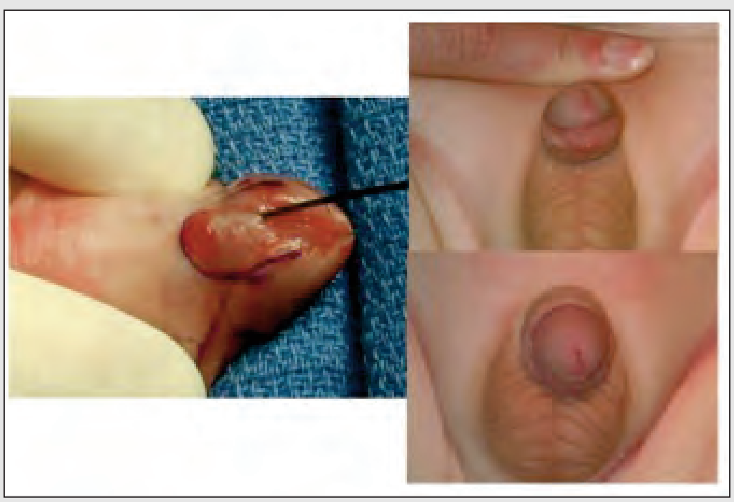


Fig. 5

Glans Approximation Procedure (GAP) is ideally suited for a distal hypospadias with deep and broad glanular urethral groove. Pictures at right are 4 weeks postoperative.

2) **Meatal Advancement and Glanuloplasty (MAGPI)** is done for a glanular meatus which is not patulous and has a shallow glans groove. A wide-mouthed meatus is not amenable to the MAGPI repair.

3) The **meatal-based flap repair** (also known as the flip-flap or Mathieu) may be used effectively for distal hypospadias, assuming no chordee is present and mobile, well-vascularized skin exists proximal to the meatus. This technique often results in a non-vertical appearing urethral meatus and is therefore **not usually the first choice for repair**. It can be useful for revisions.

Middle Variants

The amount of ventral curvature generally dictates the type of repair in middle and distal-shaft hypospadias.

1) **Tubularized plate techniques (GAP, TP, or TIP)** are the most often used provided the urethral plate is wide enough to close without tension. There must also be enough penile skin to close over the repair.

2) **Meatal-based flap**s (rarely used).

3) When there is a paucity of ventral penile skin, one of the **preputial flap techniques** may be used. The well-vascularized inner preputial skin may be mobilized on its vascular pedicle and rotated ventrally as an onlay or tubularized flap. **(Editors' Note**: This repair, initially popularized by Duckett should only be attempted by experienced pediatric urologists or plastic surgeons with knowledge of such pedicle and island fascial flaps.)

- If the urethral plate is preserved during chordee repair, then the onlay technique is used. The lateral suture lines allow for non-overlapping suture lines, as overlapping suture lines may predispose to fistula formation.
- If the urethral plate requires transection in order to repair chordee, then the preputial flap can be tubularized and used as an interposition flap. This technique has a higher risk of complications, mainly stenosis at the anastomosis.

4) **Tunica vaginalis flap procedure**. When there is minimal dartos tissue to cover the urethroplasty, a valuable source of vascularized tissue is the tunica vaginalis surrounding the testis which can act as a second "waterproofing" layer. The tunica can be accessed by dissecting into the adjacent hemi-scrotum through the proximal portion of the penile skin incision. The flap is excised with care to avoid injuring the epididymis. The flap derives its blood supply via the cremasteric vessels which are carefully preserved during dissection. When placing the flap over the hypospadias repair, avoid torsion of the penis by making sure the flap has ample pedicle length (Fig. 6).

5) **Staged procedures or free graft** (see proximal variants).

Proximal Variants

The surgical approach of these forms is discussed primarily for completeness; the authors **strongly recommend** surgeons without exceptional expertise to **avoid performing these procedures** because of the potential serious complications.

Many of the scrotal and perineal forms of hypospadias are associated with significant chordee, which requires division of the urethral plate and results in a gap to be bridged between the proximal native urethra and the tip of the glans. This can be achieved in several ways.

Fig. 6

TUNICA VAGINALIS PROCEDURE: When harvesting the flap, care is taken to not injure the epididymis. There must be ample length of the pedicle so not to torse the penis when the flap covers the neourethra.

1) **Staged repair**. The first stage consists of aggressive repair of the penile curvature. This can be accomplished by extensive dissection of the attached dartos tissues, dorsal plication of the tunica albuginea, or ventral corporotomy with insertion of a dermal or synthetic graft. The prepuce is then divided in the midline and brought ventrally to cover the ventral penile shaft. The second stage involves tubularization of the transposed preputial skin (urethroplasty) to form the urethra. Occasionally a graft is required (buccal or extra-genital) to complete the repair (Fig. 7). The second stage also includes the scrotoplasty to repair the bifid scrotum.

2) **Tubularized free grafts** may be used to bridge the proximal native urethra to the end of the glans. The most commonly used free grafts are buccal mucosa, full-thickness skin, or bladder mucosa. Preputial skin is much preferred to extra-genital skin. If genital skin is not available, buccal mucosa may be the next best tissue.

Technical Details

Magnification: Most surgeons agree that optical magnification is indispensable in hypospadias surgery. Standard operating loupes, ranging from 2.5× power to 4.5×, are generally thought to be ideal for the magnification needed for this type of surgery.

Sutures and instruments: A monofilament traction suture on a tapered needle is essential to keep the penis on stretch during the procedure. Placing it vertically allows for creation of a more vertical meatus and prevents the 2 suture holes seen on the glans when placed laterally. Most surgeons choose fine absorbable suture for urethral tubularization. Polyglycolic (Vicryl®) or polyglactin (coated Vicryl®) are probably the most common suture choices. However, some surgeons prefer the longer-lasting polydioxanone suture (PDS®). The authors prefer PDS® and Vicryl® 6-0 and 7-0, depending on the size of the penis. In adolescents, 5-0 Vicryl® or PDS® can be used. Skin closure is usually accomplished with either chromic 4-0 or 5-0 suture. Delicate instruments used in ophthalmologic surgery are well designed for the precise tissue handling required in hypospadias repair. Small, single-toothed forceps or fine skin hooks allow tissue handling with minimal trauma. Monopolar electro-cautery for bleeding control has to be used very cautiously and not close to the urethral plate; bipolar cautery is a good alternative.

Urinary diversion: The goal in any urinary diversion after hypospadias repair is to protect the neo-urethra from the urinary stream during the initial healing phase. Small, indwelling 6-8-fr silastic tubes left through the repair and just into the bladder allow drainage of the urine into the diaper in infants. We prefer the indwelling stent, used for 5 to 14 days, depending on the complexity of the repair. In older children, a 6 or 8-fr Foley catheter may be used in the simpler distal repairs, and a suprapubic cystostomy can rarely be used in more complex repairs. Suprapubic drainage should be used in complex re-operations or in any repairs requiring a free graft. Studies have suggested that for simple distal procedures, such as MAGPI, meatal-based flap, or distal tubularization, no diversion is required. Simple, small fistula repairs can be accomplished without diversion.

Fig. 7

Scrotal hypospadias requiring 2 stages: At the second stage (image at right) a buccal inlay graft is required in order to tubularize the urethra and maintain sufficient skin for coverage.

Dressings: Hypospadias dressings should apply enough gentle pressure on the penis to help with hemostasis and to decrease edema formation, without compromising the vascularity of the repair. No evidence-based guidelines suggest which dressing to use; indeed, there is data to support using no dressing. The following are commonly used dressings:

- **Tegaderm®** or thin, transparent, breathable dressings have become the most popular form of dressing. After wrapping the penis with non-stick gauze like Telfa®, the Tegaderm® is either wrapped around the penis or fixes the penis to the pubic region in a sandwich-like fashion.

- A **foam rubber** dressing, which can be placed around the penis in a liquid state is poured in a liquid state into a plastic form and then dries to a solid dressing. This leaves a soft, mildly compressive dressing that is waterproof.

- **Elastic Coban®** dressings may be used if more compression is desired; however, caution must be exercised to avoid ischemia to the repair. This should not be used in infants and young children. If used, consider removal in 12-24 hours.

Complications

The type and incidence of complications vary with the particular type of repair. Surgeon experience, attention to detail, and meticulous technique are imperative to keep the incidence of all complications to a minimum.

- **Bleeding**: Intraoperative bleeding usually comes from the glans and urethral spongiosum and can, at times, be troublesome. However, with the judicious use of the point tip cautery and delaying the glans incisions, the bleeding can be generally kept to a minimum. A rubber band tourniquet or cutaneous infiltrations with dilute concentrations of epinephrine with concentration of 1:100,000 can be helpful, but they should not replace careful technique. Postoperative bleeding is minimized once glans closure is accomplished and generally prevented by mildly compressive dressings.

- **Infection**. With perioperative antibiotics, wound infection is a rare problem in hypospadias repair. Some risk factors include pubertal patients, questionable viability of tissues, and redo surgery. Urinary prophylaxis with oral antibiotics is recommended with indwelling catheters that are open to drainage in the diaper. Whenever available, we use topical antibiotic on the suture line for the first few days after the dressing is removed.

- **Urethral stent/catheter dislodgement or extrusion**. This is a difficult problem, especially in cases where the urinary drainage/diversion is important to protect a repair. Attempts to replace the catheter or stent in the ward often fail, and may be difficult even in the OR as the urethra may be distorted around the site of the anastomosis.

- **Fistulas**. A urethra-cutaneous fistula is the most commonly reported complication after hypospadias surgery. It results from failure of healing at some point along the neourethral suture line and can range in size from pinpoint to large enough for all voided urine to exit through it. Fistulas may also be associated with meatal stenosis or distal stricture. Surgical closure should be postponed until complete tissue healing has occurred, which requires at least 6 months. A small fistula may be closed by local excision of the fistula tract followed by closure of the urethral epithelium with fine absorbable sutures. Approximating several layers of well-vascularized subcutaneous tissue over this closure, with **non-overlapping** suture lines, is important to prevent recurrence. Urinary diversion is usually not necessary in small fistula repairs. Larger fistulas may require more complicated closures with mobilization of tissue flaps or advancement of skin flaps to ensure an adequate amount of well-vascularized tissue for a multilayered closure. Urinary diversion is often necessary with more complicated closures.

- **Strictures**. Narrowing of the neourethra may occur anywhere along its course. The most common sites of stricture formation are at the meatus and at the proximal anastomosis. Most cases of meatal narrowing can be managed as an office procedure by gentle dilation in the first few postoperative weeks. Occasionally, meatotomy or meatoplasty is needed, especially when associated with a proximal fistula or a neourethral diverticulum. Generally, more proximal strictures can be treated with dilation or a visual internal urethrotomy. Open urethroplasty with excision of the stricture and primary urethral anastomosis or patch graft urethroplasty may sometimes be required.

- **Diverticulum**. Saccular dilation of the neourethra may result from distal stenosis causing progressive dilation. It may cause urinary stasis with chronic inflammation and dysuria. Obstruction may result from kinking of the urethra when the diverticulum distends. Excision of the redundant neourethra with primary closure is the procedure of choice.

Summary

Hypospadias presents with a varied degree of severity. Its repair requires all the elements of fine plastic surgery: expertise and skill with a variety of techniques, fine instruments, meticulous technique, delicate tissue handling, optical magnification, and humility. **If done otherwise, complications surely will occur**. To become skilled in hypospadias repair and to maintain those skills, excellent training and a consistent high volume of cases are required. **Surgeons who only occasionally see a boy with hypospadias should not attempt repair unless supervised by someone with experience**.

Chapter 25

Multiple Trauma Care in a Remote Hospital Setting

James D. Radcliffe

Editors' note: *This chapter is in outline form, different from the other chapters in the book, since trauma care must be well organized. I have traveled to remote hospitals around the world, and very few see the amount of trauma as is seen at Kudjip Hospital in central Papua New Guinea, where Dr. Radcliffe has served. There are entire books written about the violent behavior there.*

Triage Preparation

1) Arranging for extra help in casualty when mass casualties arrive (need for more nurses and doctors).

2) Methods of patient ID (toe tags or bracelets).

3) Using special trauma sheets and forms (see Figs. 1 and 2).

4) Equipment and medicine checklists preparation (daily, weekly, monthly, and yearly).

5) Practice drills with simulated patients/situations.

6) Security systems and personnel (crowd and criminal control).

7) Proper preparation of lab and x-ray equipment, supplies and staff.

8) Anesthesia and pulse oximeters readily available.

Triage and Individualized Care of Injured Patients with Multiple Injuries

1) **General principle**: In mass trauma conditions, first sort out, stabilize and triage all patients in ER before taking any patient to the operating theatre (OT) except for life-and-limb-threateing conditions.

2) **General principle**: "triage" applies to the whole group as well as to the individual patient using the **ABC method** of priority care and evaluation.

A) **Highest priority** goes to the most severely injured patients who are able to be salvaged. This would include the critically ill with airway, breathing or bleeding problems. These are unstable patients with abnormal vital signs, obvious blood loss, or an acute abdomen. They need to go to OT urgently.

(**Editor's note**: In most remote hospitals, the general surgeon who will provide plastic and hand surgery care must also provide care for the critically injured, and this is his highest priority. It is unfortunate if he does not have other surgeons to assist or if he cannot refer patients to another hospital, but this is usually the case. The good news is that most face and upper extremity injuries can wait up to 24 hours for care. Lower extremity wounds must be cared for within the first 8-12 hours but wounds can be well irrigated, debrided, and loosely closed and definitive care performed later—see **Clean Closed Wound Concept** in chapter 2.)

B) **High priority** patients are those who are seriously and critically injured but not yet in a life threatening situation. They may include pelvic and long bone fractures or liver/spleen injuries. These may need OT soon but not immediately.

C) **Moderate priority** goes to those with serious but not critical injuries. These would include frac tures and dislocations that need reductions and wounds that need suturing that can be done in the ER. Other doctors and nurses besides surgeons can help with these. This would include patients who need admission for observation but do not need to go to the OT, at least not that same day. (**Editor's note**: These would include most facial and extremity injuries in mass casualty situations.)

D) **Minor injuries** can be evaluated, treated and released for follow-up in the clinic. Nursing staff can be a great help with these patients after the doctor does an initial evaluation. When there are many patients to care for, it would be good if patients with minor injuries are treated in a different area than the main casualty/ER. (**Editor's Note**: Clean Closed Wound Concept should be taught to junior doctors and experienced nurses. After these patients have been seen and triaged by a physician, wounds can be cleansed and loosely closed. Definitive surgery may be carried out in a few days if tendon and nerve injury are suspected.)

E) Patients who are alive—but so severely injured that they have no reasonable hope of recovery in a resource limited setting—are in a special category of **low priority**. They may need to be moved to a secluded area for comfort care. This would include those who are certain to die soon. They need prayer, and their family will need support and counseling. This would include patients like those with severe diffuse brain injury, poor GCS, or full thickness burns >60%.

F) Patients who are **dead on arrival** and had no signs of life during transport or at presentation to the hospital need to go directly to the morgue so they do not delay the care of those who can be helped.

G) Consideration needs to be given to whether some patients from a large number arriving at a small hospital may need to be transferred to other nearby hospitals, depending on what the surgical capacity of these local hospitals. This would be, hopefully, those patients who are stable but need admission and further evaluation. With better phone service worldwide, one should be able to get the approval of the next hospital before transfer. Transferring some may actually allow more to be salvaged overall. When patients are transferred, there must be adequate nursing care in the ambulance and adequate notes must be sent (Figs. 1 and 2).

Acute Care Issues in ER/Casualty Area

1) Primary Survey by a doctor after an initial evaluation by a nurse is needed. If there are enough nursesor student nurses, it is good to have one per patient to stay with that patient for continuity. Attention to the ABCs of trauma care should be done by both nurses and doctors. (**Editor's Note**: It is important for the physician to use charts in Fig. 1 to document findings.)

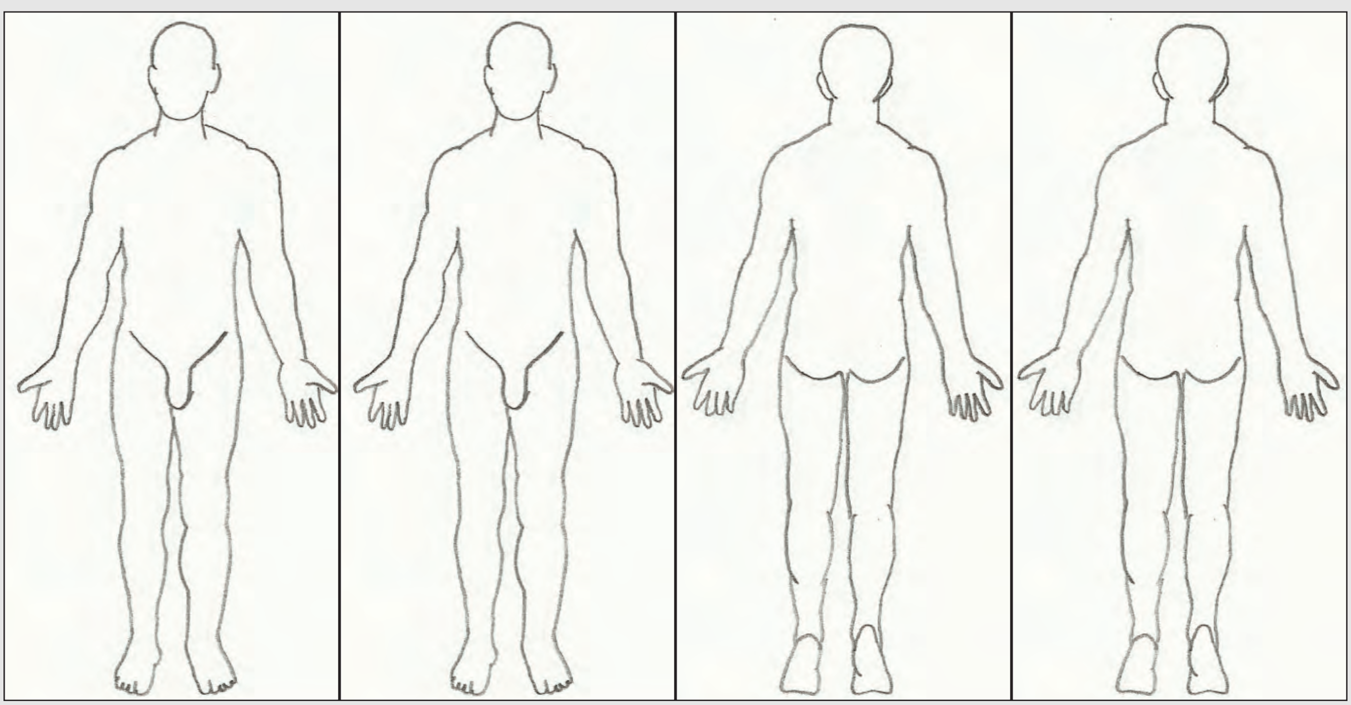


Fig. 1a-d

Anatomical sheets on charts at Kudjp Hospital in the Highlands of Papua New Guinea. These sheets help a physician or nurse do a complete physical exam and label injuries so that doctors and nurses that review patient later will understand what injuries are beneath dressings.

2) After airways are secured, any patients needing chest tubes should have these placed immediately. Initial evaluation is by clinical exam, pulse oximetry, and ultrasound with CXR (chest X-ray) only for those in whom there is a question but no acute respiratory distress. **Patients needing a chest tube acutely for life threatening tension pneumothorax do not need to wait for CXR to be done**. (**Editor's note**: Use "Trauma Sheet" as in Fig. 2 to document that these tests have been ordered and to record results when ready.)

3) **IV access** is needed for any patient with suspected blood loss, shock, near arrest, abnormal vital signs, a need to go to OT or for IV meds such as antibiotics.

4) A liberal use of **antibiotics** is acceptable in this setting of dirty or delayed wounds presenting to casualty for whom some delay in care can be expected. Those injuries that come from the farm or from a roadside accident need broad spectrum antibiotics to cover gram-positive, gram-negative and anaerobic infections.

5) If patients are going to OT, an indwelling **catheter** is necessary especially if shock is present.

6) Initial **wound care with simple debridement** of any large FB (foreign body) and quick cleansing with saline and iodine can be used. Pressure dressing is used for any oozing, bleeding areas. A few sutures can be placed to stop other more serious bleeding until transfer to OT can be arranged.

(**Editors' notes**: The best solutions for irrigation are saline or Ringer's Lactate (Hartmann's). Actively bleeding wounds need point pressure rather than a large bulky dressing. One should not put sutures in blindly to control bleeding in the upper extremity, as major nerves are often adjacent to the major vessels. Point pressure will control the bleeding until the area can be carefully exposed and evaluated in the OT. A tourniquet is not recommended as it can be forgotten in major injuries.)

7) Secondary survey needs to be done the same day in the casualty area especially after further lab work, x-rays and vital signs have been done. Patients needing admission can be placed in different wards if this is helpful to prevent overload of any one area for nursing care.

8) After the initial physician physical exam, further evaluations in the ER may include, pulse oximetry, "FAST" US (ultrasound) evaluation, chest x-ray, pelvis, C-spine x-rays, and long bone or joint films if suspected fractures or dislocation are present.

Operating Theater Concerns

1) The most seriously injured patient who is in danger of loss of life and is salvageable should go to the OT first. It is good if the procedures for the first patients going to the OT **are not extended ones**, so the other patients needing same-day urgent surgery do not have to wait a long time—especially if some are unstable in the ER.

2) It is **important** to attend only to life-threatening injuries at the first trip to the OT if other patients are waiting. There may be a need to temporize the other injuries by creating clean, stable, closed wounds (again, see "**Clean Closed Wound Concept**" in chapter 2) that can be splinted, elevated and repaired later.

3) In a setting of limited OT space, time, resources and surgeon availability, all critically injured patients can have initial correction of life or limb threatening issues; further repairs and corrections can then be scheduled as soon as possible over the next few days.

4) The next most critically ill patients with surgical problems in decreasing severity should be attended to in the OT in a system of triage. During the time in the OT other doctors can continue reassessing the injured with further surveys, vital signs, and repeat ultrasounds of chest and abdomen to determine if any patients need to be changed in the priority list for OT.

5) **Cultural factors** in given countries will determine some adjustments to certain aspects of trauma care, such as the abandonment of those who are clearly dead on arrival or certain to die despite treatment.

6) With any given patient in the OT with life-threatening issues, the airway should be addressed first, then breathing issues, followed by circulation problems including the control of continued bleeding—especially if arterial. Dislocations and fractures should be reduced, especially if some questions of distal circulation exist. Major problems like severe bleeding from liver or spleen injuries should be given high priority. **CNS compression should be released**. Pelvic fractures may need to be

stabilized.

7) Regarding extremity issues that involve multiple structures: After thorough cleansing and tourniquet application, it is sometimes wise to attend to vascular injuries first unless the bone can be stabilized quickly, thereby preventing disruption of vascular repair later by traction on the extremity. The bone, if not done first, will need stabilization of some sort with fixation unless non-displaced and stable. Then tendon repairs can be done followed by nerve repairs if this is the time for definitive repair. If other patients are waiting in line for OT time, the tendon and nerve repairs can wait initially to have definitive repair sometime in the next week or so. Close the wounds as in the **Clean Closed Wound Concept**, and then one can return to a clean wound for definitive repair later.

(**Editors' Note**: After copious irrigation and debridement, the editors would stabilize the extremity fractures before commencing vascular repairs. When cases with vascular injuries are delayed in reaching the hospital, fasciotomies should be performed in the extremity immediately, prior to bone stabilization and vascular repair.

It is important that any bandaged extremity wound be evaluated daily. Too often, these wounds are bandaged and left as more important lifesaving procedures are carried out. It is not uncommon that a bandaged but significant hand injury is unnoticed until the patient is ready for discharge. Most often, the injured part has remained beside the patient on the bed and not elevated while life threatening injuries are cared for. Once the patient recovers from these serious injuries, the patient will need good hands so he/she can return to work. Sometimes the slogan "it is just a hand" (not important as a heart, etc.) is true, and the hand is not evaluated until the patient is discharged and must begin using it. **DO NOT FORGET THE HANDS**.)

Extended Care Issues

1) The patients in ER and later in the Ward will need good monitoring with serial labs, exams, follow-up US, vital signs, pulse oximetry and more complete surveys to reassess for further injuries and complications. It is not uncommon for even good staff to miss some occult injuries (hand fractures and dislocations) in the initial confusion and rush of the multiple patients with multiple injuries in the casualty areas.

2) Further non-critical labs and x-ray follow up exams in X-ray department or by portable machines will need to be done.

3) Non-urgent cases can be scheduled in the days following the initial trauma, and some repairs can be done on the elective schedule as well.

4) If many patients were involved, the systems and philosophy of "triage" will continue to help in prioritizing the patients for OT time. Other things that must be rationed in a limited-resource setting are bed space, medical supplies, medications, and IV solutions, oxygen, and of course doctor energy and emotions.

TRAUMA SHEET

Patient # ____________ Triage Classification ____________

Name: ________________________________

Vitals: Temp ________ HR ________ RR ________ BP ________

History: ________________________________

____

____

Physical Exam:

Neuro: ________________________________

Head: ________________________________

Neck: ________________________________

Chest: ________________________________

Abdomen: ________________________________

Pelvis: ________________________________

Extremities: ________________________________

____

Injury Summary: ________________________________

____

____

Labs: ________________________________

____

X-ray: ________________________________

Sono: ________________________________

Orders: ________________________________

____

Fig. 2

Check list for exams, labs, x-rays, etc.

Chapter 26

Hand Trauma and Diagnosis

Tertius H. J. Venter

The Injured Hand

We work, earn our living and communicate with our hands. With them, we care for our families and for ourselves, emotionally and physically. The human hand has been designed and developed into the most complex and effective working instrument in the whole of creation, controlled and driven by the central nervous system.

Its power and strength lies mainly in the forearm, directed and stabilized by the elbow joint and shoulder girdle, supported by the rest of the body. The muscles of fine control are located in the hand itself. Any disruption in this complex orientation from the complex brain to the fingertip, with its vast array of sensory supply, can greatly impact the life of the patient. A manual worker may generate grip strengths in excess of 90 kg of pressure while the hand of a jeweler may perform such fine movements under magnification that they are barely visible to the naked eye.

The correct diagnosis and careful, meticulous and timely repair are of the utmost importance to restore function to an injured hand. It cannot be overstressed how important the initial correct diagnosis and management of the hand injury is. Secondary reconstructive procedures are good, but more often than not cannot restore normal function.

Soft-tissue injuries to the hand and upper extremity can destroy the special sensory function and may interfere with motion or grasp strength by exposing underlying tendons, muscles or joints. Successful repair of soft-tissue defects requires understanding of the anatomy, the techniques of reconstruction, and sound surgical judgment. The provision of skin cover by direct suture, free skin graft, or flap takes absolute priority. Skin cover alone halts the process of infection and fibrosis which are particularly harmful in the hand.

Primary wound healing is always the paramount goal in the management of the injured hand. Delayed healing predisposes to edema, sepsis, excess scarring and joint dysfunction. Every wound, even if unsuitable for actual primary closure, must be prepared for closure at the earliest possible opportunity.

Hand wounds which are not suitable for primary closure should be converted through surgical intervention into wounds amenable to delayed closure as soon as possible. Such intervention may be necessary in wounds that are contaminated, in crush injuries or when the patient presents with early signs of infection. Some wounds are already infected, and can only be closed by some means of tissue transfer. If this early effective intervention leads to primary healing, it is vastly preferable to secondary healing following infection. This may lead to the breakdown due to the inappropriate direct suture of an unsuitable wound.

Examination of the Hand

History

The patient's age, occupation, hand dominance, history of previous hand impairment or injury, time interval since injury, location and conditions under which the patient was injured (e.g., a clean or dirty environment), mechanism of injury (e.g., object that caused the cut, crush or thermal injury), and previous treatment administered are essential factors that should be obtained. Numb fingertips in a guitar player versus the same in a heavy construction worker have far different occupational implications.

Physical Examination

In examination of the hand it is important that the entire involved upper extremity, including the shoulder girdle, should be examined. Following that examination, attention is turned to the hand which is to be examined systematically.

- **The Wound.** Note the type of wound—cut, crush, thermal, contaminated or non-contaminated, tissue loss and area of the hand involved.

- **Circulation.** The presence or absence of edema, cyanosis and pallor should be noted. Radial and ulnar pulses should be checked, and the Allen test should be performed. Capillary filling is important to assess perfusion.

- **Sensibility.** It is absolutely essential that the patterns of anesthesia be carefully examined and clearly documented following any type of injury before any local anesthetic agent is used in the wound or as a peripheral nerve block. Following acute injury, the most accurate assessment of sensibility is provided by light touch with a wisp of cotton. Particularly in the frightened child or in the apprehensive adult, this is far more reliable than the use of pinprick testing. In the assessment of patients without other significant injuries, light touch and two-point discrimination are the two most valuable sensory tests. Keep in mind that there is considerable cutaneous overlap between the different cutaneous territories (Fig. 1a). However, there are certain autonomous zones. The **median nerve** controls the volar surface of the terminal phalanx of the index finger; the **ulnar nerve** controls the volar aspect of the terminal phalanx of the little finger; and the **radial nerve** controls the dorsal web space of the thumb.

- **Coverage.** Areas of skin loss and the extent thereof should be noted as well as exposed underlying structures. This information will greatly influence management of the injury.

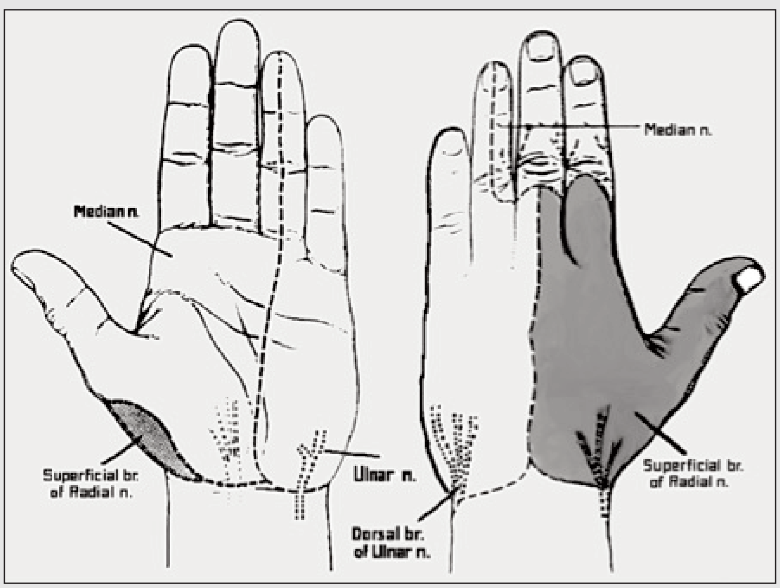


Fig. 1a

Sensory innervation of the hand (Courtesy Plastic Surgery, Principles and Practice, Mosby).

The fingertip skin and its nerve supply warrants special mention. The fingertip is the end organ for touch and is abundantly supplied with sensory receptor sites including Pacinian (deep touch) and Meissner corpuscles (light touch), Ruffini corpuscles (heat), and free nerve endings (pain). Bilateral digital nerves and arteries course between Cleland's and Grayson's ligaments on the volar surface of the digit and terminate in the pulp of the fingertip where they divide into numerous small branches. The dorsal sensory branch of each digital nerve courses dorsally at the level of the mid-proximal phalanx to supply skin over the middle and distal phalanx.

It is important to realize that the **digital nerves lie volar to arteries in the digit**, but in the palm they lie dorsal to the common digital arteries (Fig. 1b).

The skin of the fingertip and palm is stabilized for pinch and grasp by a specialized layer of thick, cornified and stratified squamous epithelium which becomes thicker with use. Uniquely patterned ridges and grooves (fingerprints) help stabilize pinch and grasp through its textured and nonslip surface. Numerous fibrous septae, including Cleland's and Grayson's ligaments, connect the volar hand skin to the underlying bone and tendon sheath which further stabilize pinch and grasp. The subcutaneous tissue between fibrous septae transmits the digital arteries and nerves. Injury to the digital nerves and in particular to the finger tips can be a potential source of chronic pain resulting from a neuroma where the digital nerve was injured or in the crushed fingertip.

- **Bones**. Radiographic examination is essential including stress x-rays of the wrist if a bone injury is suspected. An AP and true lateral X-ray of the involved part are the minimum required. Lateral x-rays of the fingers should not be taken with the digits superimposed. Either the digits must be fanned or separate laterals must be taken for each digit. Oblique x-rays are often needed to identify fractures and dislocations.

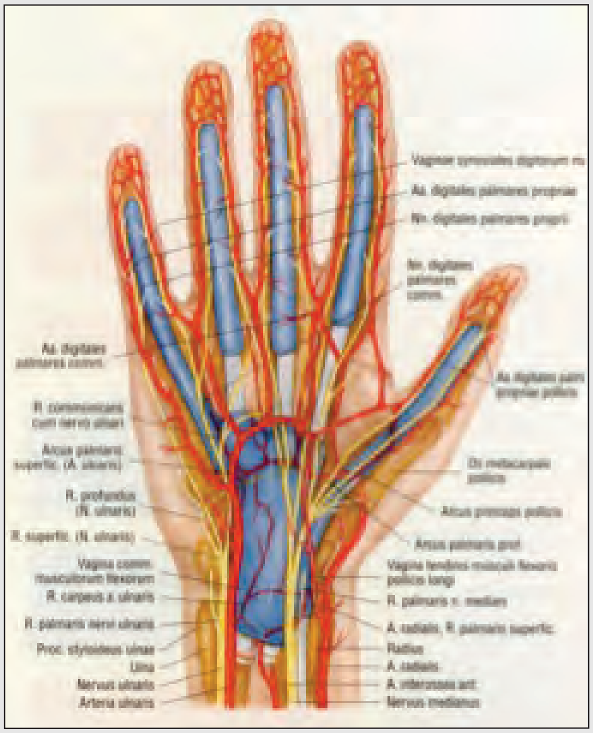


Fig. 1b

(Courtesy of Tertius Venter)

- **Joints and Ligaments**. Joint and/or ligamentous injuries are extremely common in the hand. The specific areas of tenderness must be localized relative to the various ligamentous structures, and the ranges of both active and passive motion must be recorded. Stability and instability must be noted.

  The meta-carpophalangeal joints: normal range of movement is 45 degree extension to 90 degrees flexion. It has a normal 30 degree abduction and adduction range of movement in full extension (0 degree or neutral position) In 90 degree flexion only minimal lateral movement if the collateral ligaments are intact (the ligaments are fully stretched and under tension in this position).

  The proximal and distal interphalangeal joints: normal range of movement is 0 degree (neutral position in full extension) to 110 degrees flexion. It has no abduction/adduction movement in either the flexed or extended position and neither any dorsal range of movement from the neutral position.

  Thumb interphalangeal joints: this joint's normal range of movement varies significantly but on average is 45 degrees extension to 70-90 degree flexion. There is no lateral movement.

  Thumb metacarpophalangeal joint: normal range of movement also has a fairly wide individual range with an average of approximately 20 degrees extension to 70-80 degree flexion. Lateral movement is 5-10 degrees abduction and adduction when the joint is in the neutral position but no movement in the fully flexed position.

  The ligaments in children are stronger than the epiphyseal plate and the epiphyseal plate in close proximity to the joints is frequently injured in children.

  Accurate AP and lateral x-rays of the involved joint are necessary to rule out fracture, subluxation, dislocation, or fracture-dislocation. Ligamentous avulsion injuries are common. For certain injuries, oblique or stress x-rays are very helpful.

- **Flexor Tendons**. The initial management of flexor tendon injuries is of utmost importance because such treatment determines eventual restoration of function. Treating flexor tendon injuries should not be undertaken casually. The inexperienced or occasional hand surgeon renders his patient a disservice by attempting surgery beyond his limits of expertise. The surgeon must have precise knowledge of anatomy and understand the process of tendon and wound healing. The availability of a skilled hand therapist is so important for the eventual recovery of function and if not available the treating surgeon should take on the responsibility to supply the patients with detailed information, advice and be prepared to spend time demonstrating the necessary exercises to the patient to ensure a satisfactory outcome.

  Examination of the flexor tendons of the hand: The flexor digitorum profundus (FDP) flexes the terminal phalanx of the digits (Fig. 1) and the flexor pollicis longus (FPL) flexes the terminal phalanx of the thumb. The flexor digitorum superficialis primarily (FDS) flexes the proximal inter- phalangeal joints (PIP) (Fig. 2). They

Fig. 2

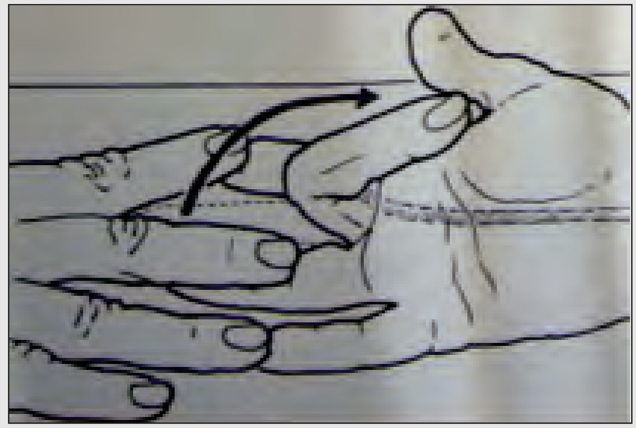


Fig. 3

FDP Tendon Function FDS Tendon Function
(Principles of Surgery, McGraw-Hill Book Company, Used by permission)

operate independently of one another, and thus if the profundus tendon is check reined by holding adjacent digits in extension, the ability to flex the finger in question at the PIP level requires intact flexor digitorum superficialis function.

Timing of Repair: Few conditions contraindicate primary repair, but primary repair should be delayed if:

- The wound contains crushed, potentially nonviable tissue.
- The pulley system has been destroyed. (**Editors' note**: Experienced hand surgeons can often reconstruct the pulleys at the initial operation. Only the A-2 and A-4 pulleys are essential and rarely are both lost in an injury—see Chapter 24.)
- The wound is severely contaminated and cannot be adequately decontaminated by irrigation and debridement at the initial surgery.

The wound should then be prepared for repair at the earliest opportunity; it must be clean and all potentially nonviable tissue debrided. The patient should be returned to the operating room in 24-48 hours for repeat debridement and definitive tendon repair. It is important to keep the wound moist between debridements (see Chapter 2).

- **Extensor Tendons**. Due to their superficial location and hand positions, extensor tendons are particularly vulnerable to trauma. The dorsum of the hand is protected only by thin skin padded with delicate subcutaneous tissue. In the fingers, the tendon itself is thin, flat, and subject to rupture. When the finger is flexed, the extensor tendon is placed under tension, further increasing its chance of injury. The extensor mechanism of the fingers is complex; its delicate balance is easily disrupted (Fig. 3). Once damaged, it is difficult to reconstruct. For this reason, **the management of extensor wounds demands the same skill and experience required for care of flexor tendon injuries.**

There are important anatomical and functional differences between flexors and extensors:

- Adhesions are less likely to pose problems after extensor repair. The dorsal skin is not tethered, as is the volar skin and is unlikely to restrain extensor excursion.
- The extensor mechanism is not surrounded by a synovium sheath except at the wrists, so that problems caused by synovial adhesions are not a concern as with flexor tendons.
- The extensor digitorum communis tendons pass to each of the four fingers, the extensor digit minimi as a second tendon to the little finger, and the extensor indicis proprius a second tendon to the index finger. These are the prime extensors of the meta-carpophalangeal joints of the fingers. (The intrinsic muscles of the hand are the main

extensors of the proximal interphalangeal and distal interphalangeal joints.) Theoretically, transection of the extensor tendon to a single digit will result in an extensor lag of that finger at the meta-carpophalangeal joint level. However, the inter-tendinous bridges (juncturae tendinum) on the dorsum of the hand and the double tendons passing to the index and little fingers may lead to diagnostic confusion.

- **Examination of the extensor tendons of the hand**: The long extensor tendons of the fingers, as described in the paragraph above, act mainly on the meta-carpophalangeal joints (MPJ). Loss of MPJ extension results from a severed long extensor tendon, though as mentioned, with some injuries only a degree of extension loss will be evident even with complete severance of the tendon because partial extension (sometimes full extension) will still be possible because of a second tendon to the little or index finger or intact inter-tendinous bridges (juncturae tendinum) to all 4 fingers. The proximal and distal interphalangeal joint extension is an intrinsic muscle function and full extension of these joints is possible with complete severance of the long finger extensors. The thumb has three extensors; the extensor pollicis longus to the base of the distal phalanx, the extensor pollicis brevis to the base of the proximal phalanx and the abductor pollicis longus to the base of the metacarpal with each of it's corresponding extensor function.

Fig. 4

1) The Central Slip.
2)The Lateral Bands.
3) Extensor Tendon.
4) Intrinsic Muscle Tendons.

(Essentials of Plastic, Maxillofacial and Reconstructive Surgery, Williams and Wilkens, Used by permission)

- **Tendon lacerations over the dorsum of the metacarpals** can easily be missed even in what appears to be a fully functioning hand. The patient may have a partially lacerated extensor tendon which could rupture at a later date. As mentioned, be aware of the interconnections between the extensor tendons which may allow the hand to move through a full range of motion but can rupture at a later stage. These wounds require careful exploration and the usual meticulous repair.

- **Wounds at the meta-carpophalangeal joint level** should be approached with caution. It is very easy to have a wound penetrating into and damaging the articular head of the metacarpals which can compound the problems in postoperative recovery. The joint capsule and the tendon should be repaired in separate layers. Human bite injuries, which include the punch injury on the opponents tooth, can be particularly dangerous in this area. A high index of suspicion for a possible penetrating injury is important. It must be remembered that the injury probably happened with the MPJ in flexion and your examination will be in partial extension. The penetration through the different layers will glide in opposite directions and not be apparent unless demonstrated with exploration of the wound. It is also important to obtain x-rays to rule out the presence of foreign bodies such as teeth.

  Incompletely treated injuries at the **level of the proximal interphalangeal joint** can also result in the "boutonniere deformity." This occurs when the extensor mechanism is damaged and the lateral bands slip volarward. The head of the proximal phalanx and base of the middle phalanx will buttonhole. A small laceration may gradually enlarge with use of the finger and as the lateral bands slip volarward, the boutonniere deformity will gradually develop.

- **Blunt trauma** which leaves the skin intact can be as destructive to extensors as open injury. Occult and incomplete injuries may be masked at first. Function may initially be normal but can deteriorate progressively, and deformities might appear insidiously as mentioned above.

  Again, whenever possible, early tendon repair should be done.

Fig. 5

(Courtesy of Tertius Venter)

- **Lacerations of the forearm muscles or muscular tendinous junctions** should be repaired with a 3/0 monofilament absorbable suture. **Fasciotomy** should be performed if there is notable sub-fascial edema. The dorsal sensory branch of the radial nerve should be carefully evaluated and repaired if lacerated. At the level of the wrist, and under the extensor retinaculum, the tendons should be repaired and transferred superficial to the dorsal ligament. This is especially true in the first dorsal compartment where a post-traumatic De Quervain's may develop.

- **Intrinsic Musculo-tendinous Function**. The thenar muscles, hypothenar muscles, lumbrical muscles, and interossei muscles have their entire musculo-tendinous course within the hand itself. There is considerable variation in the innervation of these muscles. The classic pattern is for median nerve innervation to the intrinsics of the thenar eminence on the radial side of the flexor pollicis longus (abductor pollicis brevis, opponens pollicis, and superficial head of flexor pollicis brevis) as well as the first two lumbricals. The ulnar nerve innervates the hypothenar muscles, the interossei muscles, and the remainder of the thenar muscles (ulnar head of the flexor pollicis brevis) and the adductor pollicis. The **median nerve** is tested by palmar abduction of the thumb and opposition. The **ulnar nerve** innervated intrinsics are responsible for finger abduction and adduction.

Principles in Care of the Injured Hand

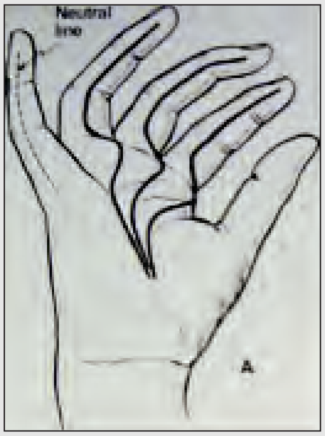
Wound Evaluation and Preparation

The priority in caring for the injured hand should be to prepare the wound for successful closure at the earliest possible opportunity if primary closure is not possible. Wounds often involve deep structures and early definitive repair must be the goal.

Adequate wound inspection and preparation is essential and requires efficient anesthesia and control of hemorrhage. Nerve blocks; digital, wrist, axillary or brachial can be used depending on the site and extent of the injury and the ability to tolerate the application of a proximal tourniquet. General anesthesia is advisable in children, and perhaps also when the need for tissue transfer from distant sites, including large skin grafts is anticipated.

The use of a tourniquet is essential in all hand surgery: Digital tourniquets should be elastic, flat and broad to avoid local damage. The tourniquet should be released prior to wound closure to allow hemostasis in an attempt to prevent possible hematomas that can cause pain, sepsis and added fibrosis. Although less than 90 minutes of tourniquet time is ideal, up to 2 ½ hours can be tolerated and preferable to deflation and re-inflation. (**Editors' note**: If the tourniquet is left up over 2 hours, steroids may be given to prevent tissue damage. In addition, if one sees the need for the tourniquet for greater than 2½ hours, then the tourniquet should be deflated for 20-30 minutes and then reinflated.)

In the acute injury, hemorrhage control is initially achieved by pressure dressings or direct finger pressure if there is a single artery causing the bleeding. One should **never** control bleeding by blind insertion of surgical clamps. If bleeding cannot be controlled by pressure bandages, a tourniquet can be applied and the patient taken to the operating room as an emergency. Hemostasis is achieved by the ligation of large vessels and the use of bipolar coagulation of the smaller bleeding points. Unipolar



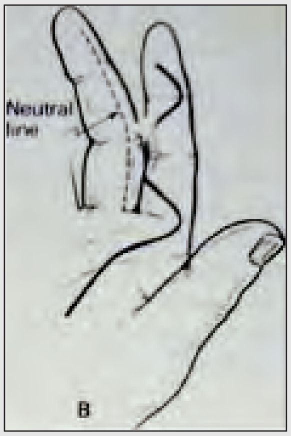


Fig. 6 **Fig. 7**

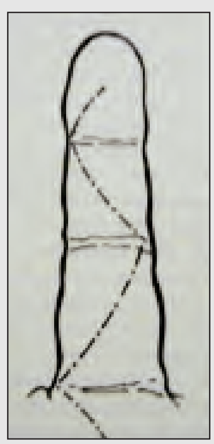
Bunnell Incisions, Brunner Incisions

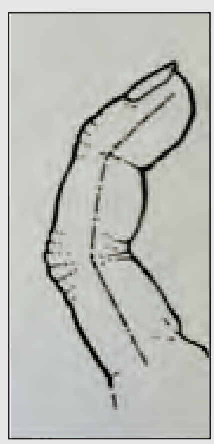
(Essentials of Plastic, Maxillofacial and Reconstructive Surgery, Williams and Wilkins, Used by permission)

diathermy is too destructive to be ideal in hand surgery, but it is understood that many hospitals will not have bipolar coagulation and will need to use the conventional cautery.

Under anesthesia, bleeding is controlled and the wound is cleansed. The whole hand is carefully washed using a physiological saline solution such as Hartman's/Ringer's lactate solution or saline. Even water can be used if Ringer's Lactate and saline are not available. The wound is copiously irrigated with the solution to remove all contaminants in the form of dirt, foreign materials, blood clots and loose devitalized tissue. Careful exploration is undertaken to ensure that no such material is missed deep in the tissues. The limb is then formally prepared and draped. The wound is assessed in great detail. A thorough assessment is made of the tissues around the wound and their vitality. Obviously dead and grossly contaminated tissue is removed. Under most circumstances the hand, like the face, has an excellent blood supply, and formal excision of all wound edges is not required. Many wounds will have to be extended to provide access to deep structures. Adequate exposure must be achieved, the blood supply of the tissues must be preserved and the incision must not predispose to later contracture. It must, if at all possible, follow lines that do not change length during flexion and extension.

The latter is particularly important on the flexor surface as these scars will be relaxed for the majority of the time, whereas extensor scars tend to be kept under some tension even during rest. To gain access to the flexor surface of the fingers any combination of zigzag and mid-lateral incisions may be used, incorporating the traumatic wound. The planning is often made unusually difficult because the initial traumatic incisions were made in the wrong place! In the Brunner incision it is unnecessary for the tips of the Z to reach as far as the neutral line (Fig. 6) as this may risk necrosis of the tip of the flap and also damage to the neurovascular bundle. In the palm, a combination of longitudinal and transverse incisions should be used. The blood supply of the palmar skin is such that extensive flaps must be raised with great caution. On the dorsal surface the flap length should be restricted and the incisions more straight than zigzag. This technique preserves the blood supply, and contracture is less of a problem. Transverse lacerations at the wrist, with deep structures divided, require longitudinal exposure. The incisions may be gently curving in each direction and do not necessarily need to begin at each lateral extent of the original wound. The flaps may otherwise be excessively long for the available blood supply. If near the wrist, a formal decompression of the carpal tunnel will become part of the exposure, and is indicated to cope with the swelling associated with





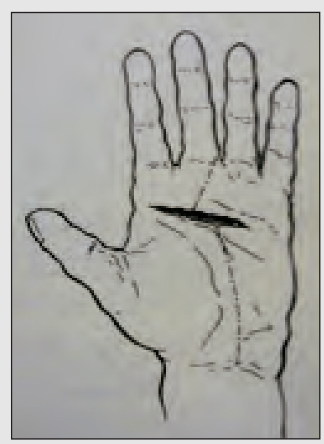


Fig. 8 **Fig. 9** **Fig. 10**

Volar Zigzag Incisions (Brunner-incision) (Bunnell-incision); Lateral Incision Extension of Palmar Wound Avoiding a straight line that will be prone to contracture

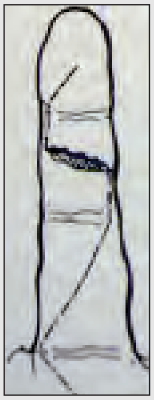


Fig. 11

Fig. 12

Brunner Incision Dorsal wound extension; Wound extension avoiding a straight line

tendon and nerve healing.

After repair, tourniquet deflation and hemostasis primary closure is done. During the surgery it is important to protect the exposed tissues from desiccation and contamination by moist dressings until all devitalized tissue has been excised. When the wound is clean and important structures repaired, then the wound may be closed. If there is any question of ongoing contamination or the need for further repairs, the patient should be returned to the operating room and the wound reassessed under anesthesia after 24-48 hours. If doubt still remains, the procedure is repeated a further 48 hours later. It is important to close the wound loosely between explorations, as long as all contaminated tissue has been excised. (This would be in keeping with the **Clean Closed Wound Concept** in Chapter 2.) If the wound is left open for 48 hours, the tissues will desiccate unless they are kept moist by continuous moist dressings, the VAC, honey dressings or loose closure (difficult to do in most hospitals). The wound should be definitively closed by 5-7 days, directly by skin grafts or flaps.

Fig. 13

Extension of the Wrist wound for adequate exposure

Wound Closure

If possible, direct wound closure is undertaken, but this must not further compromise the tissue perfusion. Excessive tension across the wound must be avoided. Some edema is inevitable in the early stages of wound healing and the surgeon must allow for this during closure of the wound. It is important to keep extremities elevated post-op.

If the wound cannot be closed without tension a skin graft or flap must be considered. A skin graft will need a healthy well-vascularized recipient bed. Any exposed tendon, bone, cartilage or joint will need flap closure. (These are discussed in Chapter 30 on **Upper Extremity Wound Reconstruction**.)

- **Suturing**. Skin apposition implies more than epidermal apposition, and although deep subcutaneous sutures are hardly ever required in the hand, the deeper skin interfaces need to be in contact to eliminate the dead space beneath the epidermis. This helps to prevent the accumulation of blood or exudate that might result in later sepsis. An interrupted monofilament suture is good and the most suitable suture sizes are 4/0 and 5/0. The use of absorbable material as a skin suture is acceptable in children but less so in adults as it may result in stitch abscesses.

  A simple, interrupted suture of Prolene® or nylon (Ethicon®) is usually suitable on the palmar surface and digits. The skin of the dorsum of the hand and of the forearm has a tendency to invert, and this can be prevented by the use of vertical or horizontal mattress sutures. Continuous subcuticular monofilament absorbable sutures (PDS®--polydioxanone-Ethicon), leave no marks, prevent inversion, and need not be removed at all. I prefer not to use absorbable sutures like Dexon® (Davies & Geek) or Vicryl® (polyglactin 910-Ethicon) in the hand as they are multifilament/braided sutures that absorb blood and other fluids into the suture and act as a nidus for bacterial growth.

  Drains are often required. If dead spaces exist, causing the risk of hematoma formation, a suction drain is preferable. Simple, soft rubber drains are useful where dead space tends to be closed by natural tissue tension.

- **Dressings of the Hand**. The purpose of a dressing is to protect, to absorb exudate or discharge, and to splint the hand in the correct position. Directly on the wound should be a non-adherent porous layer such as Vaseline® gauze and then some form of absorbent material. The method of splinting is open to much variation, depending upon the extent and type of the injury. Circumferential bandages can be used to good effect over suitable padding, but great care has to be taken to avoid excessive compression, especially proximally, where the tourniquet effect would contribute to edema. Plaster of Paris slabs, either palmar or dorsal, are easy to apply and are secure. The potentially least constricting of all is a circumferential plaster cast, but this should be split if there is any possibility of swelling.

Again, in skin grafts a non-adherent porous layer, e.g. Vaseline® gauze should be used first, and then some form of absorbent material. I usually wet the absorbent material with saline. Blood and serous exudate will not clot in the saline and cause the dressing to become stuck to the graft. (**The editors** use wet cotton over a non-adherent dressing as Vaseline® gauze or Xeroform® if available.) The single initial wetting of the dressing is adequate to prevent it from sticking to the graft. A firm bandage is then applied after careful padding of the whole hand, in the webs and between the fingers. Only the fingertips are left visible to indicate the vascular state of the hand. With a graft, it is recommended that the entire hand be **immobilized in the functional position**; wrist in 30° dorsiflexion, MPJ's 90° flexion, PIP and DIPJ's in extension, and the thumb in palmar abduction.

- **Post-operative Care**. Perhaps the most immediate postoperative danger is the formation of **edema**. Excessive and prolonged edema can have a most damaging effect upon the hand, leading to fibrosis, joint stiffness and tendon adhesions. Prevention is best, but if edema does occur, it must be reduced as a priority. Elevation is the principal means in the early stages, but movement is in fact the most essential and natural mechanism. The injured hand should be immobilized for the shortest possible time, and those parts that do not need to be immobilized should not be immobilized. The position chosen, the **functional position**, for immobilization is of considerable importance in the prevention of complications. The ideal position of the joints often has to be modified when the protection of deep repairs is overriding. The metacarpophalangeal joints are best immobilized in flexion, as in that position the collateral ligaments are taut and therefore cannot become contracted. The interphalangeal joints are safest in the extended position as the accessory collateral ligaments will then be taut. Wrist extension tends to place all these joints into their ideal positions through the tenodesis effect on the long tendons, and is thus the key to correct positioning. If movement of a particular joint does not stress or excessively disturb a wound, then it need not and should not be immobilized unless deep repairs require otherwise. Some wounds in lines of election, as outlined above, may not require immobilization at all, and this is certainly acceptable when the mobilization of other structures is a priority. For skin wounds alone, whatever splinting is used may be discontinued after suture removal, at the latest. Persistent edema can be reduced by a skilled physiotherapist assisted, if necessary, by the use of pneumatic compression devices.

- **Elevation** can be achieved by means varying from IV drip stands to slings. The 'collar and cuff' as well as the triangular sling are both bad for hands. The former, the collar and cuff, jeopardizes venous return, thereby increasing the edema. The triangular sling does not elevate the hand. One must also guard against too-high elevation, as it will lower the arterial input pressure; a simple guide is to keep the hand just above the level of the heart in the lying, sitting or walking position. In walking, it is important for the patient to keep the hand up just above heart level, and no sling should be used. When walking, rest the hand on the opposite shoulder or over the head. When lying down, rest the hand over the chest or up on a pillow. When sitting, rest the arm on the back of a couch or the elbow on the arm of a chair or couch.

  Dressings may be left in place until suture removal is scheduled, provided they are not soaked through with blood or exudate, or until it is appropriate to allow less restricted movement. Suture removal may be undertaken at 10-14 days, but if disturbance at that stage is undesirable, the removal of such inert materials as those recommended may safely be deferred.

- **Antibiotics**. The use of prophylactic antibiotics is debatable. In the case of clean-cut wounds with no significant devitalization of the tissues, if repair and closure of the wounds is done within 6 hours of the injury, there is little risk of sepsis.

Tetanus prophylaxis regimes should always be followed.

If the vitality of the tissues is impaired, or the wounds contaminated, antibiotics should be administered. Cephalosporins (anti-staphylococcal penicillin) are the minimum. In crush injuries, farm injuries, roadside injuries or those with extensive devitalized tissue, cephalosporins should be combined with gram negative and also anti-anaerobic medications such as metronidazole.

- **The Use of Free Skin Grafts in Hand Injuries**. In primary trauma situations where the successful take of a skin graft might be uncertain, a split skin graft might have to be considered. Even in the palm of hand and finger where secondary contracture is inevitable, it may indeed have to be considered for the sake of early healing, but later replaced by a full thickness skin graft when conditions for take are better.

  In a crush injury, skin grafts take less well. Crushing produces devitalization of the tissues severe enough to effect adversely the vascularization of a graft, yet insufficient to jeopardize the viability of the tissues as a whole.

  In elective surgery and in secondary repair of hand injuries, the type of suitable graft used differs in dorsum and palm. The split-skin graft, preferably thick, can be used on the dorsum, but on the palm between the fingers and in the webs, where secondary contracture would often destroy the whole point of the procedure, a full thickness skin graft is the graft of choice because it is unlikely to lead to contractures.

Specific Injuries

Cutting And Slicing Injuries

The extent of a cutting or slicing injury is usually obvious, and preliminary clinical assessment of damage is straightforward. Tendon and nerve damage are common and must be tested for, but if one excludes the guillotine amputation which is so often part of the injury, associated bony damage is uncommon. With the exception of the partially sliced off flap, skin loss is immediately obvious, and even with it, the devitalizing effect of crushing is not present to add to the difficulty of deciding clinically whether the flap is viable.

If exploration or repair of deep structures should be needed, the bloodless field created by a pneumatic tourniquet will provide the best conditions for accurate fast surgery.

The method of repair can usually be decided on the basis of the preliminary clinical examination. When there is no loss of skin, direct closure with minimal excision of the wound margins should be carried out, and here accurate suturing is as vital as on the face in order to achieve rapid healing with minimal scarring. Skin loss must be reconstructed by a free skin graft or flap. Free skin grafts, commonly split-skin thickness grafts, are generally used except when the raw area includes a structure which will not accept a free skin graft, when the pulp of the fingertip has been lost and replacement requires more bulk than is present in a free skin graft, or when subsequent repair of a deep structure such as tendon is contemplated. In these circumstances, flap cover must be provided and the type of flap depends on the site and size of the defect.

The guillotine amputation which exposes bone is, in many cases, best closed by trimming the phalanx until the tissues will close directly over it without tension. Free skin grafts do not do well over such stumps. Failure of the graft over the bone is liable to occur, and any scarring adherent to the underlying bone tends to make the graft always vulnerable.

While shortening of a finger to achieve rapid healing may be justified, particularly if only one finger is involved, the approach to the injured thumb is conditioned by the need to maintain length where at all possible. There should be no excessive trimming of a traumatic amputation to get skin cover; a free skin graft or flap should be used as the local circumstances dictate. The overriding need for conservation of finger tissue lessens with passage towards the ulnar side of the hand.

Fingertip injuries are liable to present special problems because of the nail and its bed. Sacrifice of length to get an “ideal” amputation site is not often justified at the stage of primary treatment. In a single-finger injury, it may rarely be a reasonable measure—particularly if the loss of length involved is not great. More often, the patient should be given the opportunity to make up his own mind, having used the hand at work, whether or not he wishes secondary shortening carried out.

Burst Lacerations

These are caused by forceful impact. The tissues are ruptured in a ragged fashion and there may be devitalization of surrounding skin. Careful but conservative excision is required, and probably not primary closure. If sutures are inserted, they must not create undue tension. Adhesive strips are sometime acceptable in this situation. A skin graft should be applied if the wound is of significant size.

Crush Injuries—the Crushed Hand

These are often very severe, as there is extensive tissue damage, the extent of which is difficult to assess initially. Primary closure is therefore rarely advisable, and efforts are directed to decompression rather than suture, although skin grafts may be applied quite early. Elevation to control edema is important. The dependent position required for distant flap application is a disadvantage.

A crushing injury may vary in severity and extent from the mildest subungual hematoma, through the crush injury of fingers with or without bony damage, up to the power press injury which leaves a shapeless pulp of devitalized tissue. With severe crushing, there is often a 'bursting' laceration. The brunt of the injury is taken by the soft tissues and bones rather than the tendons and nerves. Loss of skin and soft tissue by the actual injury is not a feature, but the real loss is often much greater than is at first apparent because disruption of blood vessels and devitalization of tissues may give rise to quite extensive skin necrosis. This “hidden” damage may result in unexpectedly severe edema postoperatively, and failure to guard against this edema can further devitalize the crushed tissues, particularly if they have been closed under tension.

Pre-operative appraisal of the situation can be most misleading; only during actual cleansing and surgical exploration of the wound can the injury be accurately assessed. The important points in such an assessment are:
To determine what is definitely not viable. The test already described (above) to assess the viability of skin must be rigidly applied here, and non-viable soft tissue structures excised quite ruthlessly. This may mean excision of bone, tendon, etc., when a segment of finger as a whole is judged to be non-viable. With the non-viable tissue excised, the position is assessed afresh to decide which injured structures are worthy of retention and skin cover. The detailed decisions which this implies must take into account such factors as the relative importance of the fingers and the thumb, the age, intelligence, etc., of the patient, and the extent and severity of the damage.

Much that has been said of closure following guillotine amputation applies to the crushed finger. With the sole exception of the thumb where the conservative approach always applies there are two opposing lines of argument. On the one side, the more severe the damage to the individual components of a finger—nerve, tendon, skin, bone—the stronger is the argument for amputation (though the finger as a whole may be viable), for the less chance there is of a useful digit resulting. On the other side, the greater the damage to other fingers and the rest of the hand, the stronger is the argument for retention of the injured digit even in the knowledge that it may be stiff. It is in the crushing injury particularly that a useless finger should always be considered as a potential source of skin. Filleted, it can be used to cover a skin defect of adjoining dorsum or palm avoiding the need for graft or flap.

It is often stated that any lacerations which are present as part of a crushing injury should only be loosely closed with a few tacking sutures because of the tendency to postoperative edema. In our experience, when no skin has been lost, much better results are obtained by suturing such lacerations as accurately as possible with many fine sutures, leaving no raw areas between sutures. When this has been followed by absolute immobilization (preferably with plaster of Paris) and scrupulous postoperative elevation for at least 48 hours, edema has not given rise to any trouble. It seems likely that the edema, which is so feared, is the result of failure to follow the latter part of the regime described above.

A relaxing incision can usefully be applied on occasion to the crushed finger when it is proving difficult to close its palmar aspect because of tension. A straight, proximal-distal incision through the skin of the dorsum will gape and give enough additional relaxation to allow more ready closure. Here, as in other parts of the limb, undermining must be avoided. The defect caused by the relaxing incision can be grafted with a split thickness graft.

Compared with a cutting injury of apparently

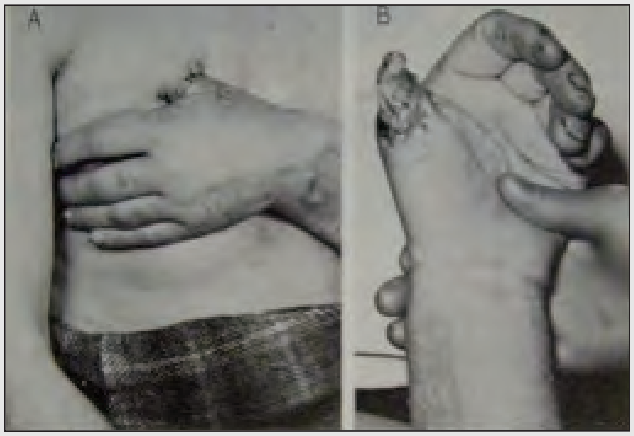


Fig. 14 **Fig. 15**

(Fundamental Techniques of Plastic Surgery – and their Surgical Applications, Churchill Livingstone, used by permission)

comparable severity, the crushing injury carries a much longer disability period and the results are poorer. The problem of the associated fracture will be considered separately.

Degloving Injuries

In degloving injuries of the hand, as elsewhere, the important pathological factor is injury to the vascular system. The anatomical characteristics of the palmar skin with its intimate attachment to the palmar fascia make it less liable to degloving, but when it is degloved the palmar aponeurosis is usually part of the tissue avulsed. Elsewhere the plane is the usual one between superficial and deep fascia.

In the pure degloving injury damage to deeper structures is surprisingly uncommon though it must always be tested for. The important surgical decision is that of viability, and skin which is not demonstrably viable must be excised.

The split-skin graft is the usual method of cover and should be used unless tendon, bone or joint is exposed. Even if it is felt that subsequent cover by a flap will be needed, the split-skin graft is still the primary cover of choice—especially when more than one surface of the hand is involved. When a direct flap is required primarily, it should be designed to cover as much of the raw area as possible with its initial attachment.

It is often difficult to estimate the precise skin loss immediately after the injury, but over-estimation is less serious than underestimation. If at the first postoperative dressing skin necrosis is found to be more extensive than was expected, and fresh slough is present, it should be excised and replaced with a split-skin graft forthwith. In this way healing and mobilization can be achieved as rapidly as possible.

Degloving of a single digit occurs occasionally and, again with the sole exception of the thumb, amputation is usually advisable. Sometimes, recommendation is made to "bury" a degloved thumb under the abdominal or chest skin (Fig. 14). It should be appreciated, however, that mere burying of the digit does nothing at all towards providing skin cover. All that can be said is that it buys time, but the provision of skin cover has not been advanced in any way. The degloved thumb should instead be inserted into a tubed flap raised on the trunk (Fig. 15).

The use of a tubed flap may be the only way of salvaging the digit, though until recently, the method did have its limitations and unsatisfactory features. These were due firstly to lack of sensation in the flap, which resulted in poor utilization of the thumb by the patient. Secondly, poor blood supply in the tube resulted in poor tip healing when the flap was separated even after delays, and subsequent inability to withstand cold.

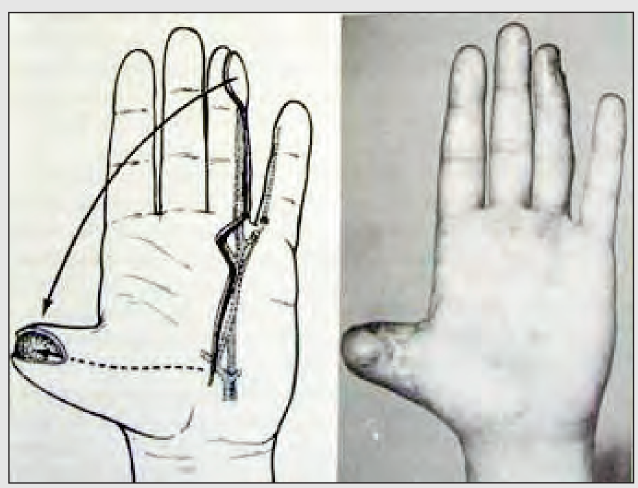


Fig. 16

Neurovascular island flap from ring finger to thumb
(Fundamental Techniques of Plastic Surgery – and their Surgical Applications, Churchill Livingstone, used by permission)

The neurovascular "island" flap used in this situation has transformed the picture. The hemi-pulp of a functionally less important finger, usually the ulnar side hemi-pulp of the ring or middle finger, is raised, pedicled on the digital vessels and nerve back to their origin in the palm, and tunneled through palm and tube pedicle to a functionally suitable site near the thumb tip. There it is sutured in position (Fig. 16). The residual pulp defect is free skin grafted. This brings both nerve and blood supply to the tip with marked improvement in utilization and vascularity. Sensation on the thumb will be felt in the ring finger and will take months for the brain to adjust and feeling to be perceived as from the thumb.

(**Editors' note**: This flap is difficult to elevate and is not recommended unless one has considerable hand surgery experience. A Moberg flap, which is slightly easier to elevate, is described in Chapter 30, **Upper Extremity Reconstruction**.)

Avulsion and Degloving Injuries

Although both mechanisms may be involved, the separation of large flaps from their blood supply is of greater significance than crushing. Large areas of specialized skin are involved, and the vascular compromise of the flaps is potentially progressive. Caution is therefore required. Theoretically it might be possible to restore the blood supply by microvascular anastomosis, perhaps using vein grafts: 'ring avulsion' is a practical example where this approach has proved successful. Otherwise successive excisions and appropriate skin replacement are required. Distally based palmar flaps are an especially serious problem, because the skin is so specialized and the anatomy of the blood supply so unfavorable.

Puncture Wounds

It is often difficult to decide how seriously to treat small puncture wounds. Obviously, if damage to the deep structures is recognized, exploration will be required. If there seems to be risk that dirt has been impregnated then a similar approach is necessary. Primary closure of the extended wound will follow if conditions are suitable. Often small puncture wounds are left open.

Friction Injuries

The problems here are similar to burn injuries, with the addition of impregnation of dirt. It is most important to remove this to avoid tattooing, which is very difficult or impossible to remove once the wound has healed. This is achieved by scrubbing. Otherwise the wound is treated similarly to a mixed-depth burn excision, with replacement of skin.

Multiple Parallel Lacerations

These are often self-inflicted. The problem is the possibility of necrosis of intervening skin, which may be worsened by attempts to suture such wounds. If the skin is alive, closure may be achieved by a combination of sub-cuticular suturing and the simple application of skin tapes and dressings.

Bites

These are injuries for which antibiotic therapy is indicated. Staphylococcus aureus is the most common infecting organism, so flucloxacillin or amoxicillin is probably the best choice. Animal bites are less potentially serious than human bites. If treated early, primary closure is usually permissible. Human bites have a far more sinister reputation, and should be treated by debridement and delayed closure. The puncture wound over the MPJ has been discussed above, and this is the situation where

Fig. 17

Fig. 18

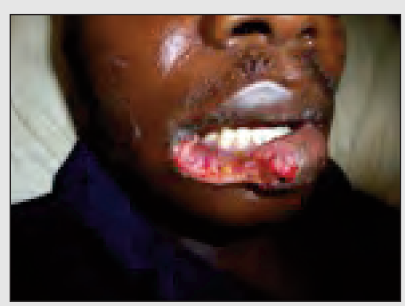


Fig. 19

(Fig. 17) Lion bites, The larger wounds were débrided and closed primarily; (Fig. 18) Camel bite which was débrided and closed primarily; (Fig. 19) Human bite: débrided and followed by delayed closure several days later (Courtesy of Louis Carter) injuries of the metacarpophalangeal joint occur, sometimes with fragments of broken teeth left in the joint. Recognition of this is the first step in proper management, followed by adequate surgical exploration.

Hand injuries are of three main types—cutting/slicing, crushing and degloving. As a rule an injury belongs predominantly to one type, but on occasion an injury has the characteristics both of crushing and degloving.

While these three types constitute distinct patterns, injuries of the hand have also been divided from the viewpoint of immediate management into tidy and untidy injuries, a division which has considerable practical value, particularly as it relates to the use of the tourniquet.

To guide the surgeon in the management of a particular wound it helps to distinguish between “tidy” and “untidy” wounds. The crucial factor is the state of viability of the tissues surrounding the wound. This relates to the mechanism of injury: incision, crush, avulsion or burn wound.

In the “tidy” injury, skin damage is clear-cut and the problems of treatment concern more the injury to tendons and nerves. Conditions for accurate and expeditious surgery are therefore essential and a pneumatic tourniquet should be used to provide the necessary bloodless field.

In the “untidy” injury, the main problem concerns viability of tissues. Since the presence or absence of circulation is crucial to such assessment a tourniquet is not used.

Distal Block Anesthesia Techniques

Common distal regional blocks are used for hand disorders. The radial, median, and ulnar nerves are easily blocked at the wrist. Epinephrine can be used with the local anesthetic agents for these blocks as well as in digital blocks as the risk of arterial spasm and digital loss has been shown not to be a reality (Emerg Med J. 2007 November; 24(11): 789–790. Epinephrine in digital nerve block P T Cherian, Good Hope Hospital NHS Trust, Sutton Coldfield, University Hospital Birmingham, UK. And numerous other articles.)

For median block, ulnar block, or radial block, 5 to 6 ml is required at the wrist level. For digital block, 2 to 3 ml is required. The use of a #25 needle is recommended. Injection should not be into the nerve but adjacent to the nerve. If the patient complains of paresthesias at the time of needle introduction, the needle must be redirected. [From R. I. Burton, Acute Joint Injuries of the Hand, in Wolfort (ed.), "Acute Hand Injuries: A Multispecialty Approach," Little, Brown and Company, Boston, 1980.]

Two specific block techniques may be of great value in the emergency room - the median, radial, and/or ulnar nerve at the wrist; and digital block at the base of the individual finger.

To block the **median nerve** (Fig. 20a), the needle is inserted either to the ulnar or radial side of the palmaris longus tendon at the level of the first

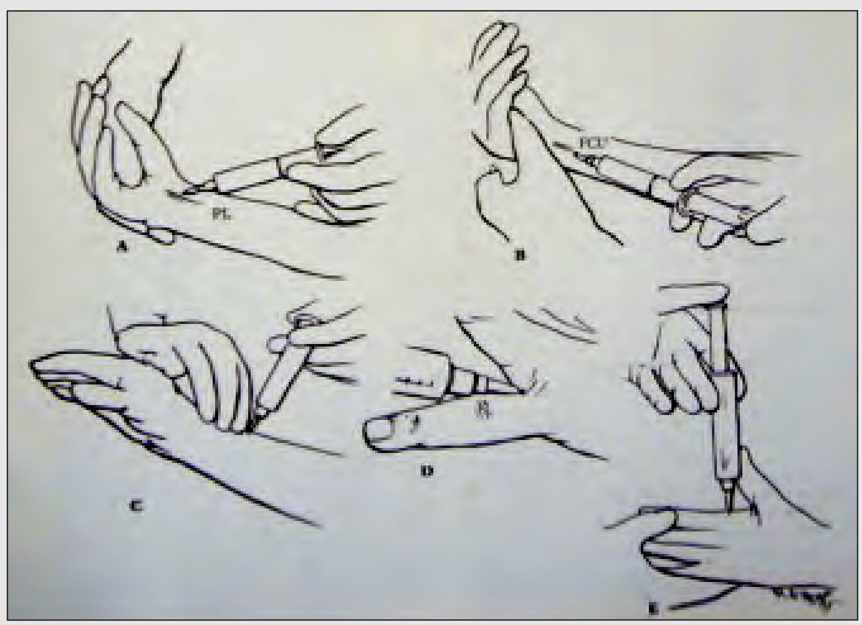


Fig. 20

Local anesthetic blocks
a) Median N.; b)Ulnar; c)Radial; d) and e) Digital

(Principles of Surgery, McGraw Hill Book Company, Used by permission) flexion crease, with the needle angled 20° distally. The **ulnar nerve** block (Fig. 20b) is inserted just to the dorsal aspect of the flexor carpi ulnaris tendon, in a plane perpendicular to the long axis of the forearm and parallel to that of the palm. The needle is introduced to a depth of 1 cm; it is essential to aspirate to be certain the tip of the needle is not within the ulnar artery. The **radial sensory nerve** (Fig. 20c) is best blocked three finger breadths proximal to the radial styloid along an imaginary line drawn between the radial styloid and the lateral epicondyle. It is at this point that the radial nerve emerges from beneath the brachioradialis tendon but has not yet split into its many branches.

The **digital block** (Figs. 20d-e) is best done by injecting a few milliliters in the web space on both sides at the base of the involved digit. This is much less traumatic, much easier, and much safer than a ring block

Further Reading

1 Mathes Plastic surgery. Stephen J Mathes. *Saunders Elsevier*.
2 Essentials of Plastic, Maxillofacial and Reconstructive Surgery. Nicholas G Georgiade. Grecory S Georgiade. Ronald Riefkohl. William J Barwick. *Williams and Wilkins*.
3 Fundamental Techniques of Plastic Surgery – and their Surgical Applications. Ian A McGregor. *Churchill Livingstone*.
4 Skin Cover in the Injured Hand. David M Evans. *Churchill Livingstone*.

Chapter 27

Flaps for Wound Coverage and Tissue Expansion

Louis L. Carter, Jr.

Introduction

This chapter will be an overview of flaps used in plastic surgery. Many of these flaps will also be covered in other chapters. Wound healing, skin grafts and the use of the VAC are also covered in other chapters.

Reconstructive Ladder

It is very important always to remember the reconstructive ladder for closure of any wound; however, it is more important to do the procedure that will give the most reliable result in each situation to minimize complications and optimize the outcome.

1 Ideally a wound will be primarily closed or closed a few days later—**delayed primary closure**.

2 **Skin grafting** should always be done acutely when the wound is clean but cannot be closed. If the wound will accept a skin graft acutely or after debridement, it should be done. In some cases, a flap may give better coverage and, if available, can be used acutely and as definitive closure.

3 **Flaps** can be used acutely when the wound is clean, and there is exposed bone, joint or tendon.

It is very important to NEVER wait for granulation tissue to form when the wound is already clean.

Blood Supply of Flaps

Flaps are either random or axial.

Random flaps are supplied by multiple vessels, often unnamed, rather than just one. Most skin flaps are random flaps, and the length of the flap should equal the width. These flaps may cover small areas and can be further classified as transposition, rotation, bilobed, etc. Reconstruction with a Z-plasty, W-plasty, or Y-V plasty also use small random type flaps. Axial flaps have one or two vessels throughout the entire length of the flap. The length of these flaps may be up to 3x the width, as long as the blood supply is in the center of the flap.

Axial flaps maybe fasciocutaneous, perforator, myocutaneous, or muscle only. Microvascular flaps are axial flaps and may also contain bone. Fasciocutaneous flaps and perforator flaps contain the superficial fascia that is superficial to muscle fascia. Blood supply to the skin lies just superficial to the superficial fascia. The best illustration of this is in the lower abdomen, where the vessels to the skin—the superficial inferior epigastric artery and vein—lie just above Scarpa's fascia, the superficial fascia. These vessels, often cauterized in open hernia repairs, can supply the entire abdominal wall skin. Most of the flaps discussed here will be axial flaps, which are very reliable. A Doppler is an ideal aid to identify arteries and their course.

Advantages of Flaps over Skin Grafts

Even though flap coverage of a wound is a more complex method than skin grafting, flaps offer a number of advantages.

1 Flaps carry their blood supply.
2 Flaps reconstruct an area with "like" tissue.
3 Flaps give a cosmetically pleasing appearance.
4 Flaps can be used to cover exposed bone and tendons.
5 Flap reconstruction over joints after a contracture release eliminates the need for long term splinting.
6 Flaps can carry other tissue as bone for reconstruction.

Mathes and Nahai have classified muscle flaps and fasciocutaneous flaps according to their blood supply.

Muscle Flap Classification

- **Type I**—one vascular pedicle, as in the gastrocnemius muscle flap where each side is supplied by either the medial or lateral sural artery.

- **Type II**—one dominant pedicle and several minor pedicles, such as the gracilis muscle that has one dominant pedicle from profunda femoral artery and several minor pedicles off superficial femoral artery.

- **Type III**—two dominant pedicles that allow the muscle to be divided in the midline and one-half used for a flap. An example is the gluteus maximus muscle, with the superior half supplied by the superior gluteal artery and the inferior half supplied by the inferior gluteal artery.

- **Type IV**—multiple segmental vascular pedicles which allow only a small portion of the muscle to be transferred. Sartorius muscle in the thigh and most of the leg muscles are in this category.

- **Type V**—one dominant vascular pedicle from one end and secondary segmental vascular pedicles from the other. The arterial supply may be divided on either end and rotated around the opposite end. Latissimus Dorsi and Pectoralis Major are examples.

Fasciocutaneous Flap Classification

- **Type A**—Direct Cutaneous, such as groin flap.

- **Type B**—Septocutaneous, vessels that course between muscles to the fascia, such as parascapular flap.

- **Type C**—Musculocutaneous, vessels from the muscle to fascia, such as anterolateral thigh flap.

Perforator flaps are vascularized sections of skin and subcutaneous tissue that are based on a cutaneous perforator—a vessel that penetrates the outer layer of the deep fascia to reach the skin. Most are also fasciocutaneous flaps. There are two types of perforator flaps:

1 **Direct** perforator—reaches skin by means of an intermuscular septum.
2 **Indirect** perforator—reaches skin by passing through deep tissues such as muscle, tendon or bone.

In many cases, the perforator flap is similar to a fasciocutaneous flap. In other cases, the flap is raised but not based on a known perforator. The perforator is found by surgical exploration, and then a "freestyle" design is developed (see chapter 29 on Perforator Flaps).

Expanders: Skin expansion is an additional method for wound closure. Using expanded tissue, flaps adjacent to the wound are advanced to close a defect.

Principles of Flap Reconstruction

In most cases, surgery is best performed under general anesthesia, since skin grafts from a separate site may often be necessary.

It is most important to measure carefully the size of the recipient area before raising the flap. "**Measure twice, close once**" is an important adage.

Antibiotics usually are given before surgery, and in some cases they are used for 24 hours after surgery. In special cases, as in diabetics or the elderly, antibiotics may be used longer.

Flaps can be sutured into place using sutures or staples. The author prefers to use a Gilles suture, a half buried horizontal mattress suture. The knot is in the normal (non-flap) skin, with the buried horizontal suture in the dermis of the flap. This suture technique causes little damage to the blood supply of the flap. An absorbable suture is excellent for children.

A skin graft used to reconstruct the donor defect is either stapled into place or sutured with running absorbable suture, such as chromic or Monocryl®. When the adjacent skin graft is not meshed, a drain is left beneath the flap for 24-48 hours. If there is meshed skin adjacent to the flap, no drain is necessary beneath the flap, as the meshed graft will allow drainage.

If a flap is used on an extremity, then it is immobilized with a bulky dressing and a splint. This is for comfort and to allow the skin graft to take and heal well.

Most flaps will not need division, but pedicle flaps from a distant location, such as a groin or SIEA flap to the hand, will need division. Normally this is carried out at three weeks. If the recipient site is severely scarred with questionable blood supply, then the flap can be partially divided at three weeks, with the remaining pedicle divided at four weeks. The flap should not be inset (sutured carefully into the recipient area) until several days later, so that tension will not be placed on the new bridging capillaries supplying the flap. Contouring the flap and in-setting it nicely for cosmesis may put tension on these recently formed capillaries around the edges of the flap, and this may lead to flap ischemia. Instead, the flap may be tacked down with a few simple sutures at the time of division. Performing a cosmetic tailoring of the flap can be done a few days later.

Flaps

These are the flaps you will commonly use. Descriptions of these flaps and others will be found in other chapters and in major textbooks. The indications for these flaps will be found here.

Flaps for Head and Neck Reconstruction

These are described in other chapters (particularly Chapters 6 on Facial Trauma).

- Orticochea—local scalp flaps with scoring of the galea for expansion.
- Scalp rotation flaps based on one or more of the five major arteries on each side:
- Forehead for nose, cheek, upper lip.
- Cervical.
- Mustardé.
- Deltopectoral.
- Pectoralis myocutaneous .
- Supraclavicular.

Flaps for Shoulder Girdle Reconstruction

The **Latissimus Dorsi Muscle Flap** may be used as a myocutaneous flap or just muscle alone. If muscle alone is used, it may be skin grafted. The latissimus dorsi is supplied by the thoracodorsal artery, a branch of the subscapular artery. The latissimus dorsi can be used in the following ways:

- Chest wall reconstruction—a myocutaneous latissimus dorsi flap is often used.
- Axillary reconstruction—it is used as a muscle only flap with a Split thickness skin graft (STSG).
- Reconstruction of the top of the shoulder and deltoid.
- Reconstruction of the biceps brachii—it is the flap of choice.

The latissimus dorsi is detached, both proximally and distally, after the resting length has been measured. The insertion on the humerus is moved to the coracoid and becomes the origin. Some leave the insertion of the latissimus dorsi on the humerus, where it will become the origin of the new biceps. Ideally, a bone anchor is used to attach it to the coracoid. The origin of the latissimus along the spine is used for the Biceps insertion, either into the stump of the Biceps or the radial tuberosity. If into the tuberosity, use the technique of tendon repair described in Chapter 33 on tendons. Ideally, the measurement of the resting length is used as the length for the transfer.

Cover back wounds—the insertion into the humerus can be divided, and the muscle turned on its secondary blood supply, the perforators from the intercostals, for coverage of the spine.

The **Parascapular Flap** is a reliable and ideal flap for axillary reconstruction. It is an axial fasciocutaneous flap based on the descending branch of the circumflex scapular artery that exits between teres major and teres minor muscles along the axillary border of the scapula, 2 cm. above and 2 cm. posterior to the apex of the posterior axilla. The vessel then courses directly inferior toward the iliac crest. Flaps centered on this vessel may be taken as wide as 10-12 cm., and the length maybe 3-4x the length. This flap will easily rotate anteriorly to reach the coracoid process of the scapula for axillary reconstruction following a burn contracture release. The pivot point is the exit point of the artery between the muscles. This is best determined with a Doppler. The flap can also be used to cover the shoulder. If the skin of the flap has been severely

Fig. 1

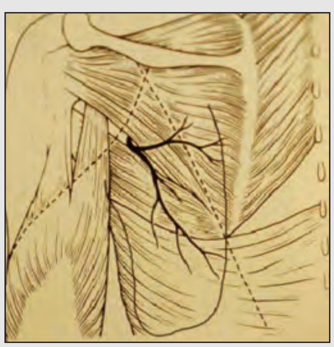


Fig. 2

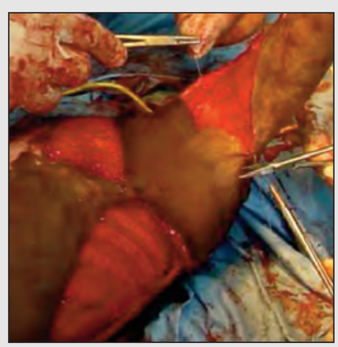


Fig. 3

Fig. 4

Parascapular flap used to reconstruct an axillary contracture that continued to break down as the child used his arm. STSG was used for donor site below joint. Mobilization of skin above flap to close arm wound.

burned, the latissimus dorsi muscle fascia or even the lateral half of the muscle may be included in the flap. The donor site may be closed if <6 cm. in width, but it often requires grafting with a meshed STSG and a stent or bolster dressing. As long as the STSG is not over the joint, the contracture will not recur. The patient in Fig. 1 was able to use the arm without splinting when the skin graft healed. (See axillary reconstruction in Chapter 12 on Burn Reconstruction.)

Flaps for Elbow Reconstruction

Latissimus Dorsi—for biceps reconstruction, see above

The **Cubital Artery Flap** is a fasciocutaneous flap taken from either side of the forearm and based at the elbow. The posterior edge of the flap is along the ulna when it is taken from either side. It can be rotated to cover the antecubital fossa or the olecranon posterior. It is based on cubital arteries from the Brachial Artery. These are small vessels, and since the flap can be taken from either side, the author believes that often this flap may be more of a random flap. Because of its location in the upper extremity, it is extremely reliable, even when the length is 3x the width and reaches to near the wrist. Some superficial scarring is acceptable in the skin of the flap. Occasionally the author will take muscle fascia with the flap to ensure better blood supply, but this is a very reliable flap in most cases without the muscle fascia. A short backcut at the end of the flap may be used to gain 1-2 cm. more, so that the flap tip reaches the apex of the wound. Ideally, when harvesting this flap, the end is taken more as a U than a V. The length of the flap must be sufficient to reach the opposite side of a burn contracture release. Primary closure of the donor site is possible only for flaps of a width less than 6 cm. Usually, the donor site is skin grafted.

Radial forearm flaps, antegrade and retrograde, are axial flaps based on the radial artery. Both require an Allen's test to ensure that the ulnar artery can reliably provide arterial flow to the thumb and radial side of the hand. With the **antegrade** flap, the radial artery is ligated at the wrist and the skin island is over the distal volar forearm. When raising this flap, care must be taken to leave paratenon over the tendons so that a skin graft can take well. This flap is


Fig. 5


Fig. 6


Fig. 7

Elbow contracture secondary to snake bite. Cubital artery fasciocutaneous flap with step cut lengthening Biceps, fractional lengthening Brachialis and Brachioradialis. Only the superficial fascia is taken with the flap.


Fig. 8


Fig. 9


Fig. 10

Snake bite requiring tendon transfers and reversed radial forearm flap.

indicated for posterior elbow and olecranon coverage. It is frequently used as a microvascular flap for facial reconstruction.

The **retrograde** flap is taken from the proximal and mid-forearm and reversed to cover dorsal hand defects, especially over the dorsum and the first web space. This is an excellent one stage procedure. Even if an Allen's test shows good flow through the ulnar artery with a complete palmar arch, a vascular clip is still placed on the artery proximally, and the tourniquet is released just before dividing the artery. This can give further assurance of adequate collateral blood supply from the ulnar artery to the thumb before the radial artery is divided. During dissection, this flap requires careful preservation of the vascular pedicles from the radial artery. A portion of the radius may be taken with the flap. Though other texts can give a detailed description of the flap elevation, it is important to carefully divide and elevate the muscle fascia of both the brachioradialis and the flexor carpi radialis with the flap. These muscles are on either side of the radial artery, and the dissection from each side must be performed carefully to protect the vascular supply to the skin. Also, the superficial radial nerve must be protected beneath the brachioradialis. One can also harvest the palmaris longus with the retrograde flap for reconstruction of extensor tendons. (See Chapter 29 on Perforator Flaps for reverse radial artery perforator flap where the radial artery is not sacrificed.)

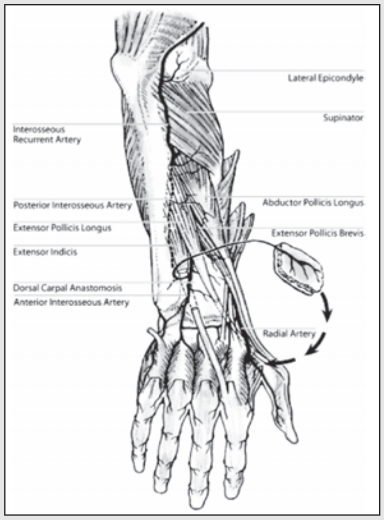


Fig. 11 **Fig. 12**

Posterior Interosseous Flap (Courtesy of David Chang).

Fig. 13

Blood supply of groin and SIEA flaps from superficial femoral artery.

These are soft, pliable flaps that easily mold into any defect. Most often the donor sites must be grafted. With the antegrade flap, care must be taken to ensure that soft tissue and paratenon are left intact over the flexor tendons so that a skin graft will take well. The donor site for the retrograde flap is over muscle and is not a problem for reconstruction. In recent years, it is common that both flaps are taken as fascial flaps alone without skin. (See Chapter 29 on Perforator Flaps and Chapter 12 on Burn Reconstruction.)

Olecranon coverage: The cubital artery flap and antegrade radial artery flaps can both be used to cover the elbow. In addition, the **Brachioradialis** (muscle) flap and a distally based **Lateral arm (fasciocutaneous) flap** may also be used to cover the olecranon, and both are based off the radial recurrent artery branches—an inferior branch for the brachioradialis and a superior branch that supplies the lateral arm flap.

Flaps for Wrist and Hand Reconstruction

Reverse Radial Forearm Flap—see above and Figs. 8-10.

The **Posterior Interosseous Flap** maybe used in wrist and hand reconstruction. The author feels, however, that the elevation of this flap is difficult, and other

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Thoracoepigastric flap (Courtesy Peter M. Nthumba).

Fig. 19

Fig. 20

Fig. 21

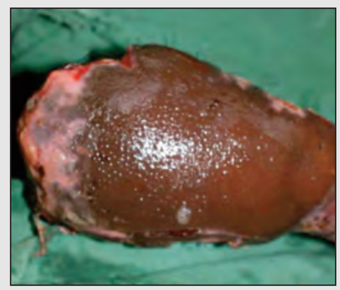


Fig. 22

Kangaroo flap above was used to cover deep circumferential burns exposing tendons and bone. The flap creates a paddle that must then be separated to allow individual digit movement. The hand, initially at risk of amputation, was salvaged (Courtesy Peter M. Nthumba).

Fig. 23

Fig. 24

Fig. 25

This patient presented with a crushed, degloved, infected forearm, for which an above-elbow amputation on had been offered. She presented at ten days with a viable but badly infected extremity. The forearm was placed in a tunnel fashioned in the anterior abdominal wall. This was used to cover the forearm circumferentially. The median and ulnar nerves were subsequently grafted – she now has sensation in all her digits. She awaits tendon grafting (Courtesy Peter M. Nthumba).

flaps are better for the surgeon in the district hospital. Figs. 11-12 show an illustration of this flap. Also, this flap is not as reliable as some other flaps. A good recent description of the flap can be found in March 2012 issue of the American Journal of Hand Surgery. This describes a safer method for raising the flap, with a wide pedicle and in-setting the flap without tunneling the flap to the recipient site.

The **Groin Flap** is a commonly used flap for hand coverage. It is a fasciocutaneous flap based on the superficial circumflex iliac artery, which runs 2 cm. above the inguinal ligament and iliac crest. The longitudinal axis of the flap is along this vessel. Distal (lateral) to the Anterior Superior Iliac Spine (ASIS), the flap becomes a random flap, but the author has found that the flap can be reliably taken at least 1½ to 2 times longer than its width past the ASIS. This flap becomes bulky past the ASIS because of the increase in subcutaneous tissue in all patients, even thin patients, and the distal end will frequently need thinning.

For dorsal hand coverage, this flap will often need debulking/defatting in one or two late stages. The flap is outlined with a marking pencil with the center of the flap 2 cm. above the inguinal ligament. The superior incision is made, and the correct plane is found by dissecting down to just above the external oblique muscle and its fascia. In raising the flap proximally, there are two dangers: First, one must be aware of and protect the lateral femoral cutaneous nerve. Second, lateral to medial elevation of the flap, the muscle fascia overlying the sartorius muscle **must** be taken with the flap in order to protect the blood supply to the flap, which enters the flap just medial to the sartorius. During the dissection from lateral to medial, when the sartorius is reached, a portion of the muscle fascia is included with the flap elevation. This flap can easily wrap around a hand or forearm for coverage.

The donor site can almost always be closed, even if the flap is 10 cm. wide. This is made possible by flexion of the hip if necessary. The main disadvantages of this flap include hand edema and stiffness (because of the dependent position that the hand while attached to the flap) and the need to for flap defatting.

Fig. 26

Fig. 27

Snake bite with contractures; cubital artery flap used for elbow reconstruction and SIEA flap to cover exposed tendons at wrist and hand.

Fig. 28

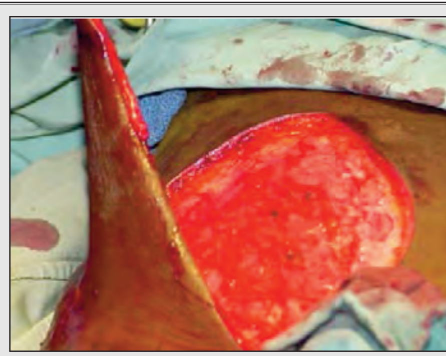


Fig. 29

Fig. 30

Extension contractures of MPJs after previous inadequate surgery using a skin graft. After complete MPJ release, the MPJs are pinned in flexion. Pins are placed through the metacarpal head and through the fingertip with MPJs flexed and IPJs extended. The SIEA flap reconstructs the dorsum of the hand.

The **Thoracoepigastric Flap** has the advantage of allowing the hand to be less dependent; this leads to less edema and a smaller degree of digit stiffness.

A line is drawn between the tip of the shoulder and the umbilicus (Fig. 15). The flap may be based on either medially (peri-umbilical perforators) or laterally (Fig. 16), based on lateral thoracic perforators. The flap dimensions depend on the size of the defect. This is a reliable flap, and may be safely raised to the mid-axillary line without delay. The flap is raised just above the muscle fascia to the lateral edge of the rectus abdominis. Children may require flap pre-expansion (Fig. 18). Most thoracoepigastric flap donor defects can be closed primarily.

When wounds require urgent cover but are more extensive than available flaps can cover, **the 'Kangaroo Flap'**, in essence a bipedicle abdominal flap may be used.

The **Superficial Inferior Epigastric Artery (SIEA) Flap** is a fasciocutaneous flap, and is the author's flap of choice for coverage of the dorsum of the hand and wrist when the Reversed Radial Forearm Flap cannot be used. The hand with the elbow flexed lies perfectly for the flap coverage. It is based on the SIEA, which arises from the Femoral Artery just inferior to the Inguinal Ligament and halfway between the ASIS and the pubic tubercle. It courses superiorly and medially toward the umbilicus. In most individuals, this is a thin flap. In contrast to the groin flap, the SIEA flap rarely needs defatting. The width of the flap can be the distance between the pubic tubercle and spine. If necessary, the length can be the entire vertical distance between the pubis and costal margin. If the patient is obese, then only the superficial fascia and overlying subcutaneous tissue may be taken. This is a very reliable flap.

The **Radial Artery Perforator Flap** is a retrograde flap at the wrist that does not require the use of the radial artery. Perforators off the radial artery at the wrist supply the flap. The flap can extend for 6-8 cm. proximal to the wrist. It can be turned and used to cover the volar wrist when a wrist contracture is released. Usually, skin grafts over the volar wrist joint will contract to leave the patient with a slight functional deformity, but the wrist will not re-contract with this flap. (See chapter 29 on Perforator Flaps for a more extensive use of this flap).

Fig. 31

Fig. 32

Radial artery perforator flap to reconstruct volar wrist after burn contracture release. This will prevent recurrent contracture better than a skin graft, even a FTSG.

The **Becker** or **Dorsal Ulnar Artery Flap** is a reverse perforator flap is based on the ascending branch of the dorsal ulnar artery, which takes off the ulnar artery 2-5 cm. proximal to the pisiform. The maximum size is 10cm. by 5 cm. (Further discussion is found in Chapter 30 on Upper Extremity Reconstruction.) This is a more reliable flap than the radial artery perforator flap.

The **Posterior Interosseous Flap** is used to cover wrist and hand wounds, but it requires considerable experience, and it is not completely reliable. It will not be discussed here.

TFL Flap—see below:

Flaps for Finger Reconstruction

The various flaps are listed here (and well-described in Chapter 30 on Upper Extremity Reconstruction).

- Y-V—Kutler and Atasoy for tip amputations.
- Moberg or volar advancement flap for thumb tip and pulp reconstruction.
- Kite flap for thumb reconstruction.
- Neurovascular Island Flap for thumb reconstruction—rarely used.
- Cross-Finger for finger pulp reconstruction with exposed distal phalanx.
- Reverse Cross-Finger for dorsal finger reconstruction.
- Side finger flaps for reconstruction of small dorsal or volar defects.


Fig. 33

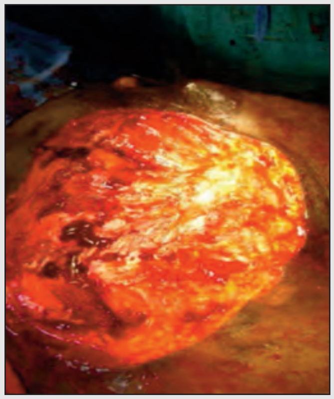


Fig. 34


Fig. 35


Fig. 36

Dermatofibrosarcoma Protuberance.
Abdomen reconstructed with TFL flap (Courtesy Dr. Bill Rhodes).

Flaps for Abdominal Wall Reconstruction

Abdominal wall reconstruction for trauma or cancer involves the use of the following flaps and techniques (see Chapter 18 for a fuller discussion):

- TFL flap—by excising above the pedicle, it may be made into an island so it will rotate better.
- Rectus Femoris flap.
- Flaps off the Deep Inferior Epigastric/Internal Mammary arteries, such as the Tram flap.
- VAC.
- Mesh.

Flaps for Pelvis and Hip Reconstruction

The **Tensor Fascia Lata (TFL) Flap** is a thin musculocutaneous flap, with the Tensor Fascia Muscle proximally and the fascia lata distally. In severe, untreated burns of the groin, the hip is flexed to relieve pain, and a hip flexion contracture may develop. Often these contractures can be released and reconstructed without the need for a regional flap. With large defects, the TFL may be needed. In unusual situations where the groin flap and SIEA flap are not adequate, the TFL flap is available to cover large hand and forearm wounds. It is possible to use the TFL flap as a fascia-only flap with a skin graft. It can be used even if the skin in the flap has been burned. The blood supply is from the lateral femoral circumflex artery, a branch of the profunda (or deep) femoral artery, and the pedicle enters the muscle approximately 10 cm. distal to the ASIS. This flap is a Type I axial muscle flap, as the arterial supply courses the entire length of the flap. The length of the flap can be 3x the width, or to within 10 cm. of the knee. If the width is less than 8 cm. the donor site may be closed. One can take fascia lata only. The central axis of the flap is located between the ASIS and greater trochanter, and then down to the lateral condyle of the tibia. Once one finds the plane under the TF distally, the flap is raised easily and quickly. (See also Chapter 12 on Burn Reconstruction.)

The TFL flap may also be turned laterally to cover trochanteric and ischial decubitus ulcers (See Chapter 17 on Pressure Ulcers).

Abdominal Wall Reconstruction: (See Chapter 18).

Also, the TFL flap **may be turned superiorly** and used for abdominal wall reconstruction, along with the Rectus Femoris flap. It is used as a muscle/fascial flap or a myocutaneous flap to cover lower abdominal defects. The flap may be divided above the blood supply from the lateral femoral circumflex artery and used as an island flap. This allows the flap to rotate and reconstruct larger areas.

The **Rectus Femoris Flap** is a muscle flap that is another choice for groin or abdominal wall reconstruction. It originates from the ASIS and rim of the acetabulum. It is supplied by the lateral femoral circumflex artery approximately 10 cm. below the inguinal ligament.

The **Anterior Lateral Thigh** perforator flap requires some experience to elevate, but is a great flap for the lower abdomen. (See Chapter 29 on Perforator Flaps.)

Flaps in Back Reconstruction

Upper Back—Trapezius muscle or myocutaneous flaps.

Mid-Back—Latissimus Dorsi turn-over flaps, after detaching insertion on humerus.


Fig. 37


Fig. 38


Fig. 39


Fig. 40

Long urethral stricture reconstructed with dartos island fasciocutaneous flap. Island flap elevated and passed with a dartos fascial pedicle beneath scrotum into the perineum. If the stricture is short, the urethra may be mobilized and repaired end to end or this flap may be used as a patch if the back wall is intact. If the circumference of the urethra requires reconstruction, this flap must be 26 mm. wide to tube.
(For more information, contact the author at llcartermd@comcast.net.)

Lower Back—Rhomboid fasciocutaneous flaps and propeller perforator flaps. (See chapter 29 on Perforator Flaps and also Chapter 13 on Neural Tube Defects.)

Flaps for Pelvic/Genitalia Reconstruction

The **Rectus Abdominis Flap** is a versatile flap that may be turned down as a muscle-only flap to cover the groin, especially the femoral vessels. It may also be used intra-abdominally to fill in pelvic defects. The muscle is divided proximally at the costal margin, and then passed into the peritoneal cavity and the pelvis. It can used to fill large defects from injuries or from massive perineal/pelvic resections for malignancy.

Prepuce flaps have been used to reconstruct urethral strictures that are common in Africa. Often the urethra can be dissected out above and below the stricture and a primary repair carried out. When the defect is too long for end-to-end primary repair, a fasciocutaneous flap based on the dartos fascia in the penis can be transferred around the penile shaft for anterior strictures, or passed beneath the scrotum for posterior or bulbous urethral defects. This flap may be taken vertically, as shown in Figs. 37-40, or horizontally proximal to the corona and circumferentially around the penis, giving up to 13 cm. length. A 26 mm. wide strip is necessary to tube and completely reconstruct the urethra. The prepuce flap is based on the superficial external pudendal artery and vein.

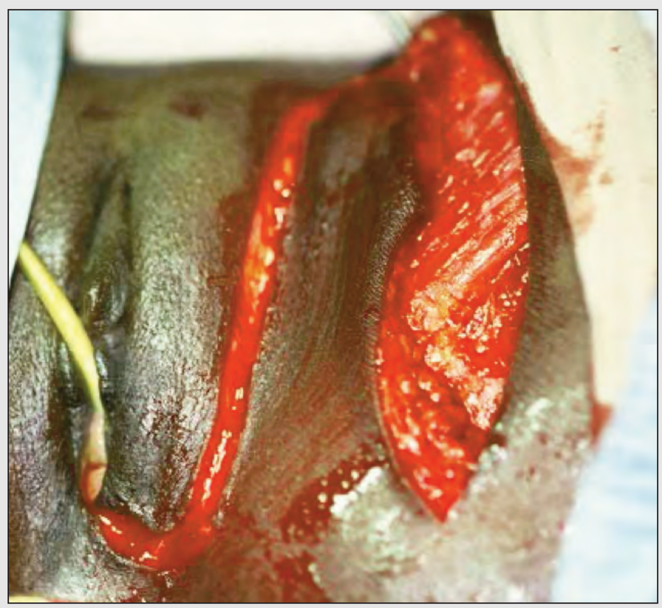


Fig. 41
Vulvoperineal flap or Singapore flap.

Vulvoperineal flaps/Singapore flap have been used for vaginal reconstruction for vaginal atresia, and also reconstruction of vesicovaginal fistula (VVF) defects.

These flaps are fasciocutaneous flaps, but must be raised deep to the adductor muscle fascia. They can be 3-4 cm. wide and 8-10 cm. long. They are based on perineal and posterior labial arteries, which are branches of the internal pudendal artery. A similar flap may be based anteriorly and also used to




Fig. 42 **Fig. 43** **Fig. 44** **Fig. 45**

Transverse back flaps. Female patient developed a large sacral decubitus secondary to radiation. Reconstruction performed with two large transverse back flaps and biceps femoris flap (see also Chapter 17 on Pressure Ulcers). (Courtesy Dr. Peter Nthumba)

reconstruct VVF defects. It is passed beneath the labia and into the vagina. This anteriorly based flap is based on the superficial external pudendal artery and vein.

Gracilis muscle or myocutaneous flaps are used for many types of reconstruction in Africa. It can be used for vaginal reconstruction or reconstruction of the anal sphincter. When used for the latter reconstruction, it must be combined with physical therapy and ideally electrical stimulation. As the gracilis is an adductor, adductor exercises help with continence.

Medial thigh fasciocutaneous flaps are excellent to reconstruct scrotal skin in Fournier's gangrene cases. (See Chapter 19 on Fournier's Gangrene.)

Flaps for Decubitus Ulcers

(See Chapter 17 on Pressure Ulcers, where other flaps for reconstruction are described.)

One flap that deserves mention here is the **Transverse Back Perforator Flap**. This flap is based on perforators off of the lumbar artery. It is taken just above the sacrum, and can be turned distally to cover large sacral defects. This flap can be a carried out to the mid-axillary line. The level of dissection is beneath the lumbar fascia.

Flaps for Knee and Lower Extremity Reconstruction

(See also Chapter 28 on Lower Extremity Reconstruction.)

The **Saphenous Flap** (and **Cross Leg Flap**) is a thin fasciocutaneous flap supplied by the small saphenous artery that runs alongside the saphenous vein on the medial side of the leg. This flap is excellent for coverage of the popliteal fossa after a contracture release. Its anterior border is along the medial edge of the tibia, and it can be taken posteriorly with 8-10 cm. (width). As in other fasciocutaneous flaps, the length can be taken approximately 3x the width. The axis of rotation is at the level of the knee joint. Flaps less than 6 cm. wide can be closed, but most of the



Fig. 46 **Fig. 47** **Fig. 48**

Saphenous flap without need for the muscle fascia of the medial gastrocnemius but only the superficial fascia (Scarpa's fascia).

Fig. 49

Fig. 50

Fig. 51

Open ankle wound requiring cross leg, saphenous, flap. Note: skin graft was applied before the flap is inset. The flap is divided at four weeks.

time the donor site is closed with a meshed skin graft.

This flap is also the most commonly used cross leg flap. The donor site is grafted and a stent dressing applied before the flap is inset into the recipient area, usually the distal third of the leg, ankle or foot. The dressing consists of Vaseline® gauze, wet cotton balls, wet and dry gauze with stent sutures tied over this dressing to hold it in place. With the knees flexed, it is important to immobilize the extremities with an external fixator so that the flap will not move. Any movement of the flap may disrupt the capillaries bridging the suture line. Also, **it is very important to put extremities, especially the knees, through a full range of motion once the fixator is removed**. There is no absolute age limit for use of the cross leg flap, though the older the patient is, the more difficulty there will be in regaining full range of motion. Again, final inset of the flap is best delayed for a week after division.

The **cross-leg flap** may also include the medial head of the gastrocnemius muscle. The muscle may be used to cover one area and the fasciocutaneous portion used for another area.

The **Medial Gastrocnemius Flap** is a Type I muscle flap supplied by the medial sural artery off the popliteal artery. It can be used to cover an exposed knee joint, the upper third of the tibia, or the popliteal fossa. Though it may be used as a myocutaneous flap, this is a bulky flap and leaves a significant donor site deformity. It is an easy flap to elevate, and can be lengthened by dissecting up to its origin, even carefully dividing the origin from just above the medial femoral condyle. In order to cover the entire anterior knee and distal to the middle third of the tibia, the muscle may be passed beneath the gracilis and semitendinosus tendons. If this is done, these tendons must be freed up proximally and distally to ensure that there is no constricting pressure on the muscle and pedicle. One or more of these tendons may be sacrificed without significant functional loss. The muscle fascia may also be scored longitudinally with multiple incisions through the

Fig. 52

Fig. 53

Fig. 54

Open ankle wound requiring cross leg, saphenous, flap. Note: skin graft was applied before the flap is inset. The flap is divided at four weeks.


Fig. 55


Fig. 56

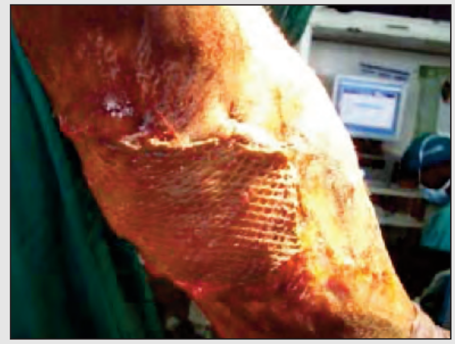


Fig. 57

Popliteal contracture with scarred skin over medial aspect of leg. Medial gastrocnemius flap was used with scoring and STSG. Scar was excised in this case.

fascia, one cm. apart, to give additional width to cover the upper third of the tibia or the popliteal space. A small portion of the Achilles' tendon is taken with the muscle so that the muscle flap can be anchored into the surrounding tissue. In all reconstructions, the muscle should be grafted with a meshed skin immediately. During elevation, care is taken not to injure the greater saphenous vein and saphenous nerve. It is important to understand that these flaps may be used acutely after the initial debridement if the wounds are clean. (See Figs. 60-64.)

It is also possible to use the **Lateral gastrocnemius muscle flap** to cover lateral knee and tibial defects, but because of the fibula, this muscle will not rotate to cover as much as desired. During elevation of the lateral gastrocnemius, great care is needed to protect the peroneal nerve. During elevation of both heads of the gastrocnemius, care is taken to preserve the sural nerve and lesser saphenous vein, which lie in the posterior midline.

The **Soleus Flap** may be used to cover middle third tibial defects. The soleus is a Type II muscle flap, with blood supply from the posterior tibial artery for the medial half and the peroneal artery for the lateral half. The medial half of the soleus may be used, as a hemi-soleus flap, or the entire muscle may be used. **The author uses the entire soleus most of the time**, unless there is a very small defect, to cover over the tibia. The soleus muscle arises from the proximal tibia, and the muscle often extends to the ankle. The muscle is deep to the gastrocnemius. In elevating the distal half of the muscle, care should be taken to carefully divide and ligate the minor pedicles from the posterior tibial artery and vein. One should ligate only the pedicles needed to allow transposition of


Fig. 58


Fig. 59

Open fracture of tibial plateau—wound debrided and medial gastrocnemius muscle flap used to cover the wound acutely, at the time of the original surgery, with the addition of external fixation and immediate STSG.

the muscle. The distal half of the soleus muscle must be dissected free from the gastrocnemius portion of the Achilles' tendon. The lateral half of the soleus can be bluntly dissected free. As with the gastrocnemius, the soleus fascia can be scored longitudinally to increase its width. The soleus can be raised as a distally based flap off the distal perforators from the posterior tibial artery to cover small wounds on the distal third of the leg. **This flap is not reliable, and the author does not recommend this distally based flap**. (See Chapter 2 on Wound Care, where a soleus muscle was used acutely to cover the distal tibia in a severe lower leg injury.)

Distal Third Tibial Defects are difficult to cover without microvascular capability. The **cross leg flap** can be used to cover these defects, but this requires

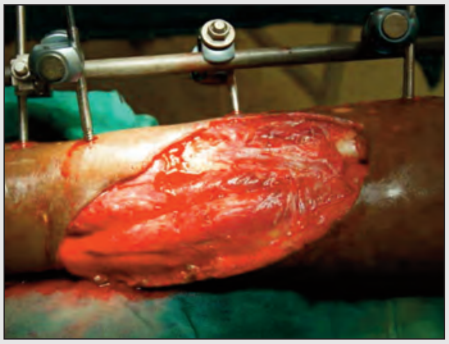


Fig. 60 **Fig. 61** **Fig. 62**

Open fracture junction of upper and middle third of tibia. Soleus muscle reconstruction with meshed STSG was used. Note the raw appearance of muscle in Fig. 61 (arrow), which shows where muscle was sharply dissected from Achilles' tendon. Reconstruction performed three days after injury with immediate skin graft.

3-4 weeks of immobilization. The **sural artery flap** is a very reliable flap when it is taken within the parameters described below. The use of the **VAC (Vacuum Assisted Closure)** or **Negative Pressure Therapy** is an excellent addition to the armamentarium of surgeons. The VAC can be used to clean up the wound and create angiogenesis and granulation tissue over bone and tendon and prepare it for skin grafting. (This technique is described in detail Chapter 4.) **Perforator flaps** off the posterior tibial artery are very useful in covering these defects. Surgeons should become familiar with these flaps, as they will likely soon become the flap of choice. Newer **Keystone Island Perforator flaps** will also become an additional method of covering the lower third of the leg (See Chapter 29 on Perforator Flaps).

Fig. 63 **Fig. 64**

Postoperative view of reverse sural artery flap, harvested as described above to cover posterior ankle wound. Superior edge of donor site is 22 cm. above lateral malleolus, but flap was delayed once to allow radical debridement of two-week old wound.

The **Sural Artery** or **Reversed Leg Flap** is a reverse fasciocutaneous axial flap that may be used for coverage of the distal tibia, malleoli, and heel. The classic flap is based on perforators from the peroneal artery to the sural artery, with the axis of rotation at least 3 fingers' breadth (5 cm.) above the lateral malleolus. The pedicle must be at least 3 cm. wide and the maximum size of the island is 9 cm. wide by 12 cm. long. The flap cannot extend more than 20 cm. proximal from the lateral malleolus unless it is delayed. Therefore, the island may begin 8 cm. above the lateral malleolus and extended for an additional 12 cm. The flap is very reliable if it is raised within these parameters. One may perform a delay procedure if there is a need to make the flap longer than 20 cm. above (proximal to) the lateral malleolus. The center of the flap is the short saphenous vein. Once this vein is found proximally, the flap can be outlined. The sural nerve must be taken with the flap to ensure viability. The flap is taken deep to the muscle fascia of the gastrocnemius proximally, and care is taken to preserve the paratenon over the Achilles' tendon. In situations where the lateral side of the ankle is injured, and when one is unsure about the zone of injury, a wider flap can be taken, based on perforators from both the peroneal and posterior tibial arteries, or delay the flap (see below). It is important to elevate the leg postoperatively and prevent the patient from lying on the pedicle. See Figs. 63-64, where the foot is elevated with an external fixator, and by traction on a Steinman pin placed through calcaneus. When one raises the flap and then returns it to its original position for several more days, this is a "delay of the flap" which encourages collateral circulation and increases the chance for flap survival.

Flaps for Foot Reconstruction

The **Dorsalis Pedis** and **Medial Plantar Flaps** are small fasciocutaneous flaps of the foot. The **Dorsalis Pedis Flap** is based on the dorsalis pedis artery, the terminal branch of the anterior tibial artery. The flap can be taken from the anterior surface of the foot, and it extends down to the MPJ level. This flap can be used to cover small foot defects and the medial and lateral malleolus. When harvesting the flap, care must be taken to leave paratenon over the extensor tendons so that a skin graft will take.

Fig. 65

Fig. 66

Fig. 67

Chronic distal third wound—12 days old. Wound debrided three times while a delayed and longer reverse posterior leg flap was taken on both peroneal and posterior tibial artery perforators, since the initial injury was on the lateral side of the distal leg.

Fig. 68

Fig. 69

Fig. 70

Reverse sural artery flap used to cover lateral malleolus. Elevation is always used in these flaps to prevent pressure on pedicle and to enhance venous drainage.

Fig. 71

Fig. 72

Fig. 73

Fig. 74

Wound over medial malleolus. Debrided, dorsalis pedis flap raised and inset. STSG.


Fig. 75


Fig. 76


Fig. 77


Fig. 78

Wound of the plantar weight bearing surface: Radically debrided, innervated medial plantar flap raised and rotated to cover the defect, with a skin graft for donor site. Flap outlined in Fig. 78.


Fig. 79


Fig. 80

An innervated medial plantar flap used to reconstruct the heel after excision of malignant melanoma. (There were no nodes in the groin and patient refused amputation.)

The **Medial Plantar Flap** is taken from the instep of the sole of the foot and is supplied by the medial plantar artery, a branch of the posterior tibial artery. This vessel travels beneath the abductor hallucis muscle to supply the sole of the foot. The flap may be rotated to cover the heel, with an axis of rotation at the medial malleolus. Terminal branches of the posterior tibial nerve (medial plantar nerve) may be taken with the flap to give a sensate heel reconstruction. The main advantage of the medial plantar flap over other types of reconstruction and especially skin grafts is that it provides "like" tissue to cover the heel. The donor area, the instep of the foot, is a non-weight-bearing portion of the foot, and may be reconstructed with a skin graft. The foot needs to be immobilized and elevated in the postoperative period, and weight-bearing is not allowed for three weeks.

Scalp Reconstruction Based on Scalp Vessels

Flaps can be based on any of the major scalp vessels: supraorbital, supratrochlear, superficial temporal, posterior auricular and occipital. A flap based on one vessel can carry the majority of the scalp skin. The patient shown in Figs. 81-83 had severe trauma to the right side of the scalp and skull in the temporoparietal area. After debridement of open fractures and repair of dural tears, a large flap based on the contralateral supraorbital artery was used to cover the defect. The flap extended to the occipital area on the contralateral side.

Frontal area covered with large flap, Millard Crane Principle: A large scalp flap, usually based off the superficial temporal artery, may be taken to cover large forehead and upper face defects. The donor area is skin grafted. Several months later the hair bearing scalp without the galea is elevated and returned to the original donor site and the skin graft removed. The galea over the forehead is then grafted with a thick split thickness or full thickness graft (see Figs. 84-87).

Tissue Expanders

Initially, tissue expanders were not included in this chapter or this book; however, the editor has recently realized that some very remote hospitals have these available. These can be used to expand tissue adjacent to a wound in order to reconstruct the defect with normal appearing and functioning tissue. These are commonly used to reconstruct scalp alopecia following a deep scalp burn. The expansion will allow a wound or scar to be replaced with normal scalp and hair. Tissue expanders increase the skin size but they do not increase the number of hair follicles in the expanded skin. (See Chapter 12 on Burn Reconstruction.)

Tissue expanders come in various sizes and shapes. The most popular tissue expanders for reconstruction are rectangular or crescent shaped. The amount of saline or water that can be instilled in these varies from as little as 50 ml. up to 2000 ml.

Expanders must not be placed near infected wounds. If the recipient area is infected, an expander should not be used until the wound is clean. Also, expanders should not be placed adjacent/parallel to the area to be covered, as they may extrude through the incision or scar as expansion occurs. Incisions for placement of expanders should be placed perpendicular to the wound to be covered, or at each end of the area where the expander is placed. Possible incisions are shown in red in Fig. 88. One may need two incisions. This is dependent on the size of the wound and size of the expander needed. Two incisions allow for easier placement of the expander while making certain it is lying flat. In the scalp, the expander is placed beneath the galea. In other parts of the body, the expander is placed beneath the superficial fascia, as Scarpa's fascia in the abdomen. Dissection of the pocket for the expander may be carried out with scissors or a blunt object, such as a urethral dilator. The author prefers the latter. In the scalp, the galea is bluntly dissected from the pericranium through the loose areolar tissue plane with the dilator.

Where are incisions placed? The author formerly placed the incision for placement of the expander

Fig. 81

Fig. 82

Fig. 83

Young boy after motor vehicle accident. Injuries covered a large area with contaminated skull fractures. Exposed skull covered with fasciocutaneous (galea) flap based on left supraorbital artery. (Courtesy Dr. Niles Batdorf)

Fig. 85

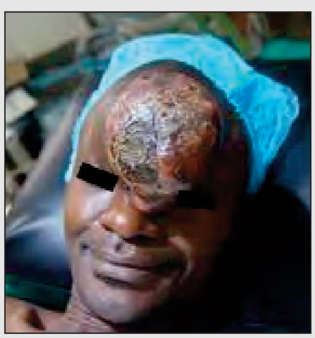


Fig. 85

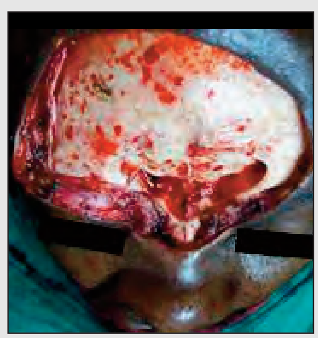


Fig. 86

Fig. 87

Additional Case.
Teenage boy with two previous excisions. Pathological diagnosis was malignant fibrous histiocytoma. The third excision required removal of anterior table of frontal sinus with obliteration of frontal sinus. Nasofrontal duct occluded with bone chips and pericranial flap. A large scalp flap based on superficial temporal artery was rotated into the defect. In several months the hair-bearing skin minus the galea will be returned to its original site. The remaining galea will be grafted (Millard Crane Principle).
Photos courtesy of Dr. Niles Batdorf

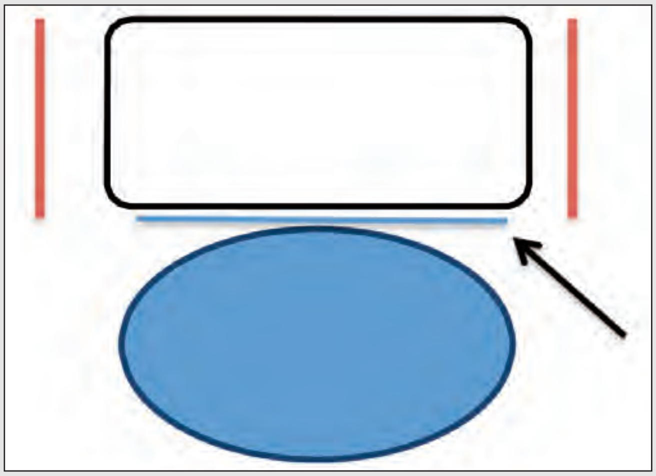


Fig. 88

Wound to be reconstructed in blue. Black rectangle represents expander. Red lines represent incisions for placement of expander. Do not place these incisions parallel to the long axis of the wound (blue line, black arrow), as the expander may extrude as expansion is carried out.

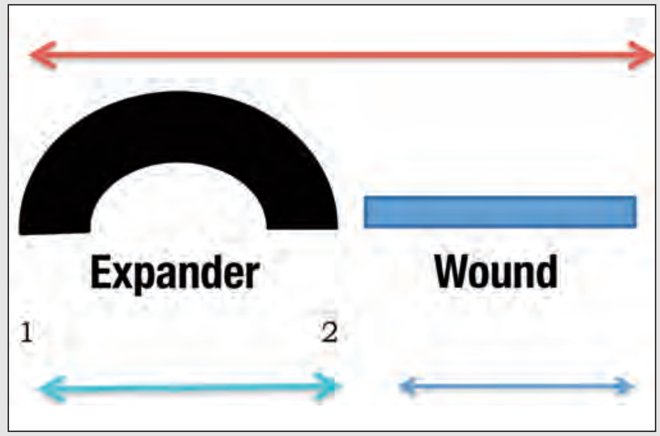


Fig. 89

How to estimate when one has expanded sufficiently: Determine the amount of expanded skin by measuring convex surface after expansion. Length of convex surface of black semicircle (the expander) equals the red line when spread out, and this must be equal to the addition of 1+2 to cover donor area plus defect.

Fig. 90

Fig. 91

Fig. 92

Fig. 93

This is an example of scalp expansion. A crescent shaped expander was used. Fig, 90 shows the burned hairless scalp. Fig, 91 shows full expansion. Fig, 92 shows the expander after removal—some fluid had been removed. Fig. 93 shows the reconstructed scalp.

along the edge of the wound (The blue line and black arrow in Fig. 88) but this may limit the amount of the expansion. Placement incisions for the expander are shown in red in Fig. 88.

It is important to place the port, or injection dome, over a bony prominence so that it can be easily located for injections.

Expansion is carried out over several weeks depending on the age of the patient and the size of the area that needs to be covered. Normally expansion is performed 2-3 times a week with a 23 or 25 gauge needle. In children, Ketamine may be required for the first few injections. Often, after these first expansions the child realizes he/she still has to have a "shot" to inject the Ketamine, and often will accept the small needle stick for the expansion. If one needs to use more than one syringe full for the injection, it is best to remove the syringe from the needle and with a sterile glove cover the needle to prevent fluid leak. In this way, multiple syringes full of saline or water may be injected. One usually knows when to stop each expansion session when the expander is tense, or when the conscious patient complains of tightness or fullness.

Expanders can usually be filled twice as much as the stated volume size. Usually, this is not necessary, if the surgeon has initially picked out the right size expander. This may be required if one has a limited supply of expanders.

How does one know when he has expanded sufficiently? This is not easy, but one method is to measure the skin over the convex surface of the expander to determine if there is sufficient expansion to cover the area before expansion plus the wound. If there is any doubt, further expansion should be carried out for another week or two. The red line in Fig. 89 represents the total amount of skin expanded—the length of the convex side of the distended expander in black. This should be slightly greater than the total of the two blue arrows in Fig. 89.

Summary

Flaps provide an excellent reconstruction of some difficult areas. There are many more flaps than listed here, but these are the most commonly used flaps. Other flaps are described in upper and lower extremity reconstruction and burn reconstruction. Knowledge of vascular anatomy is most important for the successful elevation of a flap. Temporary immobilization and elevation of the extremity is important after any flap. Also, the wounds should be dressed so that inspection of the flap may be carried out frequently during the first 24 hours. If there is a question of viability in the first 24 hours, the patient should be returned to the operating room. Frequently the flap can be salvaged if a problem is corrected early. This may require returning the flap to the donor area for a few days. This would be like a flap delay and allow for collateral circulation to develop. This chapter is written to give the surgeon an idea of which flap is best to use for various conditions in an African context. A full description of the elevation of these flaps, especially the last ones mentioned for foot reconstruction, may be found online or by contacting the author, who would be pleased to send you more details.

In flap surgery, remember to "**measure twice since you can only cut once**."

Please feel free to contact the author for further information: Louis Carter, llcartermd@comcast.net.

Chapter 28
Lower Extremity Reconstruction

Louis L. Carter, Jr. and Peter M. Nthumba

Overview

This subject is partially covered in Chapters 27 and 29 (on Flaps for Wound Coverage and Perforator Flaps, respectively). This chapter will deal with reconstruction from the knee to the foot.

Primary closure or delayed primary closure of wounds is ideal. If this is not possible, then the most reliable method available should be used, and not necessarily the simplest. If the wound is under tension after primary closure, then a more reliable method, such as a flap should be used.

It is very important that every attempt should be made to close an acute clean wound immediately, especially on the leg. Though wounds on the face and upper extremity may be closed within 24 hours if debrided and cleansed well, the 8-hour limit remains for lower extremity injures. If after an accident skin is missing but the wound is clean, then a skin graft or even a flap can be used to cover the wound immediately. A meshed graft works well. There is absolutely no need to delay closure for granulation tissue to develop.

Contaminated wounds that cannot be closed acutely because of contamination should be closed within the first seven days by delayed direct primary closure, skin grafts or flaps. After seven days, the wound will then need radical debridement before closure, unless a VAC is used. During the time the wound is left open, it must be kept moist by methods described (see Chapter 2 on Wound care).

VAC dressings have revolutionized the care of lower extremity injuries. Most conventional wound dressings will often lead to a dessicated wound, which is especially undesirable in the lower extremity. The application of a simple VAC dressing maintains a moist wound, allowing for appropriate wound cover at a convenient time. Post-debridement VACs have become the standard of care in the Editor's institution for leg wounds that cannot be closed primarily. Significantly contaminated wounds cannot be closed primarily, and often require at least two debridements before wound cover; degloved or crushed wounds may require up to three debridements to allow one determine the extent of debridement of devitalized tissue. Such wounds are best maintained in a VAC dressing in the interim. (See Chapter 4 on VAC Dressings.)

Open Fractures

Care of the open fracture wound is dictated by the fracture type (See PAACS Orthopaedic Curriculum).

Type I open fractures: small wounds, <1 cm. long, should be debrided and loosely closed if clean.

Type II open fractures: >1 cm. long, should be debrided, and, if possible, closed very loosely over any exposed bone. A second look with repeat debridement should be done within 48-72 hours. If the wound is clean after the second look, then it should be definitively closed by skin grafts, local fasciocutaneous or muscle flaps.

Type III: >10 cm. long, debrided, with a second look 24-48 hours for further debridement. Further debridements will likely be necessary, but every attempt should be made to close the wound as early as possible and definitely by seven days. In Type III, if the wound is not be closed by seven days, then a VAC may be necessary.

As far as the timing of the closure is concerned, recent studies show that it is the quality of the wound that is important before the wound is closed, not necessarily the timing of the closure. As long as adequate debridement is done, and the wound is clean, the wound can be closed at ten days, but the sooner the wound is closed, the better.

Many variables preclude definite statements regarding treatment of Type III open fractures. These variables include where the fracture occurred (on the farm, on the highway, etc.), contamination, length of time before debridement, adequacy and frequency of irrigations and debridements, tissue loss, a crush component, stabilization, how well the tissues are kept moist, vascular damage, availability of VACs, etc. The method of debridement is in the chapter on open fractures in the PAACS Orthopaedic Curriculum, pp. 6-7. Many Type III injuries may need long-term VAC use, followed by flap coverage. Occasionally, Type III injuries maybe loosely and partially closed after debridement.

A cephalosporin antibiotic should always be used, and, if microbiology is available, cultures are obtained on admission with contaminated wounds. An aminoglycoside +/- penicillin is added if the wounds are severely contaminated, likely with gram-negative and anaerobic microorganisms.

In any open fracture, early stabilization is very important before wound closure. The fracture site is covered as soon as there fixation of the fracture. If the wound is clean, SIGN nailing is an excellent method of fixation for long bones, and this is available in many hospitals throughout Africa. If nailing is not possible, then external fixation should be used. Both of these methods of stabilization allow for repeated debridements of the wound, and also allow for the use of a VAC and later flap coverage. When external fixation is used, it must be applied in such a way that a VAC and later flaps can be used. The bone should never be left exposed, or it will desiccate. Wounds must be covered with moist dressings, dressings impregnated with silver sulfadiazine or a VAC, and then closed as soon as possible, preferably before seven days post-injury. Also, honey may be used even over open fractures to keep the wound moist. There is a move not to sacrifice functional muscles and use them for wound coverage; however, the Gastrocnemius muscle flap is an excellent choice for proximal tibia coverage, while the soleus covers the middle third of the leg. These muscle flaps are easier to learn, and provide durable cover. The muscle flap should be grafted at the same time that it is raised. There is evidence that what is important for the coverage of bone, including osteomyelitic bone, is a flap with a good blood supply. Muscle flaps and fasciocutaneous flaps will provide this blood supply. The advantage of fasciocutaneous flaps is the fact that functional muscles are preserved.

Flaps for Knee and Upper Third of Tibia

The **Medial Gastrocnemius Flap** is a Type I muscle flap supplied by the medial sural artery off the popliteal artery. It can be used to cover an exposed knee joint or the upper third of the tibia, or it can be turned posteriorly into the popliteal fossa. If used as a myocutaneous flap, it is a bulky flap and leaves a significant donor site deformity. It is an easy flap to elevate, and it can be lengthened by dissecting up to its origin, and even carefully dividing the origin at the medial femoral condyle. When there is a need to

Fig. 1

Fig. 2

Open fracture of the tibial plateau. Wound debrided, medial gastrocnemius muscle flap with a skin graft used to cover the wound at the time of the original surgery, and fixation of the fracture.

Fig. 3

Fig. 4

Fig. 5

Popliteal contracture with scarred skin over medial aspect of leg. Medial gastrocnemius flap used with longitudinal scoring of the muscle fascia, and STSG after excision of large scar.

cover the entire anterior knee, and distally to the middle third of the tibia, the muscle may be passed beneath the gracilis, sartorius, and semitendinosus tendons (pes anserinus). If this is done, these tendons must be well freed up proximally and distally to ensure that there is no constricting pressure on the muscle and pedicle. Some are hesitant to pass the medial gastrocnemius under these tendons because of possible swelling and compression under a dressing. It is likely best to divide one or more of these tendons if necessary to cover a large wound over the knee. These tendons may be sacrificed without significant functional loss. The gastrocnemius muscle fascia may also be scored longitudinally with multiple parallel incisions through the fascia to gain additional width to cover the knee, upper third of the tibia. or the popliteal space after a burn contracture release. A small portion of the Achilles' tendon is taken with the muscle so that the muscle flap can be inset into the surrounding tissue. In all cases, the muscle may be grafted immediately with a meshed skin. During muscle elevation, care is taken not to injure the greater saphenous vein and saphenous nerve in the posterior midline.

(**Editor's Note:** It is rarely necessary to pass the gastrocnemius beneath the pes anserinus tendons [sartorius, gracilis, and semitendinosus]. No matter how much these tendons are freed up, there should still be concern about pressure on the gastrocnemius muscle.)

It is also possible to use the **Lateral Gastrocnemius Muscle Flap** to cover lateral knee and tibial defects, but because of the fibula, this muscle will not rotate to cover as much as desired. During elevation of the lateral gastrocnemius, great care is needed to protect the peroneal nerve. During elevation of both heads, care is also taken to preserve the sural nerve and lesser saphenous vein which lie in the midline between the heads of the gastrocnemius muscle. The muscles are **grafted immediately**.

The **Saphenous Flap** and **Cross Leg Flap** are thin fasciocutaneous flaps supplied by the small

Fig. 6

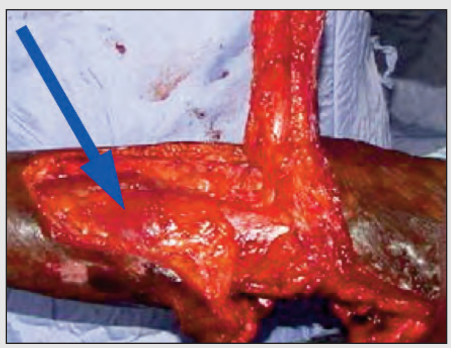


Fig. 7

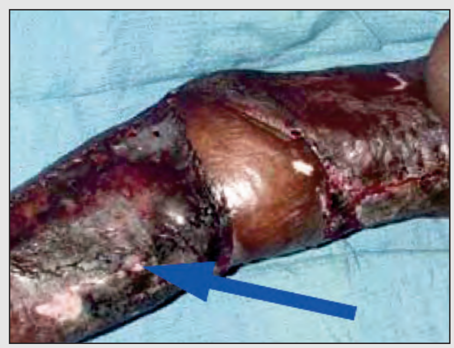


Fig. 8

Saphenous flap. The muscle fascia of the medial gastrocnemius muscle is left on the muscle. See the arrow in Figs. 7-8. The flap contains just the superficial fascia.

Fig. 9

Fig. 10

Fig. 11

Medial head of gastrocnemius muscle used to cover popliteal fossa when saphenous flap alone was not adequate.


Fig. 12


Fig. 13


Fig. 14

Open ankle wound requiring cross-leg or saphenous flap. Note: donor site was grafted before flap was inset.

saphenous artery that runs along with the saphenous vein on the medial side of the leg. This is an excellent flap for coverage of the popliteal fossa after a burn contracture release. Its anterior border is along the medial edge of the tibia, and it can be taken posteriorly, to give an 8-10 cm. width. As in other fasciocutaneous flaps, the length can be taken approximately 3 X the width. The axis of rotation is at the level of the knee joint. Flaps less than 6 cm. wide can be closed, but most of the time it is necessary to close the donor site with a meshed skin graft. This flap uses the superficial fascia, not the fascia over the gastrocnemius muscle—see Figs. 7-8 with muscle fascia still on muscle.

This flap is also the one commonly used in the cross leg flap that remains a valuable flap in Sub-Saharan Africa (see Chapter 12 on Burn Reconstruction).

The donor site must be grafted and dressed before the inset of the flap. The dressing consists of Vaseline® or non-adherent gauze, wet cotton balls to hold the skin graft down into the crevices, wet and then dry gauze, and large sutures (stent sutures) tied horizontally over this dressing to hold it in place. The recipient area is usually the distal third of the leg, ankle, or foot. With the knees flexed, it is important to immobilize the extremities with an external fixator. This fixator holds the legs together so the flap will not move. Any movement of the flap may disrupt the capillaries bridging the suture line. It is easy to elevate the legs with the external fixator. Also, it is important to put the extremities and especially the knees through a full range of motion once the fixator is removed and the flap divided—usually at three weeks. There is no absolute age limit for use of the cross leg flap, though the older the patient is, the more difficulty there will be in regaining full range of motion after three weeks. The flap is carefully inset a week after the flap is divided. (After flap division, a few sutures hold the end of the flap in place. After a few days to a week, final insetting of the flap is done.)

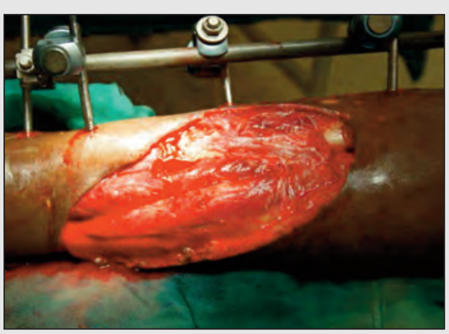


Fig. 15


Fig. 16


Fig. 17

Open fracture junction of upper and middle third of tibia. Soleus muscle reconstruction with meshed STSG was used. Note the raw appearance of muscle in Fig. 16 (arrow), which shows where muscle was sharply dissected from Achilles' tendon (end of hemostat). Reconstruction performed three days after injury with immediate skin graft.

Fig. 18

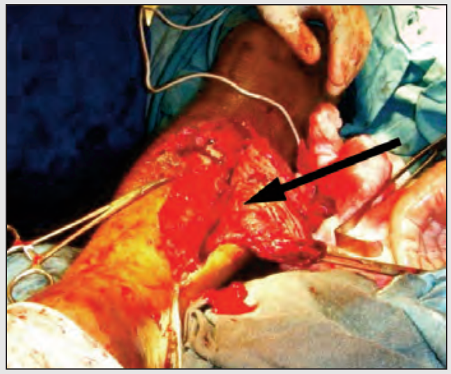


Fig. 19

Fig. 20

This is a similar case to the one shown in Figs. 14-17, where soleus muscle was used for middle third tibial fracture. Note the scoring (arrow) of the muscle to increase the width.

Fig. 21

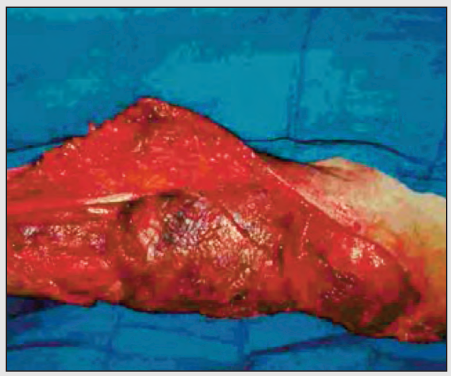


Fig. 22

Fig. 23

Reconstruction of a large tibial defect with both medial gastrocnemius and soleus muscles. The patient will do well with lateral gastrocnemius. Note scoring of the soleus muscle.

When additional coverage is needed, the cross leg flap may also include the medial head of the gastrocnemius muscle. The muscle may be used to cover one area and the fasciocutaneous saphenous flap for another area.

Middle Third Defects

The **Soleus Flap** may be used to cover middle third tibial defects. This is a Type II muscle flap. The posterior tibial artery supplies the medial half of the soleus, and the peroneal artery supplies the lateral half. Only the medial half of the soleus may be used, a hemi-soleus flap or the entire muscle may be used. The author uses the entire soleus most of the time (unless there is only a very small defect) to cover over the tibia. The soleus muscle arises from the proximal tibia, and the muscle often extends to the ankle. The muscle is deep to the gastrocnemius. In elevating the distal half of the muscle, care should be taken to carefully divide and ligate the minor pedicles from the posterior tibial artery and vein. One should ligate only the pedicles needed to allow transposition of the muscle to cover the defect. The distal half of the soleus muscle must be sharply dissected free from the gastrocnemius portion of the Achilles' tendon. The lateral half of the soleus can be bluntly dissected free. As with the gastrocnemius, the soleus fascia can be scored longitudinally to increase its width.

The soleus can be raised as a distally based flap, on the distal perforators from the posterior tibial artery, to cover small wounds on the distal third of the leg. This distally based flap is not reliable, and the author does not recommend it. The plantaris tendon is located between the gastrocnemius and soleus. (See Chronic Wound Chapter where a soleus muscle was used acutely to cover the distal tibia in a severe lower leg injury.)

Fig. 24 **Fig. 25**

Post-op view of reverse sural artery flap harvested as described to cover posterior ankle wound. Superior edge of donor site is 22 cm. above the lateral malleolus. The flap was delayed once to allow for the extra length and to give time for further debridement of the two-week old wound.

Distal Third Tibial Defects

These are difficult to cover without microvascular capability. The following four techniques do not require microvascular techniques:

The **Cross Leg Flap** can be used to cover these defects, but this requires 3-4 weeks of immobilization and multiple stages.

The **Reverse Sural Artery Flap** is a very reliable flap when it is taken with the parameters described below. Technique for the Reverse Sural Artery Flap: It is a reversed fasciocutaneous axial flap that may be used for coverage of the distal tibia, malleoli, and heel. The classic flap is based on perforators from the Peroneal Artery to the Sural Artery with the axis of rotation at least three fingers' breadth (5 cm.) above the lateral malleolus. This flap may also be classified as a perforator flap. The pedicle must be at least 3 cm. wide and the maximum size of the flap is 9 cm. wide by 12 cm. long. **The flap cannot extend proximally more than 20 cm. from the lateral malleolus without delaying the flap**. The flap is very reliable if it is raised within these parameters. Some surgeons may prefer to stage the flap elevation and inset because of questionable reverse blood supply or the need to extend the flap proximally, beyond 20 cm, for more distal coverage. The **center of the flap** is the lesser saphenous vein. Once this vein and sural nerve are found proximally between the two heads of the gastrocnemius, the flap can be outlined. These structures must be included in this flap.

The sural nerve and the lesser saphenous vein must be taken with the flap to ensure viability. The proximal end of the flap is taken deep to the muscle fascia of the Gastrocnemius, but care is taken to preserve the paratenon over the Achilles' tendon. In situations where the lateral side of the ankle is injured and when one is unsure about the zone of injury, a wider flap can be taken based on perforators from both the peroneal and posterior tibial arteries, and the flap can be delayed (see Figs. 26-28).

Posterior Tibial Perforator Flaps

These are excellent flaps for coverage of lower extremity wounds. They are based on one or more perforators from the posterior tibial artery. A description of this flap is found in Chapter 29 on Perforator Flaps.

Fig. 26 **Fig. 27** **Fig. 28**

Chronic distal third wound—12 days old. Wound was debrided three times, and the reverse posterior leg flap (modified reverse sural artery flap) was delayed and lengthened at each debridement. The flap was based mainly on the posterior tibial artery perforators because of the zone of injury on the lateral side of the distal leg.

Fig. 29

Fig. 30

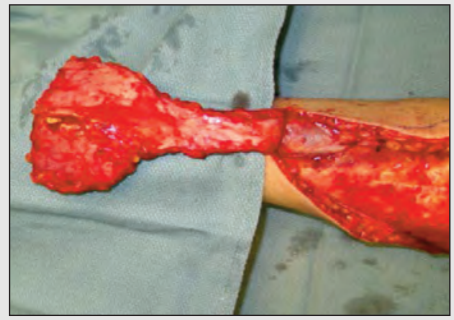


Fig. 31

Fig. 32

Fig. 33

Fig. 34

Reverse sural artery flap design; elevation; delay; inset; and the final result. Note VAC over the heel and narrow, 3 cm. pedicle. (Courtesy Dr. Blair Summitt)

Keystone Island Perforator Flaps

These are island fasciocutaneous flaps taken in a "keystone" design adjacent to the defect. Perforators adjacent to the defect supply the skin of the flap (again, see Chapter 29).

Fasciocutaneous Flaps

Many other fasciocutaneous flaps are possible in the lower extremity. Unless based on a definite vessel or perforator, care must be taken not to take the flap longer than 2 X the width. In addition, care should be taken to rotate the flap gently into the new position. If necessary, the flap can be delayed once or twice to gain more length. A small backcut can help a flap better rotate to cover the defect. Retrograde flaps can be taken based on known perforators. In all these flaps, a delay may help maintain vascularity, especially when used to cover large wounds, or when there is the need to rotate the flap sharply for coverage. (Ideally, the flap is never rotated acutely.) As long as the recipient wound is kept moist, closure can be delayed for several days.

The use of the **VAC (Vacuum Assisted Closure or Negative Pressure Therapy)** is an excellent addition to the armamentarium of the plastic surgeon. The VAC can be used to create clean wounds and stimulate angiogenesis and granulation tissue over bone and tendons to prepare the wound for skin grafting or flap closure. This technique is described in detail in Chapter 4 on VAC, and also in Chapter 2 on Wound Care).

Foot Defects

The **Dorsalis Pedis** and **Medial Plantar Flaps** are small fasciocutaneous flaps of the foot. The Dorsalis Pedis Flap is based on the dorsalis pedis artery, the terminal branch of the anterior tibial artery. The flap can be taken from the anterior surface of the foot, and it extends down to the MPJ level. This flap can be used to cover small foot defects and the medial and lateral malleolus. When harvesting the flap care must be taken to leave paratenon over the extensor tendons so that a skin graft will take.

The **Medial Plantar Flap** is raised from the instep of the sole of the foot. Blood supply is the medial plantar artery that is a branch of the posterior tibial artery. This vessel travels beneath the abductor hallucis tendon to supply the sole of the foot. The flap may be rotated to cover the heel with an axis of rotation at the medial malleolus. Terminal branches of the posterior tibial nerve may be taken with the flap to give a sensate heel reconstruction. This will require loupe magnification to dissect these branches from the digital nerves that are not sacrificed.

Fig. 35

Fig. 36

Fig. 37

Fig. 38

Wound over medial malleolus. Debrided, dorsalis pedis flap raised and inset. STSG.

Fig. 39

Fig. 40

Fig. 41

Fig. 42

Wound of the plantar weight bearing surface: Radically debrided, innervated medial plantar flap raised and rotated to cover the defect, with a skin graft for donor site.

Fig. 43

Fig. 44

Medial plantar flap used to reconstruct the heel after excision of a malignant melanoma. An innervated medial plantar artery flap was used.

The main advantage of the medial plantar flap over other types of heel reconstruction and especially skin grafts is that it provides "like" tissue to cover the heel and it can also provide a sensate reconstruction. In elevating this fasciocutaneous flap, the longitudinal fibrous septa must be divided. These run the length of the foot between the metatarsals and the plantar fascia. The neurovascular bundles lie on either side of the septa. The donor area, the instep of the foot, is a non-weight bearing portion of the foot, and may be reconstructed with a skin graft. The foot needs to be immobilized and elevated in the postoperative period. Weight bearing is not allowed for three weeks.

Achilles Tendon Injuries

(See also Chapter 33 on Tendon Injuries)

Acute open injuries can be repaired with several core weave sutures, as in flexor tendon injuries, or a Krackow whip stitch with a large braided non-absorbable suture—probably the largest available in the hospital and usually silk, Mersilene®, or

Ethibond®. It is best to expose the tendon through a medial incision. The ankle may then be casted in plantar flexion for 6-8 weeks. If the Achilles is avulsed off the calcaneus, it can be repaired using large anchors or with sutures passed through drill holes in the calcaneus. Acute closed ruptures can be treated open or closed with equally good results in recent literature studies.

The Krackow suture is shown in Fig. 45. Many now add a second suture to give four strands for both Achilles tendon and biceps tendon repairs.

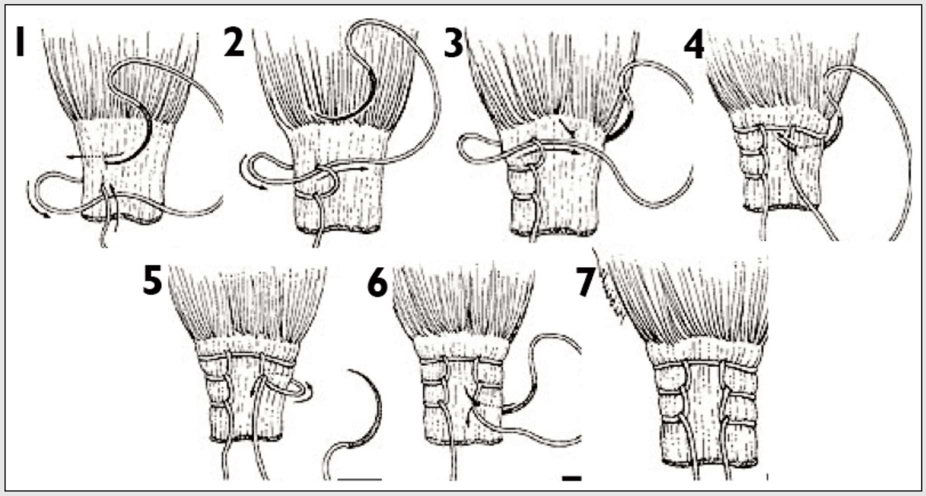


Fig. 45

Krackow suture for Achilles tendon repair (Courtesy of Kenneth A. Krackow).

Achilles Tendon Defects

Where a substantial defect in the length of the Achilles tendon exists, there are a limited number of options for restoring plantar flexion. The peroneus brevis muscle-tendon flap has become the Editor's preference for reconstruction of Achilles tendon defects. The tendon is used as graft, while the muscle provides well vascularized tissue that can be grafted over, completing soft tissue cover. Occasionally, more tissue is needed than can be provided by a skin graft, and a perforator flap may be used as in the case presented in Figs. 46-48. This patient was able to regain normal Achilles tendon function at 4 months post-operatively.

Ankle Injuries with Bone Loss

Ankle injuries frequently accompany other lower extremity injuries, although they can be isolated (as shown Figs. 49-55). These pictures depict a very severe ankle injury with loss of both malleoli, and entire ankle mortise, leading to an unstable ankle joint. Note that the tibia is exposed both medially and laterally. Although an amputation had been considered, this injury was in a 16 year-old, and with an otherwise normal leg and foot, salvage was agreed upon.

An extended posterior tibial artery perforator flap was elevated and delayed, and later used to cover both defects. The ankle joint was exposed and infected, draining pus. Cartilage was debrided from

Fig. 46

Fig. 47

Fig. 48

15 cm Achilles tendon loss following debridement after trauma and infection. The Peroneus brevis muscle is raised based on its distal blood supply, with ligation of its main pedicle proximally. The tendon is then woven into any remaining Achilles tendon, or though the calcaneus distally, and with the stump proximally. It may then be grafted over with skin, or a flap used to cover this repair and any other soft tissue defect. The foot is placed in a back slab, and the patient allowed partial weight bearing at 8 weeks, and full weight bearing at 12 weeks.

Fig. 49

Fig. 50

Fig. 51

Fig. 52

Severe ankle injury in a 16 year-old with loss of both malleoli and entire ankle mortise. Amputation was considered, but salvage was pursued due to the patient's age.

After debridement, tibia and talus were fused using two Steinman pins, and metatarsal fractures were fixed with K-wires. The wound was covered with an extended posterior tibial artery perforator flap.

Fig. 53

Fig. 54

Fig. 55

At 3 months, all the hardware was removed, and the patient mobilized without crutches. He regained a near-normal gait, and was able to use his lower extremity at one year post-operatively. Note plantigrade foot with ability to wear sandals and even shoes, should the patient so choose.

the tibia and talus, and two Steinman pins used to fuse the tibia to the talus. The sub-talar joints were essentially normal, hence movement in these joints was preserved. Metatarsal fractures were fixed with K-wires.

The technique used for ankle fusion is simple, both technically and in resource use, and is excellent for such injuries as an ankle fusion will either be needed later, or will occur with ongoing ankle sepsis. The author has found that excision/debridement of the cartilage stops the sepsis. And the fusion proceeds uneventfully. A plain radiograph is taken prior to removal of the pins to assess fusion.

The Mangled Extremity

This describes any extremity that has sustained sufficiently severe injury to a combination of vascular, bony, soft tissue, and/or nerve structures that results in subsequent concern for viability of the limb.

Defining criteria for lower extremity salvage following severe high energy trauma continues to be a challenging and controversial topic, while reconstruction of complex compound multilayer defects is the most significant factor in deciding the fate of an injured limb.

With the advent of modern techniques came the era of the struggle over when to apply these techniques to salvage a limb. These include:

- Antibiotic therapy.
- Arterial repair.
- Microsurgical free tissue transfer.
- Surgical stabilization of severe lower extremity fractures with open reduction and internal/external fixation techniques.

Injury factors that proved to be of the highest significance in the decision for limb salvage included:

- Muscle injury—this has **the highest impact on the**

decision to salvage the limb**. The salvaged limb may function poorly because of the risk of infection, nonunion, and poor function.
- Absence of plantar sensation—**2nd highest impact** on surgical decision making.
- Arterial injury—**3rd highest impact** on surgical decision making.
- Tibial fracture pattern.
- Presence of an open foot fracture.
- Bone loss.
- Vein injury.

Patient and family decisions on limb salvage versus amputation must be respected. They must however, be made to understand that “salvage" of a mangled extremity is no guarantee of functionality or employability.

They must also realize that **neither** salvage **nor** early amputation can guarantee, by any means, that the patient will return to a previous normal, pain free extremity.

The decision to amputate may be immediate (i.e. within the first 24 hours) or delayed (i.e. secondary procedure within the first hospitalization).

Factors that influence the limb salvage decision-making process include:
- Those related to the leg injury itself.
- Extent and severity of associated injuries.
- Patient factors—age, physiologic reserve, associated injuries, pre-injury functional level. Also important are patient resources.
- Training and experience of the attending surgeon.
- Resources available.

Amputation should not be considered as a treatment failure, but rather as a means of meeting the goal of treatment.

The Lower Extremity Assessment Project (LEAP) was an important milestone in the evolution of limb salvage attempts. This was a multicenter, prospective outcome study of 601 patients with high-energy lower extremity injury.

While plantar sensation was previously the most important factor in the process of deciding on whether to amputate or salvage an extremity, the LEAP study established that **many patients who had an initial insensate foot regained plantar sensation within two years after injury**. An initial absence of plantar sensation was not a reliable indicator of the need for amputation, as 55% of patients with no plantar sensation initially reported plantar sensation at 24 months. The initial loss of plantar sensation may have been secondary to neuropraxia or reversible ischemia, and is not representative of permanent nerve damage.

Thus **absolute** criteria for amputation currently include:
- Non-reconstructible vascular injury.
- Crush injury with warm ischemia of > 6 hours.
- Severe bone and soft tissue loss with tibial nerve transection.

Relative criteria for amputation are as follows:
- Elderly patients in shock with a mangled limb.
- Massive soft tissue loss associated with bone loss.
- Mangled Extremity Severity Score (MESS) of 7 (especially with absent plantar sensation).
- Severe ipsilateral foot trauma.
- Polytrauma.
- Patients who are not expected to tolerate reconstruction.

Scoring Systems

To bring objectivity into the decision-making process, multiple scoring systems are in use. The purpose of these scores is to allow accurate prediction, either of the need for amputation or the possibility of salvage.

These scores have high specificity and low sensitivity, and can make useful predictions about limb salvage potential, but cannot reliably predict which limbs should be amputated.

Scoring systems, however:
- Do not clearly define severity.
- Are difficult to apply clinically.
- Are too complex or inclusive to use prospectively.
- They are derived from retrospective data (small numbers of patients).
- No long-term data was used to validate the criteria.
- Each index was validated in the same sample from which it was developed, leading to exaggerated estimates of accuracy.

Scoring systems do not consider factors related to the patient's age, wishes, quality of life, pain, occupation, social support system, family status, or financial resources. Therefore, while scoring is important, the


Fig. 56

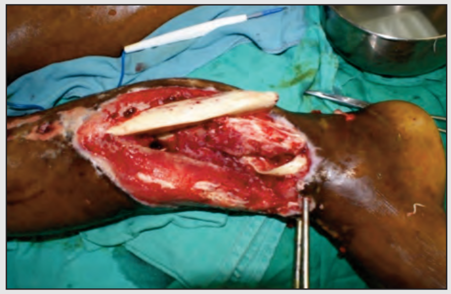


Fig. 57


Fig. 58

50 year-old obese man run over while drunk. Presented with an infected Gustillo 3B tibio-fibula fracture. The patient and family wanted limb salvage, and after nearly two months, soft tissue was accomplished, and bone transport planned. Unfortunately chronic osteomyelitis set in, despite multiple operating room visits. At 12 months, he requested for an amputation, and now walks quite comfortably using a prosthesis.

surgeon must also include factors such as the social environment within which the patient lives, including their socio-economic status.

For example, where lower extremity prostheses are easily available and affordable, an attempt to salvage a severely injured limb that will require long hospitalization and multiple procedures, including multiple re-admissions, the cost may be prohibitive, especially for a patient who pays out of pocket, and an amputation may be therefore desirable from the outset.

The reader is encouraged to read up on the following scoring systems:

- Mangled Extremity Severity Score—MESS.
- Limb Salvage Index—LSI.
- Predictive Salvage Index—PSI.
- Nerve Injury, Ischemia Soft Tissue Injury, Skeletal Injury, Shock, Age of Patient Score—NISSSA.
- Hannover Fracture Scale—HFS-97.

Western literature indicates that above 70% of lower extremities involved in high energy trauma are currently salvaged. More than 70% of patients prefer salvage. A seven-year follow-up for in the LEAP trials showed no functional difference between those who underwent salvage and those who had amputations. Johansen et al. reported that a MESS score >7 predicted amputation with 100% accuracy. Delayed amputation resulted in over 20% mortality from sepsis, as compared to no mortality in primary amputation. Not all authors are in agreement on the use of cut-off scores, and many suggest an evaluation of individual patients.

While evaluating the scoring systems, it is important to note that MESS, NISSSA, and HFS-97 scores are influenced by the results of initial neurological examination (with the assumption that an acute sensory debilitation correlates with decreased limb-salvage potential and the initial examination demonstrates the final deficiency), which the LEAP study clearly showed to be untrue, because ischemia, contusion, stretch, or compression can cause transitory neurological deficit, with recovery expected in up to 55% of such patients. These scores were all developed before the LEAP study.

Further, current scoring systems are not useful guides in the decision of whether to acutely amputate or salvage a severely mangled lower extremity, because there is no scientific evidence available to identify injuries that will proceed to late amputation.
Because a large number of trauma-amputees are young breadwinners in their families, it is important to bear in mind that the functional outcomes of both amputees and limb salvage patients are generally poor, as physical and psychosocial functional levels deteriorate over time, with only 60% returning to work in 7 years, while 25% report limitations.

Amputation level has significant implications on functional activity; through-knee amputees have poor outcomes at 2 and 7 years post-injury—they have the slowest timed walking speeds. Poor patient satisfaction scores are associated with:

- Older age.
- Less education.
- Female sex.
- Poverty.
- Poor social support.
- History of smoking.

Principles of Limb Amputation

Unless one is performing an amputation in a damage control situation ("guillotine" amputation), the goal with amputation surgery is a functional extremity with a residual limb that successfully interacts with the patient's future prosthetic and external environment. In a patient that has not been adequately resuscitated, or who has significant contamination or infection, blast, or crush mechanism, a staged amputation may improve functional results by preserving length.

A number of salvaged limbs will, over time, require amputation because of non-healing wounds, unresponsive chronic osteomyelitis or significant bone loss, and thus initial limb salvage does not necessarily translate to limb function.

After taking all factors into consideration, the surgeon should have a long discussion with the patient and family about the options available, including projected costs and hospitalization(s).

Summary

Flaps provide an excellent reconstruction of some difficult areas. There are many more flaps than listed here. These are the most commonly used lower extremity flaps. Knowledge of vascular anatomy is most important for the successful elevation of a flap. Temporary immobilization and elevation of the extremity is important after any flap. Also, the wounds should be dressed so that inspection of the flap may be carried out frequently during the first 24 hours. If there is a question of viability in the first 24 hours, the patient should be returned to the operating room. Frequently the flap can be salvaged if the problem is corrected early.

Further Reading

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2 Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. J Trauma. 1990 30(5):568-72; discussion 572-3.

Chapter 29
Perforator Flaps

Peter M. Nthumba

Introduction: The Evolution of Flaps

Cutaneous flaps have a long history and have evolved from the random- pattern flaps. Random-pattern skin flaps have limited length: width ratios, and therefore largely limited applications.

The concept of axial flaps was introduced by McGregor and Jackson in 1972 with their description of the groin flap. Bakamjian had in 1968 unveiled the deltopectoral flap, an axial flap.

Ger and Orticochea described musculocutaneous flaps, while Ponten reported the use of fasciocutaneous flaps, which allowed the use of flaps with significantly longer length to width ratios.

The angiosome concept was introduced by Taylor and Palmer in 1987. After total body studies of the blood supply to the skin and the underlying deep tissues, they divided the body anatomically into three-dimensional vascular territories, "angiosomes", supplied by a source artery and its accompanying vein(s) that span between the skin and the bone. Each angiosome is linked to its neighbor, in each tissue, by a fringe of either true anastomotic arteries without a change in caliber, or by reduced-caliber choke (retiform) anastomotic vessels. Each angiosome therefore defines the safe anatomic boundary of tissue that can be transferred separately or combined together on the underlying source vessels as a composite flap.

The Perforasome Concept and Perforator Flaps

The perforasome concept is thus an advancement of the angiosome concept. A perforasome is the vascular territory of a single perforator. Each perforasome is connected to its neighbor both by direct and indirect linking vessels.

Freestyle perforator flaps are flaps designed only on the basis of a Doppler signal, in the absence of a known flap. In the absence of a Doppler, a flap may be designed in the area adjacent the defect, beginning with the exploration for the perforator at the base of the potential flap that would form the pivot of the flap. Freestyle perforator flaps should, however, be designed close to areas with known perforators, such as along intermuscular septae.

Koshima and Soeda reported experience with the inferior epigastric perforator flap in 1989. Since then, many perforator flaps have been described, in all regions of the body. Perforator flaps have the advantages of reduced donor site morbidity, reduced recovery time, the ability to contour the flap according to a specific defect, and hence improved aesthetic outcomes. Further, flap harvest is relatively quick, and the recipient site has a similar texture, thickness, pliability, and pigmentation to that which has been lost.

The nomenclature remains somewhat controversial, as to what should be called a perforator flap. An attempt at standardizing perforator flaps nomenclature suggested the following: Cutaneous flaps may be either cutaneous flaps or musculocutaneous perforator flaps.

Cutaneous Flaps (Direct)	Musculocutaneous Flaps (Indirect)
Axial, septocutaneous, fasciocutaneous	Musculocutaneous perforator flaps
Source artery passes through deep fascia only, no other structures.	Source artery to skin arises from and passes through the underlying muscle

Table 1

The terms **septocutaneous perforator flaps** and **musculocutaneous perforator flap**s are, however, the most common in use, describing respectively, cutaneous flaps perfused by a source vessel that passes between two muscles (septal perforator) and those perfused by vessels that pass through muscle.

The author has found perforator flaps most useful in three otherwise difficult anatomic areas: the leg, the hand, and the neck/orofacial regions, providing excellent options equivalent to free flaps, yet feasible in low-tech environments.

The Leg

Traditionally, musculocutaneous flaps, principally the gastrocnemius and the soleus, have been used for coverage of soft tissue defects of the proximal and middle third of the leg, respectively. High energy lower extremity trauma in Sub-Saharan Africa is the result of road-traffic accidents or gunshot wounds. Inadequate or inappropriate management of the resultant injuries frequently leads to the development of chronic osteomyelitis. The most common reason for this eventuality is failure to provide an early and adequate soft tissue cover for exposed bone. Anatomically, the distal third of the leg has little or no muscle, with multiple tendons and subcutaneous bones (tibia and fibula). Loss of soft tissue cover of this anatomic region is therefore particularly challenging for the surgeon. Indeed, even in high-income environments, soft tissue defects of

Case 1

A 30 year-old male presents with a Gustillo 3B tibiofibular fracture, sustained after a road traffic accident. He was transferred to the author's institution about 1 week after the accident. Soft tissue in the middle and distal thirds of the leg was extensively damaged in the accident (Fig. 1). The orthopaedic team performed an initial debridement and stabilized the leg with an external fixator. He also had a compound fracture of the lateral malleolus that was plated (Fig. 2). The plastic surgery team was requested to review the patient a week later, to see whether leg salvage was possible.

An initial ipsilateral hemisoleus flap was used to cover the defect. The muscle had been badly damaged, but was still possible to gently dissect out and cover the bone. After a skin graft, a negative pressure therapy dressing was applied. The result was a much smaller defect, but still a challenge (Fig. 3). The easiest and quickest option, in the absence of a free flap, which would offer significant challenges in terms of pedicle length, and vessels to anastomose to, and in the presence of an ongoing low-grade infection, was a cross-leg flap. A contralateral pedicled posterior tibial artery perforator flap was raised and inset (Figs. 4 and 5). The flap was divided at three weeks, with all wounds healed on review at two months after admission to the hospital.

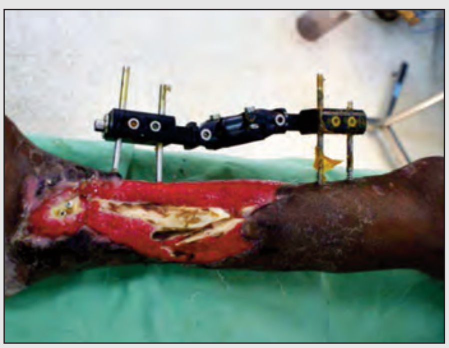

Fig. 1

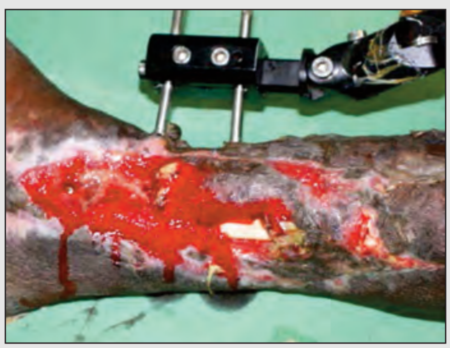

Fig. 2

Fig. 3

Severe lower third leg injury. Initial hemisoleus flap used from z one of Injury with partial failure. Without availability of other local muscle or fasciocutaneous flaps, a cross-leg posterior tibial perforator flap, based on large distal posterior tibial perforator, was used.

Fig. 4

Fig. 5

External fixator holds legs side by side. Note in Figs. 3 and 4 that the legs are not acutely bent as they would be with a traditional cross-leg flap. Division was carried out in 3-4 weeks.

the lower third of the leg remain a significant challenge to reconstructive surgeons, with sometimes significant free flap reconstruction failure. This varies according to locale, experience of the surgeon, equipment, and supplies, etc.

The leg has three source arteries, the posterior tibial, anterior tibial, and peroneal arteries, from which perforators arise and supply overlying skin territories. An understanding of the surface markings of the three source arteries is essential for one to raise perforator flaps, especially in the absence of a Doppler for mapping out the perforators.

Surgical Technique

A Doppler and a pair of loupes are important, although not absolute necessities, in planning and raising perforator flaps. A Doppler will accurately locate the site of a perforator, and therefore enable rapid designing of the flap, depending on the defect.

In the absence of a Doppler, a flap is designed, with the pivot point placed over the most likely position of a perforator, centered preferentially over an intermuscular septum. Loupe magnification is essential for the identification of the perforator, especially early after trauma, as identification may otherwise be impossible. An incision in made along one side of the proposed flap, down to the fascia, and the flap is raised up to the septum, where a perforator closest to the defect is located, and the flap re-adjusted to suit the new pivot point. Ideally the perforator should be dissected out for a distance of 2 cm. The flap is now raised and inset.

High energy trauma presents a number of difficulties, including the fact that the flaps raised may be frequently based on perforators located within the zone of injury, and therefore at a high risk of failure. The author does not attempt to dissect out a length of the perforator in such circumstances, because of the high risk of injury to the vessels.

In a severely injured leg, it may be impossible to locate a useable perforator, in which case, **a contralateral perforator flap** is raised as a cross-leg flap, inset, and separated at three weeks (Figs. 1-5). Cross-leg perforator flaps have the advantage of enabling comfortable positioning of the two limbs alongside each other, without the need for cumbersome knee flexion, as in traditional cross-leg flaps. Where cross-leg flaps may be either cumbersome or impossible, flap delay on likely injured perforators within the zone of injury may be performed. These flaps require the use of an external fixator to hold the legs in place.

The posterior tibial artery perforator flap may be designed for any defect, and the propeller flaps may be as small or as large as the defect to be covered (Figs. 6-8). Large flaps, or those elevated acutely within the zone of trauma, may develop tip necrosis (Fig. 9-12).

Case 2

A 60 year-old female presented with a leg ulcer that was reported as a squamous cell carcinoma on histology. The lesion measured about 4 cm. x 4cm. (Fig. 6). A full thickness 6 cm. x 6 cm. defect, including tibial periosteum, resulted upon excision. A posterior tibial artery perforator flap (Fig. 7) was raised and used to reconstruct the defect, with split thickness skin grafting of the donor site (Fig. 8).

Fig. 6

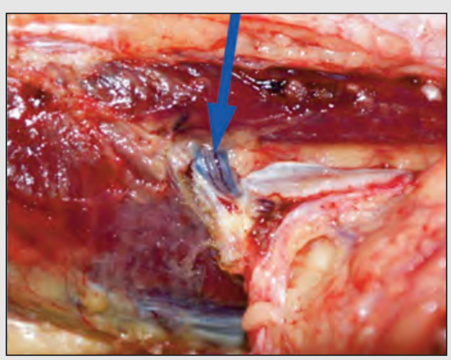

Fig. 7

Fig. 8

Posterior tibial perforator flap turned at right angles as a propeller flap after the perforator had been identified (arrow in Fig. 7). Squamous cell carcinoma was located over tibia, with periosteum excised with the lesion. Outline of propeller flap can be seen to the left in Fig. 6.

Case 3

A 25 year old female presented with a large chronic ulcer that was clinically suspicious for malignancy (Fig. 9). A wide excision (down to the bone), was performed, and the resulting defect covered using a large posterior tibial artery perforator flap (Fig. 10, 11). The large flap developed tip necrosis (Fig. 12).

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Long standing ulcer suspicious for Marjolin's Ulcer. After wide excision including periosteum, posterior tibial perforator flap raised on proximal perforator (not as large as distal). Even though distal tip did not live, it responded will to a VAC dressing.

Schaverien and Saint-Cyr in 2008 in anatomic dissections of the leg found perforators of the posterior tibial, anterior tibial and peroneal arteries in three distinct areas at regular intervals of approximately 5 cm, starting at 5 cm above the intermalleolar line.

The anterior tibial artery perforators were found predominantly between the tibia and tibialis anterior, and between the extensor digitorum longus and the peroneus longus within distinct intermuscular septa.

Peroneal artery perforators emerge through the posterior peroneal septum; proximally these emerge through the soleus or peroneus longus muscles, whereas distally they emerge between the flexor hallucis longus and the peroneus brevis. These perforators predominantly emerge 13 to 18 cm proximal to the lateral malleolus.

Posterior tibial artery perforators are found mainly between the soleus and flexor hallucis longus, in three clusters: 4 to 9 cm, at 13 to 18 cm, and at 21 to 26 cm from the intermalleolar line.

Thus posterior and anterior tibial perforators are found at the 4 to 9 cm and 21 to 26 cm intervals, above the intermalleolar line, while at the 13 to 18cm interval, perforators originate from the posterior tibial and peroneal arteries. Posterior tibial artery perforators are the largest and most consistent, with an accompanying venae comitantes. Chan et al. found no posterior tibial perforators in the proximal third of the leg, with clustering in the mostly in the distal third, and the distal part of the middle third, in a largely Asian population. No anatomical studies have been performed in the African population, but

Case 4

A 22-year- old presented with a 3 year history of left leg chronic ulcer, located just above her lateral malleolus. She reported having had the ulcer skin grafted 3 times, and was looking for a permanent solution, as the ulcer was painful. She had no clinical features of a venous incompetence on either leg (Fig. 13).

At surgery, the ulcer was excised, below which a thickened and dilated short saphenous vein was found, most definitely the cause of the recurrent ulceration (Fig. 14). After excision of all the ulcer tissue, a peroneal artery perforator flap was raised, rotated 180° (propeller flap), and inset (Fig. 15). Skin graft for the secondary defect was harvested from the same leg.

Fig. 16 shows the outcome at 2 weeks.

Fig. 13

Fig. 14

Fig. 15

Fig. 16

Chronic venous ulcer in a patient with no clinical evidence of varicose veins. Treated multiple times with skin grafts. Ulcer excision and a propeller flap based on the peroneal artery perforator flap were used to reconstruct it.

Case 5

A 35 year old diabetic male patient presented with tropical diabetic hand syndrome of the left hand. Upon debridement, he had lost the index finger and most of the skin of the dorsum, with exposed tendons. A radial artery perforator flap was used to cover the defect (Fig. 17-19).

Fig. 17

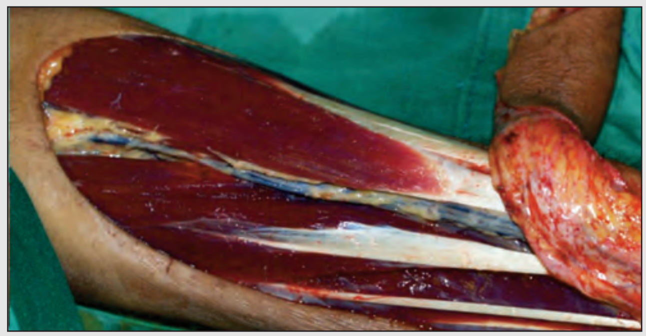

Fig. 18

Fig. 19

Diabetic hand syndrome: Reverse radial artery flap could be used, but would sacrifice the radial artery in a diabetic patient. Radial artery perforator flap used instead. As long as only superficial fascia is taken with the flap near the wrist, there is skin available to cover possibly exposed tendons. The only drawback is the wide pedicle that will make the rotation more difficult than with the traditional reverse radial forearm flap.

the clinical experience of the author suggests a distribution similar to that reported in Caucasian studies.

The perforator flaps so raised may be rotated up to 180°, creating the 'propeller' flap. Care must be taken when insetting the flap, that the pedicle is not twisted leading to vascular compromise and flap failure. Venous engorgement is often the first event leading ultimately to flap failure. Fifty percent of medial leg perforators may be accompanied by a single vein, often inferiorly placed. Most of the rest had two veins, with three of 40 arteries unaccompanied by a vein.

Reverse sural artery flap is also a perforator flap, but the perforators are usually not carefully dissected out as the other perforator flaps in this chapter. This flap is discussed in Chapters 27 and 28.

The Hand

Soft tissue defects of the dorsum may result from trauma (including burns), infection, or as a result of a surgical procedure (e.g. burn contracture release). When such a defect leaves exposed tendons without peritenon, or will require tendon reconstruction later, simple skin grafting will not suffice, and a flap will be required. In low-income environments, especially in the absence of a reconstructive surgeon, either a groin or a thoraco-epigastric flap would be most suited; this requires at least two, and frequently three, procedures.

Local/regional flaps have the advantage of being single-staged, while offering tissue similar to what is missing. The pedicled reverse radial artery forearm flap is such a regional flap that, however, requires the sacrifice of a major artery. The radial artery forearm perforator flap on the other hand, while it is based on the radial artery as a source artery, and provides regional tissue as needed, does not require the sacrifice of the source artery, being based on the distal perforators. A major perforator will usually be found located with 2cm proximal to the radial styloid process.

The Neck and Orofacial Region

Supraclavicular skin is thin and pliable, the perfect source for neck and oro- facial skin, as it closely resembles that of the neck and face. The supraclavicular artery flap has been used both as a pedicled and free flap, for the reconstruction of a large variety of defects around the head and neck,

Case 6

A 25 year-old man who had suffered burn injuries at age six presented with a dorsal contracture of his right wrist and hand. After the contracture was released and the hand pinned in the position of function, a radial artery perforator flap was fashioned and used to cover the defect (Figs. 20-21).

Fig. 20

Fig. 21

Burn contracture release and excision of the scar. Reverse radial forearm perforator flap one stage reconstruction with good volar forearm skin.

Fig. 22

Anatomy of the supraclavicular perforator flap.

including the neck (for post-burn contractures), face (post-burn scarring and noma), oral, tracheal and sternal defects, as well as palatal and nasal lining. Its use gives results equivalent to or even superior to the use of free flaps.

It has a consistent anatomy, is easy and quick to elevate, with a short learning curve. The origin of the supraclavicular artery may be delimited by a triangle formed by the clavicle, the sternocleidomastoid muscle, and the external jugular vein. Safe margins for flap elevation include: (1) anteriorly, the clavicle, (2) posteriorly, the superior border of the trapezius muscle, and (3) inferiorly, the insertion of the deltoid muscle (Fig. 22). Donor sites of flap widths 10 cm or less will usually close primarily, unless surrounded by scar tissue, in which case skin grafting is necessary. Common flap complications include flap tip and partial flap necrosis. Scar widening, hypertrophic scarring, and keloids may develop in the long term. This flap can be elevated even after oncologic neck dissection.

Case 7

A 20 year-old lady suffered severe burns to the face and neck, resulting to a severely scarred face, with ectropion of both eyelid and lip, as well as a severe neck contracture with chin on the sternum. A contracture release with the use of a left supraclavicular flap, along with the release of the eyelid and lip contractures were performed (Figs. 23-25).

Fig. 23

Fig. 24

Fig. 25

Extensive burn contracture release with supraclavicular perforator flap and skin graft reconstruction.

Case 8

A 15 year-old boy was referred to the author with a history of burns sustained as a child. He was found to have a neck contracture. A contracture release was performed, with the defect closed using a left supraclavicular flap, with excellent results (Fig. 26-28).

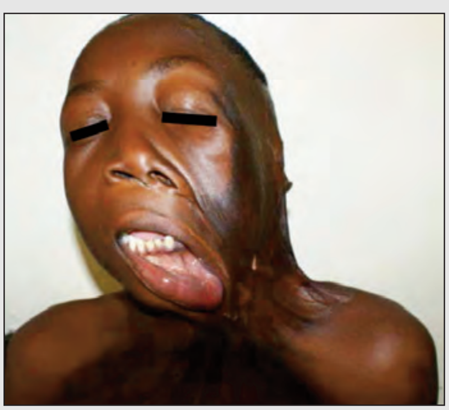

Fig. 26

Fig. 27

Fig. 28

Reconstruction of burn contracture with supraclavicular perforator flap.
Note residual scar that may be a problem in some patients.


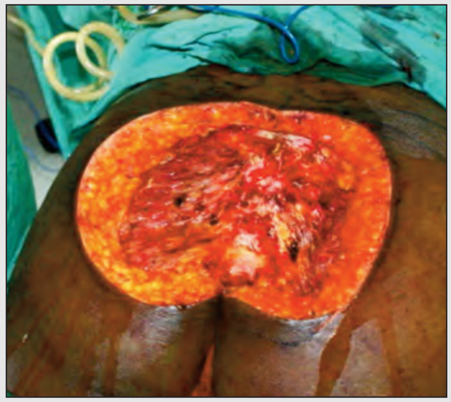


Fig. 29 **Fig. 30** **Fig. 31**

A woman developed a large sacral decubitus secondary to radiation. Reconstruction performed with two large transverse back flaps and biceps femoris flap (See Chapter 17 on Pressure Ulcers).

Back

A perforator flap is the transverse back perforator flap. This flap is based on perforators off of the lumbar artery. It is taken just above the sacrum and can be turned distally to cover large sacral defects as seen in Figs. 29-31.

Summary

Perforator flaps will definitely be the answer for a number of our reconstructive needs in the future. The editors suggest that surgeons first master the basic flaps. The one perforator flap that can be put into our practice immediately is the posterior tibial perforator flap for immediate reconstruction of lower leg and ankle trauma, giving excellent coverage for bone and tendons. The other flap that can also be used for the lower leg and ankle is the reverse sural artery flap that is also a perforator flap. (It is further discussed in Chapter 28 on Lower Extremity Reconstruction.) Most distal tibial and ankle defects can be covered by one of these flaps. Perforator flaps have given the plastic surgeon many new alternatives for reconstruction of the entire body, especially the distal third of the leg.

(**Editor's comments**: Dr. Nthumba has been in the forefront in the use of perforator flaps in Africa.

Though the perforator flaps include the superficial fascia, the dissections initially extend beneath the muscle fascia in order to identify the perforators. This deep fascia may be included in the flap or a cuff of deep fascia may be taken with the pedicle and the dissection continued superficial to the muscle fascia and deep to the superficial fascia.)

Addendum: Keystone Island Perforator Flaps

A new perforator flap design is the "**keystone island perforator flap**" which takes skin and superficial fascia in a keystone pattern adjacent to the defect that needs to be covered. This keystone flap is trapezoidal in shape and bent in the shape of an arc. The longest side or convex side is designed on the side opposite the defect to be covered. The height of the trapezoidal flap is at least the same height or greater

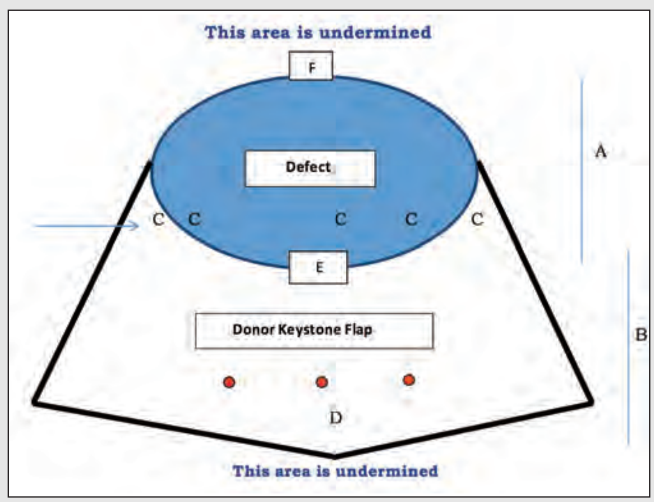

Fig. 32

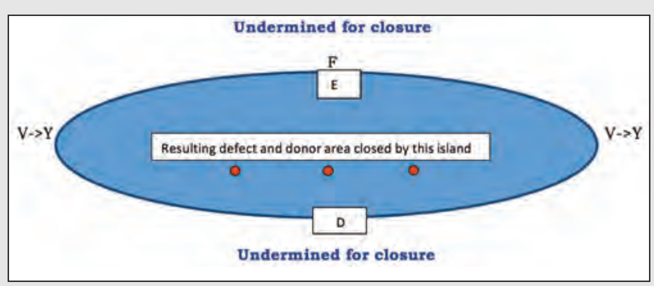

Fig. 33

than the defect to be covered, to capture the perforator blood supply. Ideally the flap lies in the longitudinal axis of the dermatomes. This will help ensure the flap will run parallel to longitudinal neurovascular structures and enable inclusion of perforators. By incising completely around this "keystone" flap area, it allows extended mobilization of tissue adjacent to the defect that is supplied by perforators. Careful dissection (often blunt dissection) is carried in a plane beneath the superficial fascia or deep muscle fascia to identify the perforators. These are preserved. When the original defect is closed by this flap, then tissue surrounding the "keystone" flap donor area must also be undermined in order to close the secondary defect, or a skin graft can be used. The ends are closed in a V-Y manner. Also, Keystone flaps may be placed on both sides of the defect for a midline closure. When using one keystone flap, it is important that it be placed on the side of the wound with the most laxity. In the lower leg, this is usually medial and posterior.

In Fig. 32, B, the width/height of the keystone flap must be equal or greater than A, width/height of the defect to be closed. C, the angle between the defect and sides of the keystone flap should be approximately 90°. D, the convex side of the keystone flap, should be a semi-circle between the ends of the trapezoidal flap and not straight lines as shown in the figure. Red dots indicate perforators. E is the side of the keystone flap nearest the defect and F is the side of the defect opposite the keystone flap. E is sutured to F and D becomes the opposite side of the defect closed by the flap. When the defect is closed by the keystone flap, the ends may be closed in a Y-V manner. This narrows the height of the defect. At the end of the case, the closure results in a circumferential suture line around the island flap that is supplied by underlying perforators.

Case 10

A 30 year-old gentleman involved in a road traffic accident sustained a Gustillo 3B tibial injury 10 days prior to presenting to the author's hospital. He had a compound mid-tibia segmental open fracture, with a large area of soft tissue loss. The skin of the lateral aspect of the leg was preserved (Figs. 34-36). A large Keystone flap based on the peroneal artery perforators was raised and used to cover the exposed tibia after a thorough debridement. The secondary defect was skin grafted, as was the degloved area on the medial aspect of the leg (Figs. 37-38). Figs. 39 and 40 show the reconstructed leg at 3 weeks post-op.

Fig. 34

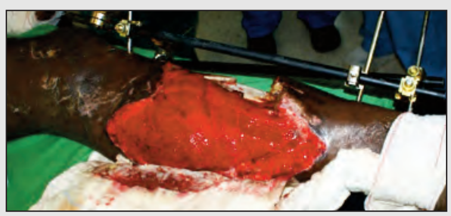

Fig. 35

Fig. 36

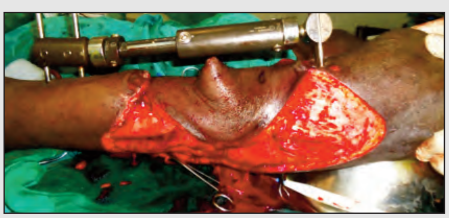

Fig. 37

Fig. 38

Fig. 39

Fig. 40

There are many applications of the keystone flap, and the reader is referred to the book *The Keystone Perforator Island Flap* by the originators of this method of closure, Behan, Findlay, and Cheng Hean Lo. The authors are from Melbourne, Australia, and this is an Elsevier publication from 2012 with ISBN: 978-0-7295-3971-5.

Conclusion

The surgeon in Africa now has multiple local methods to cover the lower third of the leg. In most cases a microvascular free flap will not be necessary.

These new methods include:

1 Posterior/anterior tibial artery and peroneal artery perforator flaps.
2 Reverse sural artery flap.
3 Keystone island perforator flap.
4 VAC with a secondary skin graft.
5 Cross-leg flap.

Also, local rotation fasciocutaneous flaps are possible. The decision on which flap or method to use depends on some factors including location of the defect, zone of injury, vascular status, the presence of an open fracture, the age of the patient, history of smoking, surgeon's knowledge and experience with each method of closure, etc.

Chapter 30

Upper Extremity Reconstruction

Tertius H. J. Venter

Introduction

An injury to the upper extremity may have significant consequences for the individual. It may not only compromise self-esteem, but also implicate loss of one's ability to work and provide for self and family, with potentially devastating consequences. It is important that early diagnosis and strategically well-planned treatment be instituted from the outset.

Extensive skin and soft tissue trauma, along with injuries involving multiple structures and organs, must be managed actively and effectively. Open wound management and healing by secondary intention have no place in the upper extremity. Maximum preservation of motion can only be achieved with early wound closure, and this should be the aim of the treating surgeon.

Wounds are typically caused by:

- **Slicing** by sharp instruments, in particular fingertip injuries with loss of the highly tactile skin.
- **Avulsion** injuries with degloving of a finger or more extensive areas of the upper limb.
- **Penetrating** injuries by sharp instruments with nerve and tendon damage.
- **Crushing** injuries by blunt objects with soft tissue, bone and joint damage.
- **Thermal** injuries.
- **Mangling** injuries—a severe injury where all or most of the five organ and tissue systems of soft tissue, bone/joint, muscle/tendon, vessel, and nerve are affected.

Mangling injuries are caused by high-energy forces as gunshot wounds, explosives, motor vehicle accidents, and industrial injuries (e.g. power saw).

Also, there may be a combination of sharp, crushing, avulsion, and thermal components.

The wound may also be severely contaminated, depending on the location and mechanism of injury.

Evaluation of the Patient

Complete evaluation of the patient for potential life-threatening or other associated injuries is essential before focusing the attention on the hand.

The mechanism and time of injury should be accurately determined. The patient's occupational and social histories are important in determining post-operative compliance and in planning the reconstructive goals.

Examination of the extremity should be systematic with attention to the:

- Motor and sensory function.
- Vascular status: the peripheral pulses, color, temperature, and capillary refill time are assessed to determine the vascular status. Pulse oximetry, if available, is helpful in assessing ischemia.
- Skeletal injury: deformity, crepitance (crepitus), bone tenderness, and need for X-rays are indicated.
- Extent of soft tissue loss is carefully noted and, in particular, the exposure of vital structures.
- Continuity and function of muscles and tendons.

Management

The treating surgeon will often be confronted with the decision between an attempt to salvage or to amputate an extensively injured upper extremity, and especially a part of the hand or a finger. The decision can be very difficult as the functional recovery of a salvaged extremity, hand or finger may be limited or completely lost. Multiple reconstructive procedures with associated morbidity, prolonged hospitalization, disability time, and financial implications must be weighed against the potential successful functional recovery and risk of ending with useless and/or painful limb, hand or finger. Compliance with long-term therapy is always a concern. Whether or not therapy is available is important. Every mangled upper extremity though should be assessed for possible salvage. Serious associated injuries, systemic disease, severe crush, avulsion, contamination of the wounds or injuries at multiple levels will favor amputation rather than an attempt to salvage. Cultural implications with an amputation must be considered. Sometimes a useless limb is more important from a cultural standpoint than a functional limb. This is seen when the surgeon is asked to salvage a useless finger even though this

Fig. 1 **Fig. 2**

A near-complete amputation at the wrist. (Courtesy Peter M. Nthumba)

Fig. 3 **Fig. 4** **Fig. 5**

The same case shown in Figs. 1-2 after operation. The initial surgeon offered a completion amputation, which the patient refused and was discharged with an infected wound "against medical advice" to an institution of own choice. He has useful "helping hand" with acceptable hand function at 15 months following initial surgery. (Courtesy Peter M. Nthumba)

often will lead to the limited function of the remaining normal hand.

Limbs injured by sharp objects can be salvaged, and useful function restored, at least a "helping hand." Where vascular supply is preserved, it would be appropriate to refer the patient to a center where the limb may be salvaged. See below.

Timing of Reconstruction

The first steps in the reconstruction of the severely injured limb would require initial adequate debridement followed by skeletal stabilization, revascularization, and soft tissue coverage. **Early soft tissue coverage is essential in limb salvage**. This improves the vascularity to the traumatized area and reduces the risk of infection. Soft tissue cover is also technically easier in the early stages. With a delay, tissues and vessels become more friable, and tissue planes more difficult to identify with progressive increase in edema.

Reconstruction of tendons and nerves should be done early rather than late. If possible, skin should be closed primarily, or with skin grafts or flaps as soon as the wound is clean. Tendons, nerves, and definitive bone stabilization may be delayed. In some cases, with a clean wound and with surgical expertise available, primary corticocancellous bone grafts, nerve grafts, tendon transfers and even tendon grafting can be performed at the time of soft tissue coverage. Reconstruction should be delayed up to 7-10 days with severely contaminated wounds that require debridements every other day to create a clean wound. When the surgeon lacks experience in treating hand injuries, adequate debridement and tagging of the cut structures (tendons/nerves) is adequate in the initial management. The wound should be loosely closed if possible (see the Clean Closed Wound Concept in Chapter 2). The patient should then be referred for formal reconstruction.

Principles of Treatment

The initial treatment includes meticulous debridement, wound irrigation, antibiotic administration, tetanus prophylaxis and wound culture if your hospital has good microbiology. Antibiotics should be administered in the emergency department, continued intravenously for at least 72 hours, and should cover both gram-positive and gram-negative organisms. A first- generation cephalosporin is recommended for simple wounds. Gram- negative and anaerobic coverage are added in complex wounds. Coverage against anaerobic organisms should be added in any farm or human bite injury.

Debridement

Copious irrigation with careful debridement and removal of all foreign material and nonviable tissue is crucial and should be done under tourniquet control. This also provides a good opportunity to assess the extent of the injury and to carefully identify the nerves and vessels to prevent iatrogenic injury. The tourniquet should be released and the viability of the remaining tissue assessed. Skin and subcutaneous tissues are then sharply debrided to bleeding edges, and muscle is debrided back to contractile or twitching muscle. Contractility is a better indicator of muscle viability than is bleeding. Loose, small bone fragments should be discarded unless they constitute a part of an articular surface.

Contused or contaminated nerves are left in continuity. Cut nerves are debrided to healthy-appearing fascicles. At the time of repair, this is best done under magnification (3.5 loupe magnification). Primary repair or nerve graft will fail if the injured segment is not resected.

Bone Stabilization

Definitive, stable internal fixation should be done early to allow access to the extremity for wound care and early joint range of motion when applicable. Intra-articular fractures should be anatomically reduced. Stable fixation is imperative to allow early range of motion. Each hospital will have different equipment for bony fixation. Plates, intramedullary rods, external fixators are ideal but not always available. Some will only have K-wires, Steinman pins, and cerclage wires. Fixation is dictated by the fracture pattern and location. Unless one has substantial experience in ORIF techniques and exposures, open reduction is probably not indicated. One can accomplish a lot with K-wires, Steinman pins, and plaster. (See the PAACS online Orthopaedic Curriculum for further information.)

Vascular Reconstruction

Definitive revascularization is done once skeletal stabilization is completed. Lacerated vessels are resected to a healthy-appearing vessel wall both proximally and distally. Contusion along the adventitia suggests injury within the intimal layer as well. A "ribbon sign" (convoluted or tortuous course of the digital vessels) indicates injury to the media layer of the vessel and requires resection of the involved area and reversed vein grafting. Loupe magnification is usually indicated.

When possible, primary repair is preferred. However, it is better to resect a questionable area and to use a reversed vein graft than to perform a primary repair under tension. Reversed vein grafts are available from several sites. The most commonly used grafts for long segments in the upper extremity are the saphenous vein or a forearm vein.

(**Editors' Note**: Many surgeons will not have loupes or microscopic capability to perform small vessel repairs. If the brachial artery in the arm or both the radial and ulnar arteries in the forearm are damaged, and there is distal ischemia, a repair should be attempted.)

Musculotendinous Reconstruction

Primary tendon repair is preferable whenever possible. The exceptions are a crush or avulsion injuries, which precludes primary repair. Delayed reconstruction with tendon grafts or Silastic rods, if available, should then be considered. When FDP and FPL tendons are injured beyond repair, grafts or transfers should be done. Available donor tendons are either palmaris, FDS tendons that have been cut, plantaris or toe extensor tendons. Do not repair the badly crushed FDS tendons. These can be used for grafts or transfers.

Nerve Evaluation

Neurapraxia: The integrity of the axon is preserved, but there is disruption of conduction (both electrical and chemical) due to derangement of axonal transport and selective demyelination. The supportive structures (endoneurium, perineurium, and epineurium) are all intact. Patients can expect a full recovery, without surgical intervention, in a matter of days to weeks.

Axonotmesis: The integrity of the axon is interrupted (usually by section or shear). The intact endoneurium provides a guide for axonal regeneration. Wallerian degeneration does take place, with nerve regeneration along the endoneurial tubules taking place at ~1mm/day. No surgery is indicated, and patients should expect a variable recovery.

Neurotmesis: The integrity of the supporting structures is disrupted, ranging from disruption of the endoneurium preventing axonal regrowth to complete transection of the nerve. These all need repair.

Treatment: Lacerated nerve ends should be debrided under magnification to healthy-appearing fascicles. To compromise resection to preserve length will only result in poor or no functional recovery. Nerves need to be cut back to healthy fascicles. No more than 1-2 cm mobilization of the proximal and distal ends of the nerves should be done as it will cause devascularization of the nerve ends. To avoid repair under tension, nerve grafting should be done—donor nerves are the sural, superficial peroneal, or lateral ante-brachial cutaneous nerves.

Skin and Soft Tissue Reconstruction

Soft tissue coverage is of primary importance for the coverage of bone, joint, tendons, neurovascular structures, and metal fixators.

Most areas of skin loss can be managed with a split skin graft. Where bone, joints, tendons, nerves, major vessels, and metal fixators are exposed, there a need to consider local or distant flaps. The need for extensive coverage, reliable vascularity of the flap, and early mobilization usually necessitates the use of axial flaps. Fasciocutaneous flaps are recommended when tendons are exposed as they facilitate tendon gliding. The most commonly used flaps are the radial forearm flap, groin flap, and superficial epigastric artery flap. The thoraco-epigastric and 'kangaroo' flaps are other excellent flaps that may be used for extensive defects. (See Chapter 27 on Flaps for Wound Coverage.)

Post-Operative Management

Whenever possible, the extremity is splinted in the position of protection or safe position: wrist 20° dorsiflexion, MP joints 80-90° flexion and the PIP and DIP joints in extension. This is done by applying a dorsal or volar Plaster of Paris slab/splint. Elevation is vital to reduce edema, help control pain, and to regain early motion.

Early rehabilitation of the extremity is important, and the patient will need constant motivation and be repeatedly reminded that early motion reduces edema, adhesions, and scarring. This will need to be done by the surgeon if there is not a competent therapist available. (See Chapter 33 on Tendon and Nerve Injuries.)

Reconstruction of Specific Areas

Fingertips

Isolated fingertip injuries are extremely common. **Four anatomical structures of the fingertip** need consideration: the skin, the pulp, the bone, and the nail with its nail bed.

The fingertip can get damaged in varying degrees. Methods of reconstruction include possible direct repair, free skin graft, skin flap, or proximal amputation. The method of reconstruction depends on the extent of the damage to each of these four components.

- **Skin and pulp Loss**: When only skin and very little pulp is lost, one may allow the wound to heal secondarily. Full thickness skin grafts are used for larger wounds if the bone is not exposed. If bone at the tip is exposed, then small V-Y flaps as the Atasoy or Kutler flaps may be used. (See below). If a distal tip is amputated, it can be cleaned, replaced and loosely sutured. Even without complete survival, the replaced tip serves as a biologic dressing.

- The majority of injuries which lie **between these extremes** have varying degrees of loss of the pulp, skin, bone, and nailbed.

- The **partially avulsed fingertip** injury attached by a pedicle of the pulp. With a cutting type of injury, the nail may be cut transversely and the distal remaining part partially attached. It is surprising how small the pedicle may be and still have survival of the avulsed flap. A decision as to viability should only be made after the flap has been replaced in its correct position to eliminate the adverse effect of torsion and angulation on the blood supply of the flap. In most cases, the partially avulsed part should be loosely sutured back in place and the nail retained and replaced in its bed to provide a splint and to ensure a smooth nail bed. When the nail bed has been transected, care should be taken to get the edges accurately apposed with small absorbable sutures.

- **When there is an associated fracture**: If a simple fracture, a K-wire or hypodermic needle, 18 to 21 gauge, can be used to stabilize the fracture and the DIP joint. A severe comminuted fracture with skin loss may require an amputation.

The ideal fingertip reconstruction should maintain digital length, preserve nail function, provide adequate soft-tissue padding, and most importantly, give near-normal sensation without pain.

Treatment of Specific Fingertip Areas

Nailbed Injuries

Lacerations to the nailbed should be meticulously repaired if possible with loupe magnification—to prevent subsequent nail deformity. The nail is removed under digital tourniquet control with a hemostat, scissors, or a small periosteal elevator, and the matrix accurately approximated with small absorbable sutures, preferably 6-0 absorbable sutures. The nail or Vaseline® gauze dressing is used to cover the wound. If the nail can be used, it is the preferable 'dressing' and can be sutured in place with one suture laterally on each side. If necessary, these stitches are removed after 10-14 days as the new nail begins to push the replaced one distally. Sterile gauze dressing with a small splint is used to protect the fingertip for 3-4 weeks during healing. A Penrose drain or the long finger of a sterile glove can be used to exsanguinate the finger for an avascular field for this surgery. It is wrapped from the tip to the web space, clamped with a hemostat and the distal end released for exposure and surgery.

Tip Amputations

- **Small tip amputations** that do not expose bone or have limited bone exposure can be treated by cleansing and daily dressing changes. Healing is by secondary intention, usually within 2-4 weeks. This method is best used in small children and adults when morbidity is not a factor. If the patient cannot afford sufficient time out of work it can be treated by a full-thickness skin graft harvested from the ulnar side of the hypothenar eminence.

  (**The editors** prefer to place and leave a small piece of Vaseline® gauze on the tip, and this allows healing by epithelialization.)

- **Larger Areas of Skin and Pulp Loss and when Bone is exposed: V-Y Flaps**

Fig. 6

The Kutler Flap.
(From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery,* used by permission from Lippincott, Williams and Wilkins)

Two types of V-Y advancement flaps using palmar tissue can be used to close fingertip amputations with exposed bone. The **Kutler** reconstruction (Fig. 6) is with bilateral V- shaped flaps cut from the sides of the digit and advanced distally over the tip to preserve length and remaining nailbed. This technique is best used in transverse or volarly directed amputations where minimal volar

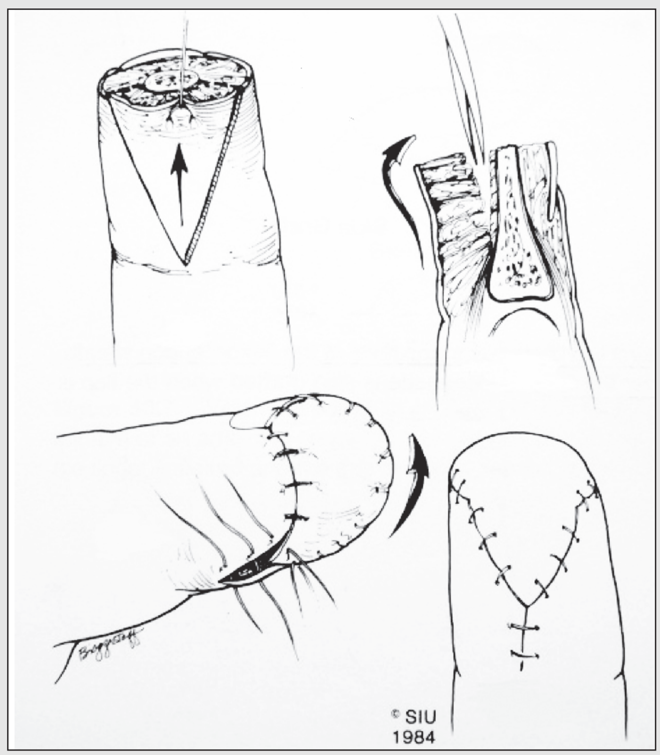

Fig. 7

The Atasoy Flap.
(From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery,* used by permission from Lippincott, Williams and Wilkins)

soft tissue remains. The flaps are cut on either side of the mid-lateral line by incising the skin only. Gentle scissor dissection is used to divide the fibrous septa to the underlying bone. Care must be taken to preserve the branching digital arteries and nerves that transverse the septa into the flaps. The amputated bone is smoothed with a rongeur and the flaps gently pulled with skin hooks over the tip. They are sutured together without tension in the midline, and the donor defect closed in a V to Y fashion.

A similar technique best suited for transverse mid-nail or dorsally directed amputations is the **Atasoy** volar advancement flap (Fig. 7).

Technique: A single V-shaped volar advancement flap is cut at right angles to the skin, again freeing the fibrous septa from the bone and tendon sheath, from distal to proximal, while maintaining the neurovascular branches into the flap. The flap is pulled over the smoothed distal phalanx, and the base sutured to the nailbed without tension, while the donor area closed in a V to Y fashion. If this flap is sutured under tension there is a real danger of a subsequent 'parrot beak' deformity of the nailbed as the distal end of the nailbed is pulled volar. This deformity is difficult to correct.

Both the Kutler and Atasoy finger flaps are good single surgical procedures that provide nearly normal sensation and texture to the fingertip. Sutures are removed after two weeks. Again these small flaps are tedious, and without prior training, these can be difficult to perform.

(**Editor's note**: These are tedious little flaps and most general surgeons in district hospitals will not have the time or expertise to do these unless they have had training to do so. In most cases, the exposed bone will be shortened and a limited amputation carried out. If less than ½ of the nailbed is remaining, then the nail matrix should be completely removed. These flaps are mentioned here for completeness.)

- **Volar Advancement Flap—Moberg**
  Moberg described a large volar flap that is cut along the mid-lateral line bilaterally and advanced at the level of the flexor tendon sheath to the tip. The dissection is **dorsal** to the neurovascular bundles, and these are carried with the flap. The

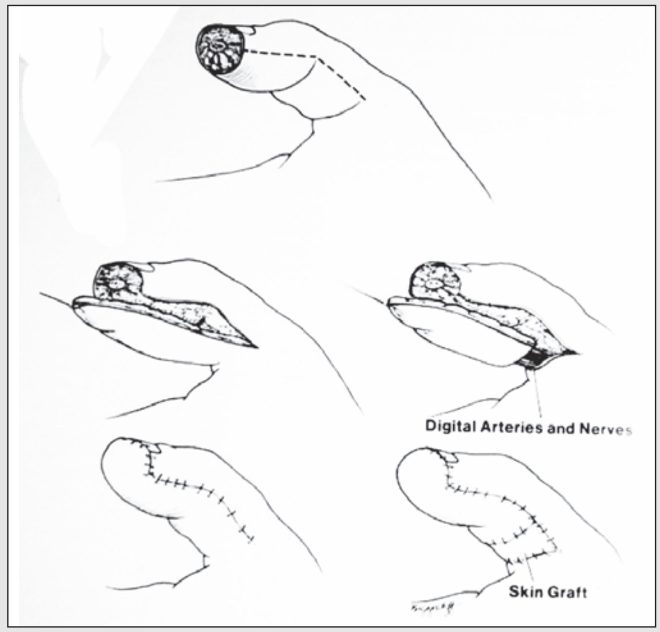

Fig. 8

Volar advancement flap—thumbs only! (From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery,* used by permission from Lippincott, Williams and Wilkins)

Fig. 9

Fig. 10

Volar advancement flap.

dissection is just volar to the flexor tendon sheath. The finger is flexed, and the large volar flap advanced to cover the tip defect. Occasionally, an incision is made in the skin and subcutaneous tissue proximally at the level of the MPJ to allow the flap to be advanced further distally without tension (lower right illustration in Fig. 8. This area at the base of the thumb must be covered with a full-thickness skin graft. This is the flap of choice to cover distal thumb amputations, and **it should ONLY be used for thumb tip amputations**. The thumb has four arteries, two volar and two dorsal. Other fingers only have two volar arteries with branches to the dorsum. A similar flap raised on fingers will likely divide these dorsal branches with possible ischemia to the dorsum of the distal finger. The Moberg flap provides excellent sensory reconstruction for pinch. This is not a difficult flap to elevate if one has loupe magnification. (Please see an orthopaedic or plastic surgery text for a full description of the procedure.)

- **Standard Cross-Finger Flap**
  Cross-finger flaps are used to reconstruct volarly directed tip amputations with exposed distal phalanx and insufficient local tissue for coverage of the exposed bone. If there is soft tissue over the bone, then a FTSG is used. The standard flap is centered over the dorsum of middle phalanx of an adjoining finger and drawn slightly wider than the tip defect. The mid-lateral line is identified at the tip of the interphalangeal joint flexion creases by flexing the proximal and distal interphalangeal joints. This line marks the lateral limit of the flap on the opposite side of the adjoining donor finger. It is elevated by scalpel dissection at the level of the extensor tendon paratenon that must be preserved. The flap is

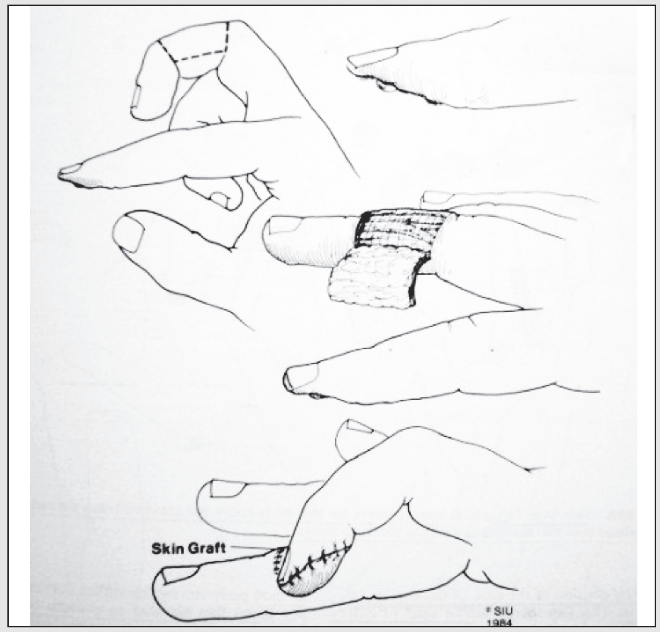

Fig. 11

Cross-finger flap.
(From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery*, used by permission from Lippincott, Williams and Wilkins)

Fig. 12

Fig. 13

Cross-finger flap for exposed flexor tendons of the middle phalanx ring finger. Full thickness skin graft for middle phalanx donor site on the long finger.

Fig. 14

Fig. 15

Fig. 16

Homodigital artery flap. This is a reversed island flap based on one digital artery and surrounding fatty tissue. The blood supply for the flap comes through distal arches from the contralateral digital artery near the DIPJ. Flap can be different sizes based on the area needed to cover. It is used mainly to cover. DIPJ and dorsum of middle and distal phalanges.

opened like a book page, and the injured finger flexed to place the defect on the undersurface of the flap where it is sutured. The donor defect and sometimes a portion of the base of the flap are covered with a thick split or full-thickness graft. The flap is divided at 14 days. Active motion of all fingers is encouraged after division to minimize stiffness.

Flaps Used to Cover Exposed Finger Joints

- **DIPJ**—Homodigital artery flap.
- **PIPJ**—Arterialized side finger flap or reverse FDMA flaps,.
- **MPJ**—Flag flap or First Dorsal Metacarpal artery flap (FDMA) reversed.

Homodigital Artery Flap

This is a **reversed** island flap based on one digital artery. One must do an Allen's Test on the finger to ensure that the contralateral digital artery is patent. The ipsilateral digital nerve is spared. The island is located just distal to the web space, see Fig.14 below. The digital artery is dorsal and surrounding fatty tissue is taken with the pedicle. The fatty tissue will contain small veins for venous drainage. The flap is supplied distally by collateral circulation, distal arch, from the contralateral digital artery. The flap is rotated at the level of the mid-middle phalanx. A FTSG is used to reconstruct the donor defect. This flap may also be used as a cross-finger flap.

Arterialized Side Finger Flaps

When adjacent fingers are injured and unavailable as donor sites for cross- finger flaps, a proximally based arterialized side finger flap from the lateral

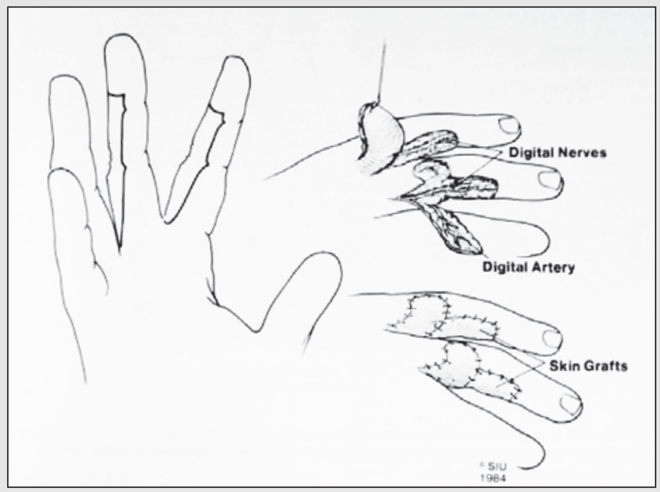

Fig. 17

Arterialized Side Finger Flaps.
(From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery,* used by permission from Lippincott, Williams and Wilkins)

volar surface can be rotated dorsally to cover the exposed proximal interphalangeal joint (PIPJ). The flap includes a single digital artery but leaves the digital nerve intact. The flap is centered volarly over a single digital neurovascular bundle, preferably on the non-dominant side of the finger, and the flap is extended 3-5 mm past the distal interphalangeal joint flexion crease. The volar incision begins along the midline of the digit distally, and is angulated away from the midline toward the entry point of the digital artery into the finger at the metacarpophalangeal joint (MCPJ) flexion crease. Cleland's and Grayson's ligaments are divided along the length of the digit, preserving the digital nerve while elevating the artery with the flap. A pre-operative Allen's test of both digital arteries is necessary, as the inadvertent elevation of a flap including the only viable digital artery may result in loss of the finger. The donor site is darted (short transverse incisions in the crease) at the distal and proximal interphalangeal joint flexion creases to prevent a straight line volar scar. The flap is rotated dorsally to cover the defect and the donor site covered with a thick split or full thickness skin graft secured with a stent dressing. The inclusion of the digital artery creates an axial pattern flap that has excellent vascularity, helping to resolve and prevent infection, and thus preserving joint function. Sensation to the pulp of the finger on the donor side is not impaired. The skin graft becomes re-innervated, and the flap is durable during flexion of the proximal interphalangeal joint.

(**Editor's Note**: This is an excellent flap, but because of the excellent blood supply in the finger, the digital artery is probably **not needed** in most cases. If the

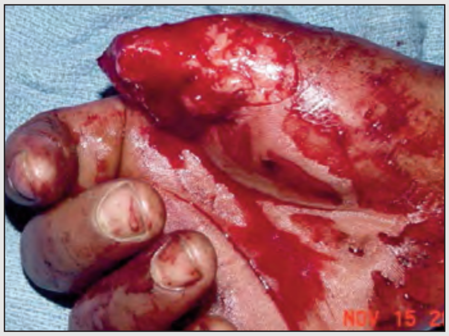

Fig. 18

Fig. 19

Fig. 20

"Kite Flap" or First Dorsal Metacarpal Artery Flap.

Fig. 21

Fig. 22

Fig. 23

Fig. 24

Fig. 25

Fig. 26

Fig. 27

Complication of congenital duplicated thumb surgery. Wound debrided, FDMA flap raised and inset. Note that the fascia of the first dorsal interosseous muscle was taken with the flap—(Fig. 23, blue arrow). Also, a narrow strip of skin was taken with the flap. The flap was not tunneled. FTSG from the wrist used to graft dorsum of the index finger. Two weeks post-op in Fig. 27. The patient may need flexor tendon reconstruction at a later date.

soft tissue and superficial fascia are taken with this flap, the perforating vessels from the digital artery will likely supply the flap. This flap may be used to cover open and exposed PIP joints.)

The First Dorsal Metacarpal Artery Flap (FDMA)—Kite Flap

In patients with extensive thumb tip loss, larger than can be covered by the Moberg flap, the First Dorsal Metacarpal Artery Flap (FDMA) is a good option. This flap will save the maximum length of the thumb and will cover the end of the bone with good quality padding. The flap can be sensate if the digital nerve of the thumb is anastomosed with a dorsal branch of the radial sensory nerve in the index finger. This is rarely done. This flap can reconstruct both dorsal and volar thumb defects, and dorsal and volar areas of tissue loss at the bases of the long and ring fingers.

Technique: This is an island pedicle flap based on the first dorsal metacarpal artery. It is normally taken off the proximal phalanx as shown in Figs. 18-20. The flap is taken down to (not including) the epitenon, and the soft tissue pedicle is as wide as the flap. **It is important to take the fascia of the first dorsal interosseous muscle** with the pedicle in the dorsal hand to preserve the blood supply. The island flap can reach the distal thumb tip. The donor site is best reconstructed with a FTSG.

For another case where this valuable flap was used, see Figs. 21-27.

This flap may also be reversed based on perforators from the volar digital arteries at the web space. A proximal island at the base of the metacarpals may be taken and turned distally to cover the PIPJ area.

Also, this same tissue can also be used as a cross-finger flap for reconstruction of the volar-distal phalanx of the thumb. It is based on the radial digital artery in the index finger. This flap is also taken from the dorsal aspect of the proximal phalanx. The flap is divided on the ulnar side, turned over to the radial side, and the distal phalanx of the thumb defect is placed into the flap and sutured as a cross-finger flap. The radial base of the flap is divided in two weeks.

Flag Flap

Cover of open wounds with exposed tendons over the middle phalanx is described above. For wounds over the proximal phalanx with exposed tendons, a flag flap from the adjacent finger may be used. The shape of the flap is like a "flag." The blood supply comes in through a narrow pedicle, the "pole", in the webspace on the radial or ulnar side. It is supplied by a dorsal metacarpal artery. It can be rotated to cover the adjacent finger and the donor site covered with a FTSG or a thick STSG. It can also be passed through the webspace to cover volar defects on proximal phalanx or the proximal MPJ area on the same or the adjacent finger. The flap is raised just as the Kite Flap above. The entire skin over the dorsum of the proximal phalanx is raised from mid-axial to mid-axial lines and from the level of the webspace to the crease of the PIP joint distally. The paratenon is left, and a FTSG or thick STSG is used to cover the donor site.

Dorsum of the Hand and Wrist

Split skin grafts do well on the dorsum of the hand. Ideally a thick split thickness sheet graft is used (0.015-0.018 inch in thickness), but if there is a lack of donor skin, the skin can be meshed. If the paratenon of the tendons is intact, the tendons can be grafted directly. If the paratenon is not intact and tendon, extensor retinaculum, bone, or joints are exposed, then flap coverage is indicated.

Fig. 28

Fig. 29

Fig. 30

Flag flap (Courtesy Dr. Jimmy Waldrop).

A most reliable flap, large enough to cover the wrist and dorsum of the hand up to the proximal phalanges is the **reverse radial forearm flap**. This flap is also useful to cover volar hand defects. The same flap, if based proximally, can cover most of the forearm and elbow area.

Two alternate flaps of importance in forearm and hand reconstruction are the **dorsoulnar flap (Becker Flap) and the posterior interosseous artery (PIA) flap.**

All three are **fasciocutaneous** flaps and provide options for adequate and durable cover, and all provide a good cosmetic result.

Also, two distant fasciocutaneous flaps will be covered: Superficial inferior epigastric flap and groin flap.

Radial Forearm Flap

Areas of Cover:
- Dorsal wrist and hand (reverse flap).
- Palmar surface of the hand (reverse flap).
- Ante cubital fossa.
- Posterior elbow.

The forearm flap is based on the radial artery and the venae comitantes.

(This flap is also discussed in Chapter 27 on Flaps).

The radial artery is one of the two terminal branches of the brachial artery. Although it is smaller than the ulnar artery, it appears to be the more direct continuation of the brachial artery. It begins at the division of the brachial artery, about 1 cm distal to the skin crease of the elbow, and passes along the radial side of the forearm to the wrist. The pulsation of the artery is palpable in the interval between flexor carpi radialis tendon on the ulnar side and the lower part of the anterior or volar border of the radius on the radial side. It branches, with a large branch passing radially through the anatomical snuffbox, beneath the tendons of the first and third dorsal compartments. Then it passes between the first and second metacarpals and the two origins of the first dorsal interosseous muscle from bases of thumb and index finger metacarpals. It then terminates in the deep arch. In the proximal third of the artery, the brachioradialis is radial and pronator teres is ulnar; in the lower two-thirds, the brachioradialis is radial and the tendon of flexor carpi radialis is ulnar. The hand and fingers derive their blood supply mainly from the superficial arch of the ulnar artery and, to some extent, from the deep palmar arch.

The radial artery supplies the flap through numerous branches that pass directly upward in the reflections of the deep fascia in the inter-muscular spaces, between the brachioradialis muscle and flexor carpi radialis. Accordingly, the fascia of these two muscles must be included in the flap and dissection extended down below the radial artery. The diameter of the

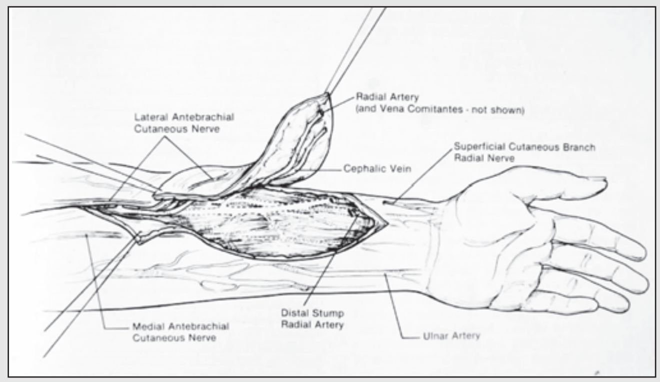

Fig. 31

Surgical Anatomy of the Radial Forearm Flap (From *Essentials of Plastic, Maxillofacial and Reconstructive Surgery,* used by permission from Lippincott, Williams and Wilkins)

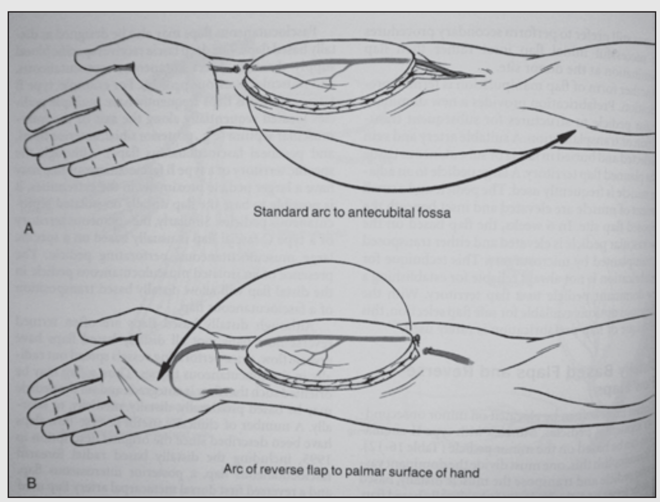

Fig. 32

The Radial Forearm Flap. A) Proximally based and proximal arc of rotation.
B) Distally based and distal arc of rotation (From *Mathes Plastic Surgery,* used by permission from Elsevier)

artery at the origin is approximately 2.5 mm, and at the wrist is 2 mm. The radial artery supplies all the skin of the flexor aspect of the forearm and a large area of the radio-dorsal aspect.

Operative Technique of Radial Forearm Flap

An **Allen's test** should be done to ensure adequate distal (ulna to radial) arterial communication to sustain the blood supply to the radial side of the hand when the radial artery is sacrificed. The examiner occludes the radial and ulnar arteries at the patient's wrist. The patient then clenches his hand one or more times to squeeze the blood out of the hand. After a few seconds, the patient extends his fingers, and the blanched color of the hand and fingers is noted. The pressure on radial and ulnar arteries is then sequentially released. If the respective arterial tree and arch is intact, a rapid return of color of the palm and fingers is noted. If there is a deficiency in the radial or ulnar artery supply, pallor is maintained for a long period after releasing this vessel. (If the patient is unable to follow directions, a BP cuff may be used. The hand is elevated and the hand and forearm exsanguinated with an Esmark. BP cuff is inflated. The radial artery is occluded with finger pressure; the BP cuff released, and one observes if there is arterial flow to the radial side of the hand through the ulnar artery. A Doppler is ideal to document flow when using this flap.) The required shape and size of the flap are mapped on the flexor surface of the forearm. The flap can be designed on any part of the volar forearm skin.

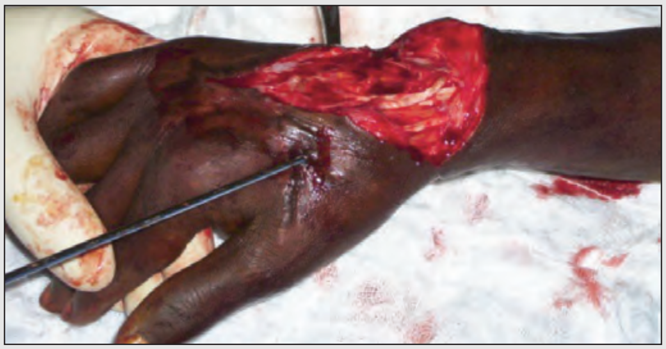

Fig. 33

Fig. 34

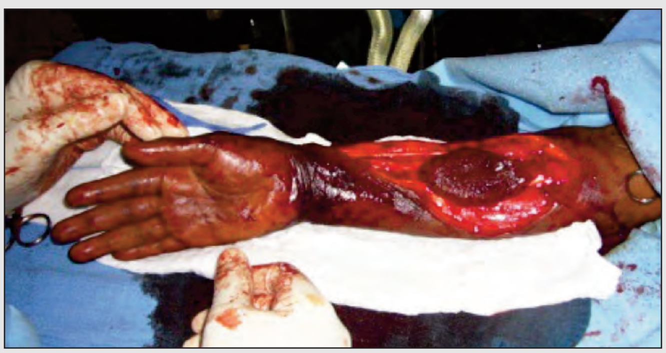

Fig. 35

Fig. 36

Fig. 37

Fig. 38

Reverse Radial Forearm Flap raised, transferred, and inset. Donor area grafted.

Surgical Technique

A pneumatic tourniquet is used. The flap is raised from each side, along with the deep muscle fascia from the flexor carpi radialis and brachioradialis. The dissection is carried deep to this fascia down until the radial artery is identified. The flap is then further raised by following the course of the radial artery from proximal (or distal) with care being taken to include the deep fascia of the forearm in the flap. This forearm flap, a fasciocutaneous flap, receives its blood supply from the radial artery that lies deep to the fascia and gives off numerous branches that perforate the fascia and form a subdermal plexus. The venae comitantes carry the venous outflow from this flap territory. The flap may be raised up to the level of the elbow joint, identifying the bifurcation of the brachial artery. Once the entire flap is raised, the tourniquet is released, and the viability of the flap is assessed. One should clamp the artery at either end to ensure flap viability and hand vascularity prior to dividing the artery. The flap is then transferred and sutured into the defect. The donor site of the forearm can be closed directly (if a narrow flap) or covered with a split-thickness skin graft. Unfortunately, the donor site is not well hidden.

(**Editor's note**: Chapter 29 on Perforator Flaps describes elevation of the same flap based on radial artery perforators without the need to sacrifice the radial artery.)

Dorso-Ulnar Flap (Becker Flap)

(Becker C, Gilbert A. *Eur J Plast Surg* 1988; 11:79-82.)

Areas of Cover:

- Dorsal Wrist and Hand (reverse flap).
- Palmar Surface Of The Hand (reverse flap).
- First Web Space.

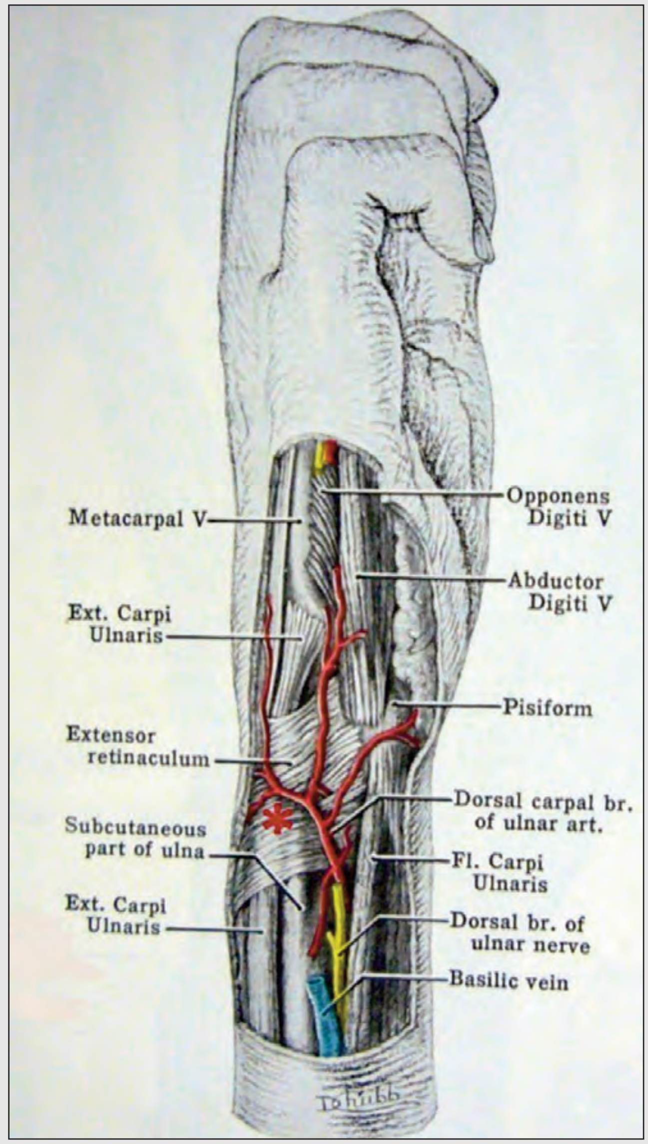

Fig. 39

The Dorsal Ulnar Artery.
(From *Grant's Atlas of Anatomy*, used by permission from Lippincott, Williams and Wilkins)

Fig. 40

Fig. 41

Doppler Localization (Fig. 40) and Outline (Fig. 41) of the Dorso-Ulnar Artery Flap

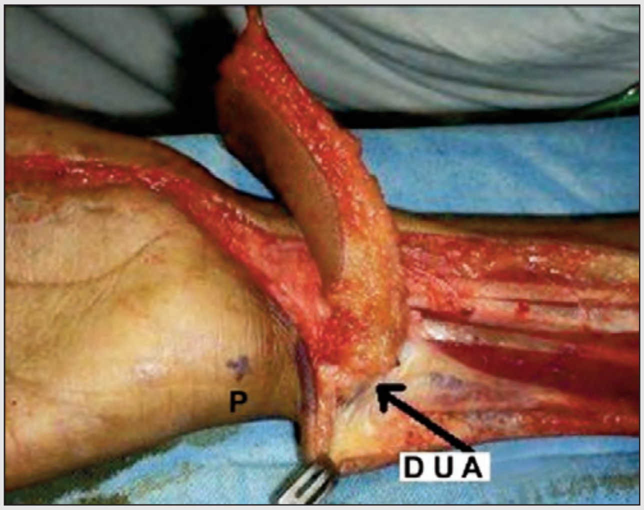

Fig. 42

Dorsal-Ulnar Flap (Becker Flap) elevated. (Figs. 40-42: From Clinical Study of Dorsal Ulnar Artery Flap in Hand Reconstruction, Department of Plastic Surgery, Aligarh Muslim University, J. N. Medical College, AMU, Aligarh, UP - 202 002, India)

The dorsal ulnar artery fasciocutaneous flap, first described by Becker and Gilbert in 1988, is perfused by the ascending branch of the dorsal ulnar artery, one of the major branches of the ulnar artery in the distal forearm. The flap described here is a retrograde perforator flap. The importance of this flap lies in the possibility of mobilization of tissue for reconstruction of the hand without losing a major vascular axis. The dorsal ulnar artery fasciocutaneous flap can be raised as an island flap. The disadvantages of the dorsal ulnar artery flap are the retrograde venous drainage

and the relatively small defects that can be covered. The maximum size of the dorsal ulnar artery flap should be only 10 by 5 cm. The flap is useful for coverage of smaller defects over the volar or dorsal aspect of the wrist and palmar surface of the hand.

Operative Technique

Dorsal ulnar artery was localized with the help of Doppler examination (Fig. 40). Operation can be done under general anesthesia or axillary block with tourniquet control and loupe magnification. The flap is designed according to the defect that requires cover (Fig. 41).

The anterior limit of the flap could safely be placed up to the palmaris longus tendon, and posteriorly the flap may be extended to the extensor digitorum communis tendon of the fourth finger, giving a width of 5 to 9 cm. The longer length of the flap allows for cover of the defects of the wrist, palm, radial border of the hand, and the first web space. The length of the flap is determined by the major axis of the tissue loss, but can extend up to 20 cm. The flap is raised as an island flap. The dissection started from the ulnar side of the wrist and forearm from proximal to distal including the deep fascia. The pedicle is exposed by retracting the flexor carpi ulnaris radially. The pedicle emerges from the ulnar artery 2 to 5 cm proximal to the pisiform. Care must be taken to preserve the dorsal branch of the ulnar nerve. The dorsal ulnar artery is dissected to its origin from the ulnar artery that permits 180° rotation of the flap (Fig. 39, 42). The space between the defect and the pedicle of the flap is incised, and a sulcus created by excision of subcutaneous tissue. The tourniquet is released; hemostasis achieved, and the flap transferred to the defect. The subcutaneous pedicle of the flap is skin grafted to avoid tension. The donor site is closed primarily, if possible, after undermining the edges of the defect—this is usually possible if the defect is less than 4 cm wide. Larger donor defects require skin grafting. A non-adherent dressing is applied, and the hand is immobilized in neutral position for about a week. Active and passive physiotherapy is continued for three months.

The dorsal ulnar artery flap is a very good local option that is available for the soft tissue coverage of defects of hand without sacrificing any major vascular axis of the hand. The dorsal ulnar artery island flap is convenient, reliable, and easy to manage, and is a single-stage technique for reconstructing soft tissue defects of the palm, dorsum of the hand, and first web space. Early use of this flap for reconstruction allows the preservation of vital structures, decreases morbidity, and allows for early rehabilitation.

Posterior Interosseous Artery (PIA) Flap

(**Editor's Note**: Though this is a possible flap for wrist and hand coverage, it is a difficult flap to elevate, with inconsistent reliability. It also requires loupe magnification that is not always available. Therefore, this flap is not recommended for the general surgeon in the district hospital, unless they have been trained to use it during their training. The other flaps described are more reliable and easier to elevate. A good recent description of the flap can be found in March 2012 issue of the *American Journal of Hand Surgery*. This article describes a safer method for raising the flap with a wide pedicle, and in-setting the flap without tunneling the flap to the recipient site.)


Fig. 43


Fig. 44

Defect in palm. Artery marked with doppler location and flap design.

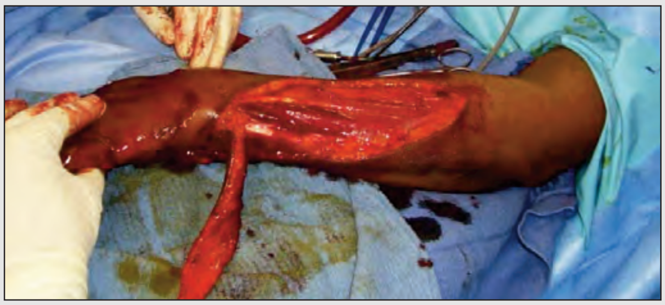
Fig. 45

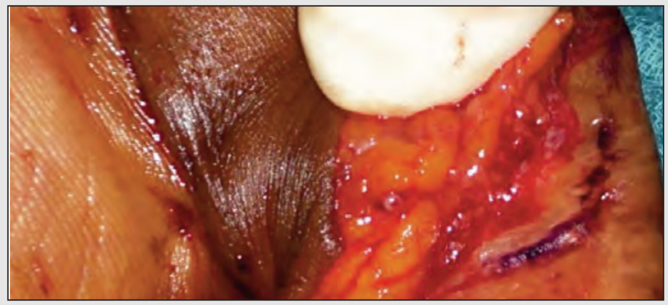
Fig. 46

Flap raised on dorsal ulnar artery, which is visible distally or at proximal end of flap.


Fig. 47

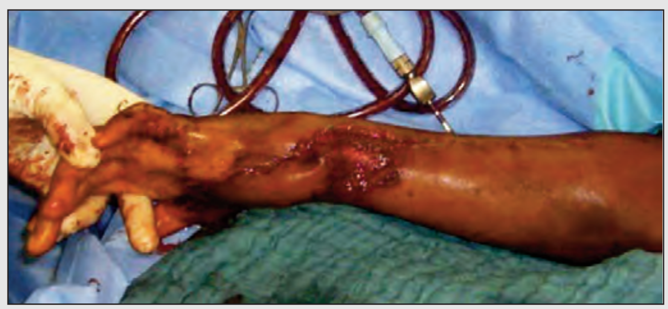
Fig. 48

Flap sutured in position on the palm. Direct closure of donor area except for the distal 4 cm covered with a split skin graft.


Fig. 49


Fig. 50

Posterior Interosseous Artery Flap.

Superficial Inferior Epigastric Flap

This flap is discussed in both Chapter 12 on Burn Reconstruction and Chapter 27 on Flaps. This is an **excellent flap** and easy to elevate. It does require two stages, the second being to divide the flap.

Groin Flap

This flap is also discussed in both Chapter 12 and Chapter 27. This flap may be thick, and some just take the fascia and some subcutaneous tissue and skin graft it. This flap will likely need defatting.

Conclusion

Soft tissue defects of hands require early coverage so that physiotherapy can be commenced as early as possible. Coverage is necessary to replace missing skin and to protect exposed structures. Various flaps have been described. The reverse radial island flap has the disadvantage of sacrificing a major vascular axis. Distant flaps require 2-3 weeks of immobilization and are very uncomfortable. Some are bulky, as the groin flap, and require thinning or defatting by yet another one or more procedures. Free flaps require microsurgical skills and can be lengthy and tedious procedures.

Chapter 31
Anterior Chest Wall Reconstruction

Russell E. White

Introduction

The reconstruction of anterior chest wall defects has evolved over recent decades, owing largely to the development of cardiothoracic surgery, the improved understanding of vascular anatomy, and the significantly increased use of muscle flaps and myocutaneous flaps for reconstruction. Sternal wounds, previously left to heal through secondary intention or skin grafts after repeated dressing changes, now often receive early treatment with combinations of muscle flaps and myocutaneous flaps. This section will look at the options available for reconstruction of anterior chest wall defects and the special considerations in this area.

Indications for Reconstruction

In general, indications for chest wall reconstruction fall under one of the four categories listed in Table 1. In most western practice, infection is one of the most common indications, given the large volume of cardiac surgery undertaken and the dreaded complications of sternal infection or dehiscence after sternotomy. With improvements in surgical technique and more common use of minimally invasive techniques, this is becoming less common—thankfully occurring generally in less than 1% of cases. It should be remembered, however, that use of a single internal mammary artery for bypass procedures increases this risk 2-4 times, and using bilateral internal mammary arteries increases risk 4-8 times. Radiation induced chest wall damage has become less common with improvements in radiation therapy techniques. In African practice, where sternotomy is not a common incision and radiation therapy is not widely available, reconstruction for defects following tumor excision and defects following trauma are the most common indications.

Table 1

1	Infection
	- Most commonly sternal dehiscence or infection following sternotomy
	- Occasionally from necrotizing fasciitis due to Ludwig's angina
2	Radiation Damage
3	Defects following tumor resection
4	Trauma

Indications for Anterior Chest Wall Reconstruction

Chest Wall Skeletal Reconstruction

In managing reconstruction of the anterior chest wall, one must decide whether or not to include reconstruction of the bony chest wall skeleton. In general, the factors to consider include the mechanics of breathing, cosmetic issues, and protection of vital organs. With these factors in mind, the decision to provide skeletal wall reconstruction generally is made by answering the following questions.

1 **What is the anticipated size of the defect?** While two complete ribs can be safely resected and the thoracic defect closed primarily, many authors would argue that if more than three ribs are resected, then skeletal reconstruction should be considered. Other authors have considered more specifically the actual size of the defect, arguing that defects larger than 5 cm in diameter should be considered for reconstruction.

2 **What is the location of the anticipated defect?** Defects in the posterior chest wall less commonly require skeletal reconstruction, due to the overlying muscle bodies and the scapula. Defects in the lateral wall of the chest may produce visible defects which are cosmetically unacceptable to the patient. This is particularly true of defects in the lower chest, whereas lateral defects higher in the chest are often covered by the axilla and upper arm. If cosmesis is of significant importance in these lateral defects, one may wish to consider using more rigid, shape-holding fixation, such as polymethylmethacrylate (see below).

3 **What is the condition of the chest wall?** If infection is present, such as for sternal infection

Table 2

1	Polypropylene mesh (e.g. Marlex® mesh and Prolene® mesh)
2	Polytetrafluoroethylene (PTFE)
3	Composite patches (generally combination of polypropylene and PTFE on opposite sides of the same patch)
4	Polymethylmethacrylate (PMMA, commonly referred to as "bone cement")
5	Bioprosthetic mesh (human or xenogeneic dermal matrices)

Exogenous materials used for Chest Wall Reconstruction

Fig. 1

Flaps available for anterior chest wall defects. A) Turnover pectoralis major flap; B) advancement pectoralis major flap; C) greater omentum flap; D) rectus abdominus flap. (Drawing courtesy of Vera Steury)

or dehiscence following sternotomy, then the use of prosthetic materials in skeletal reconstruction is contraindicated (with the possible exception of bioprosthetic mesh—see below). In these cases, muscle flaps or myocutaneous flaps alone are used for coverage, and in general, the mechanics of breathing can be preserved. If the chest wall has been irradiated, some authors would argue that this produces significant chest wall stiffness, and so may obviate the need for skeletal reconstruction.

Materials available for skeletal chest wall reconstruction essentially include those listed in Table 2. Polypropylene mesh is generally the cheapest and most readily available material. It is used as either a single or double layer and is sutured with either interrupted or continuous permanent suture to the undersurface of the circumference of the bony defect. As with all meshes and patches, it should be sutured under moderate tension to achieve a semi-rigid fixation of the chest wall. Polypropylene mesh allows for tissue ingrowth, but also has the potential disadvantage of more adhesions to underlying tissues. PTFE patches promote negligible tissue ingrowth, but are often significantly more expensive. PMMA is often used as a "sandwich" between two layers of polypropylene mesh. This creates a rigid prosthesis that can provide variable shapes for structural reconstruction. The use of PMMA is frequently associated with seroma formation. Bioprosthetic mesh of

Table 3

Structure	Max. Size	Arterial Supply
Pectoralis Major	15 x 23 cm	Pectoral branch of thoracoacromial artery (advancement flap); Perforating branches of internal mammary artery (Turnover/reverse flap)
Latissimus Dorsi	25 x 35 cm	Thoracodorsal artery
Rectus abdominus	25 x 6 cm	Superior epigastric artery
Greater Omentum	40 x 60 cm	Right or left gastroepiploic arteries

Flaps available for anterior chest wall defects.

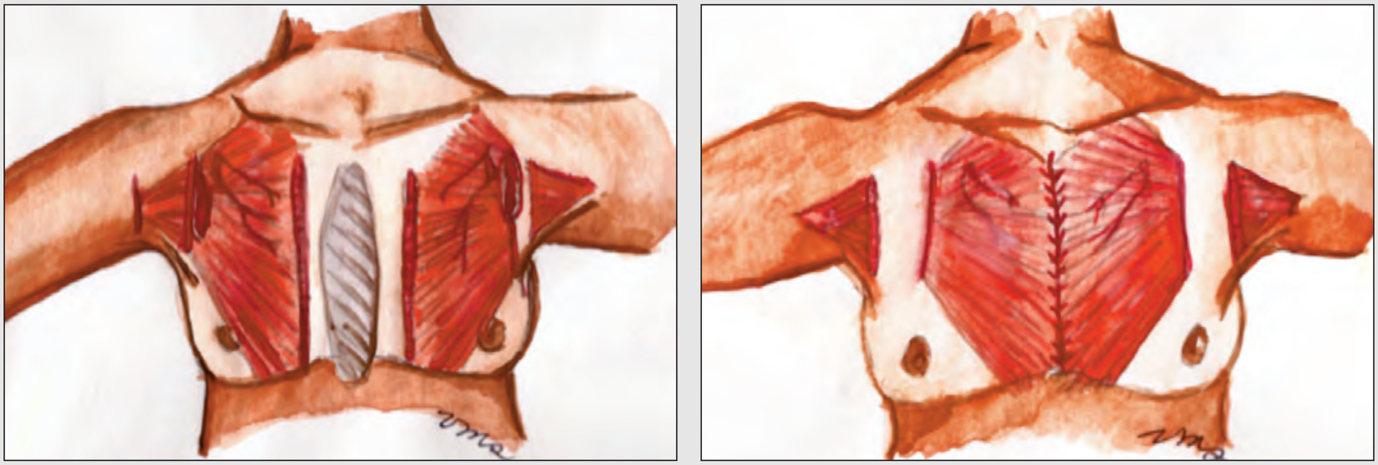

Fig. 2

Bilateral pectoralis major advancement flap based on the thoracoacromial artery can be used to cover a sternal defect. (Drawings courtesy of Vera Steury)

large enough size to cover chest wall defects is generally the most expensive option. However, it offers the possibility of use in infected sites after appropriate debridement and dressing changes. Long term data on the durability of this approach is lacking at this time.

Flaps for Anterior Chest Wall Reconstruction

The possibilities for flap coverage of the anterior chest wall are shown in Table 3 and Fig. 1. In general, free flaps are not required for anterior chest wall reconstruction, as a variety of pedicled flaps will provide adequate coverage.

1) The Pectoralis Muscle

The pectoralis major muscle provides excellent coverage of the sternum, and can be used either as:

- Advancement flap (Fig. 2 A-B), based on the pectoral branch of the thoracoacromial artery, or
- Turnover/reverse flap (Fig. 3 A-B), based on the perforating branches of the internal mammary artery.

In either case, it is generally divided near its insertion on the bicipital groove of the humerus (i.e. lateral to the thoracoacromial pedicle) to allow for mobility. The turnover flap reconstruction may provide greater coverage for the lower sternum, which is often difficult to cover with the advancement technique.

2) Lattissimus Dorsi Flap

The lattisimus dorsi can be used either as a pedicled muscle flap or as a myocutaneous flap. It is a hardy flap and can be used to cover a large area when based on the thoracodorsal artery. The latissimus dorsi flap is covered in much greater detail in Chapter 32.

3) Rectus Abdominis

The rectus abdominus can also be utilized as a pedicled muscle flap or as a myocutaneous flap for anterior chest wall reconstruction. Its utility for breast reconstruction is well recognized, but it can

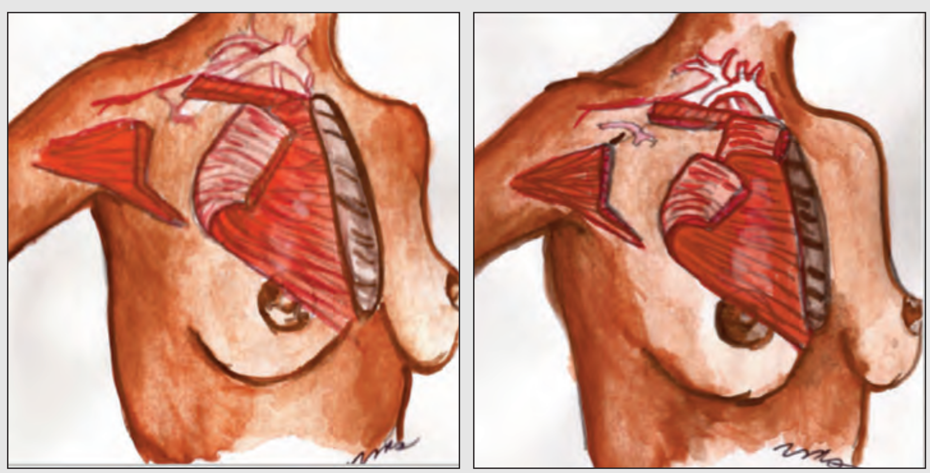

Fig. 3

Reverse (turnover) pectoralis major flap based on internal mammary perforators (3A). The flap can split in the direction of muscle fibers (3B).
(Drawings courtesy of Vera Steury)

also be utilized for chest wall reconstruction. If the rectus abdominus is used for sternal reconstruction, one must be certain of the patency of the internal mammary vessels which supply the superior epigastric vessels.

4) The Greater Omentum

The greater omentum is a well-vascularized structure which can be used for coverage of defects of the anterior chest wall. It is approached through an upper midline laparotomy and can be based on either the right or left gastroepiploic artery, depending on the location of the chest wall defect (Fig. 4 A-B). The omentum can be used to cover large defects, and can generally reach any area of the anterior chest wall. It is usually tunneled over the costal margin to the site of the chest wall defect, but can also be passed through a diaphragmatic window to reach the mediastinum. Prior to closure of the abdomen, some authors advocate the suturing of the greater curvature of the stomach to the transverse colon to reduce the risk of gastric volvulus or internal hernia in the region of the lesser sac.

Fig. 4

Greater omental flap with dual blood supply from right and left gastroepiploic arteries. Flap mobilized based on right gastroepiploic artery. (Drawings courtesy of Vera Steury)

Fig. 5

AP and lateral view of large sternal tumor.

Clinical Case

- The following case illustrates the use of three of the flaps discussed: Pectoralis major advancement flap, latissimus dorsi myocutaneous flap, and a greater omentum flap. The patient was a 45 year old male who presented with a large anterior chest wall mass which had been growing for approximately one year. Physical examination revealed a generally fit man with a 15 cm x 14 cm mass extending approximately 9 cm anterior to the level of the sternum (Figs. 5 A-B).

- The lesion appeared to emanate from the sternum with a slight preponderance to the right side of the chest. The remainder of the physical examination was normal. Chest radiograph revealed a lesion that was destructive of the bony

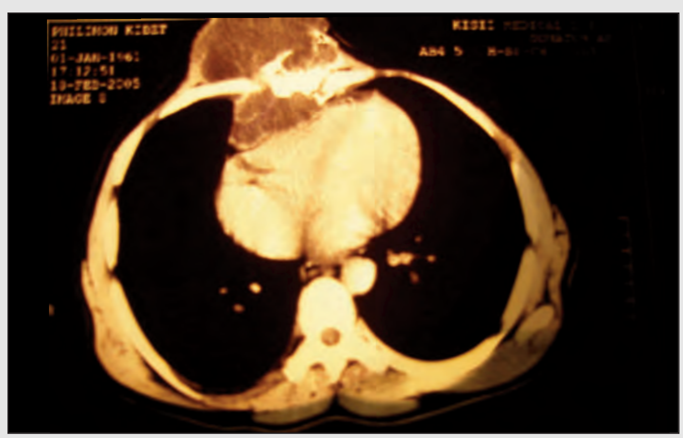

Fig. 6

CT scan showing destructive lesion of sternum with preserved fat plane adjacent to pericardium.

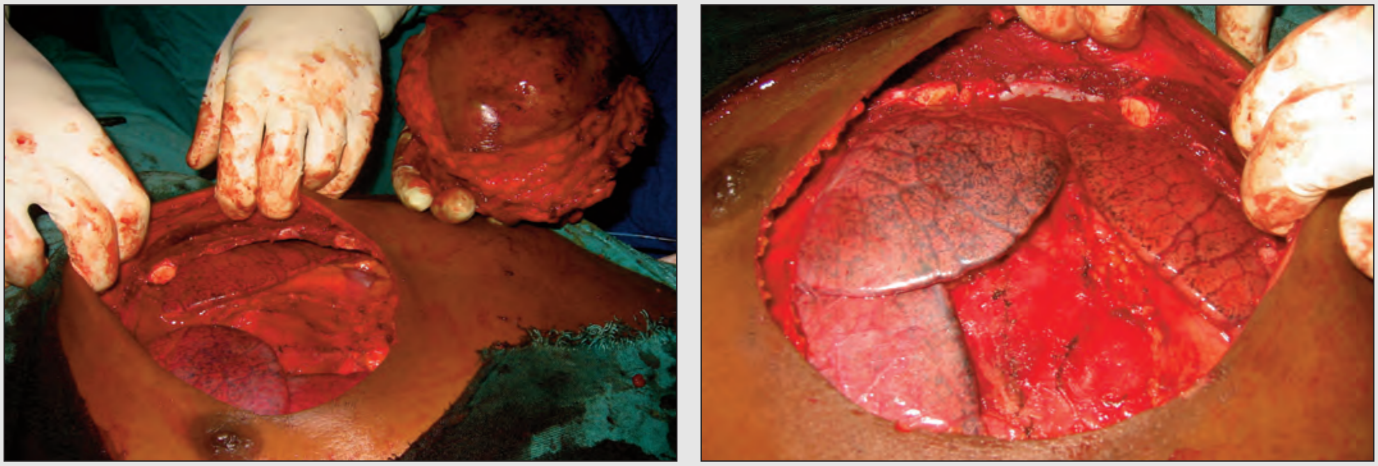

Fig. 7

Chest wall defect after tumor resection. The manubrium and transected third ribs can be seen superiorly; the pericardium and bilateral lungs are visible inferiorly.

sternum, but the lung fields were clear. A CT scan of the chest was obtained (Fig. 6).

- The CT revealed extensive destruction of the sternum by a soft tissue tumor, with an intrathoracic extension of the tumor, but without evidence of invasion of any mediastinal or thoracic structures. Incisional biopsy revealed a moderate grade osteosarcoma of the sternum. The patient underwent en-bloc resection of the chest wall lesion, involving resection of the sternum, but sparing the manubrium. The resection also included the cartilaginous portions of six ribs bilaterally with both pleural cavities widely entered. The pericardium was spared as there was no pericardial invasion. This resection resulted in a large defect of the anterior chest wall (fig. 7 A-B).

- The initial plan was to use bilateral pectoralis major advancement flaps to cover the defect after chest wall skeletal reconstruction. The pectoralis major advancement flap can reach the entire anterior chest wall, except the lower portion of the sternum. However, in this case, partial resection of both pectoralis major muscles had been a part of the tumor resection, with more of the right pectoralis major resected than the left. After lateral division of the left pectoralis major insertion on

Fig. 8

The left pectoral advancement flap is quite small (arrow). The omental flap has been harvested via laparotomy. One half of the omental flap has been inset deep to the double layer Marlex® mesh skeletal reconstruction.

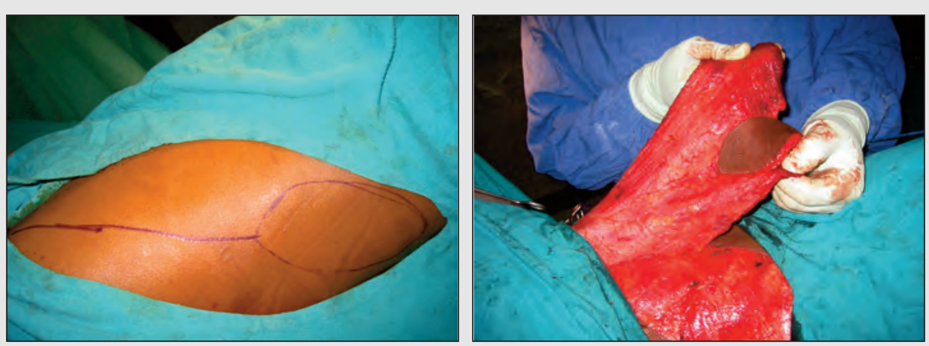

Fig. 9

Planning for right LD myocutaneous flap (9A).
LD myocutaneous flap, with distal skin paddle visible (9B).

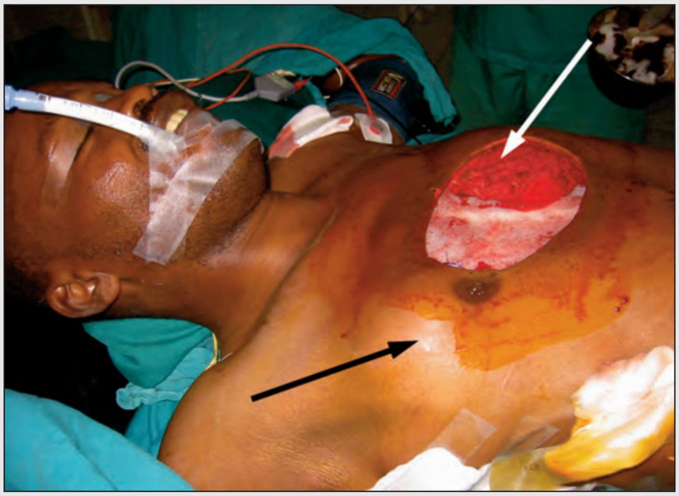

Fig. 10

LD donor site has been closed and patient turned back to supine position. Bulge from LD flap can be seen under the skin in the right pectoral region (black arrow). The anterior omental flap is visible in the left side of the wound (white arrow).

the humerus and mobilization of the muscle on the thoracoacromial pedicle, it became clear that there would be insufficient muscle coverage even after bilateral pectoral advancements (Fig. 8). Therefore plans were made to harvest the right latissimus dorsi as a myocutaneous flap, and the greater omentum as a split pedicled flap to provide additional coverage to the inferior left part of the wound, as well as deep to the anticipated skeletal reconstruction. Bilateral chest tubes were placed and the wound was temporarily covered with a moist, occlusive dressing.

- The patient was repositioned in the left lateral position and measurements made for harvesting the right latissimus dorsi as a myocutaneous flap. The flap was raised on the thoracodorsal pedicle and placed into a subcutaneous tunnel over the remainder of the right pectoralis major muscle (Figs. 9 A-B). The donor site defect was closed primarily over closed suction drains.

- The patient was turned back

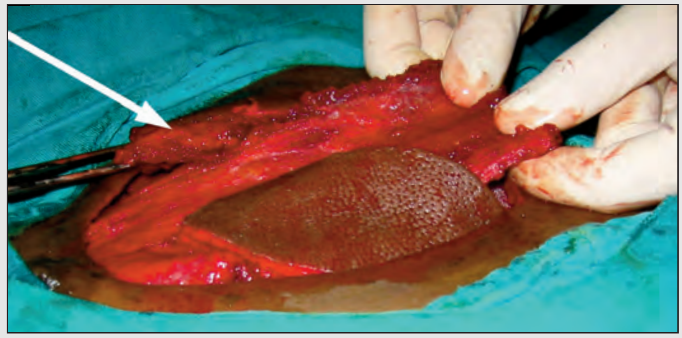

Fig. 11

Right LD flap is inset in the wound. The left pectoral flap (arrow) is drawn from left to right and interdigitated with the LD flap.

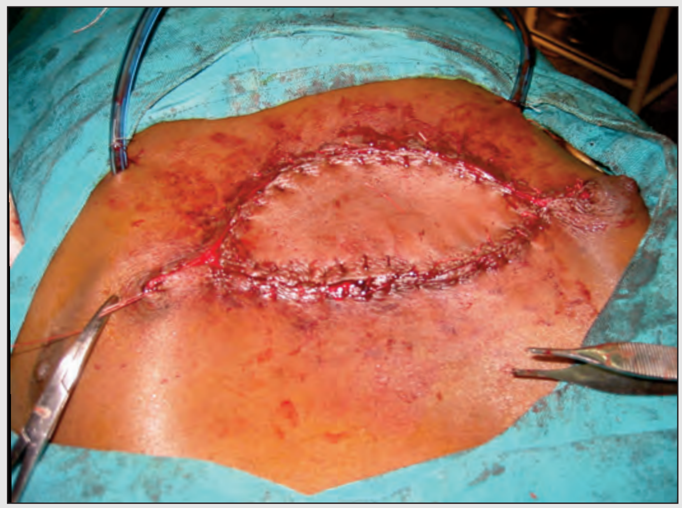

Fig. 12

Final closure with LD myocutaneous flap in place over closed suction drains (view from head of patient).

Fig. 13

Postoperative result at 2 weeks (13A), and 4 weeks (13B).

to the supine position, and a small upper midline laparotomy performed to harvest the greater omentum based on the left gastroepiploic artery. The omental flap was split into two tongues of tissue. This allowed one portion to be placed directly over the pericardium and lungs to reduce adhesions between the polypropylene mesh and the mediastinal/thoracic structures. The remainder of the omentum was used, along with the left pectoralis major muscle, to fill the left side of the defect. The skeletal defect was repaired with a double layer of polypropylene mesh fixed with interrupted nonabsorbable suture around the circumference of the chest wall defect (Fig. 10).

- The previously harvested latissimus dorsi myocutaneous flap was brought into the wound and overlapped with the left pectoralis major flap superiorly and the greater omental flap inferiorly (Fig. 11).

The wound was closed over bilateral closed suction drains (Fig. 12). The final results are shown in Fig. 13.

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10 Thanks also to Vera Steury for her excellent drawings used to illustrate the concepts in this chapter.

Chapter 32
Latissimus Dorsi Myocutaneous Flap in Chest Wall and other Reconstructions

Peter Bird and Peter M. Nthumba

Introduction

The latissimus dorsi pedicled myocutaneous flap (LDMF) was first described by Ignio Tansini in 1897 to reconstruct the anterior chest wall after radical breast cancer surgery. Its use since then has been extensively reviewed by others, and the reader can refer to these articles for a historical narrative (see references).

This chapter discusses the indications for the LDMF and the surgical technique to raise it. In the authors' experience, the LDMF serves as an extremely useful autologous tissue coverage and breast reconstructive tool for multiple pathologies—including breast, chest wall, and shoulder girdle malignancies, and head and neck pathology—especially when adjuvant therapies are unavailable. The LDMF has also been used for the reconstruction of elbow flexion and deltoid function, shoulder and olecranon coverage, and arm coverage (as a chimeric flap with the scapular in the reconstruction of the humerus). It can also be used for the reconstruction of the neck, face and oral cavity. The LDMF is a very hardy and, therefore, attractive flap because it has a high success rate and leaves minimal donor morbidity.

The LD is the largest flat muscle in the body, extending from the angle of the scapula to the posterior iliac crest and from the midline posteriorly to the posterior axillary line. Its shape and reliable blood supply entering superiorly—the thoracodorsal vessels—make it ideal for rotating the LDMF around a pivot point in the axilla. If the main thoracodorsal trunk is divided—either deliberately if it is encased by tumor or accidently—an alternative vascular supply to the LD exists from a large branch that usually supplies serratus anterior, but in this case with reverse flow. Also, the LD can be rotated to cover the spine based on perforators from the intercostals at the origin of the muscle. Any amount of skin overlying the muscle can be used, as perforating vessels from the muscle supply this skin very reliably.

The pectoralis muscles in the anterior axillary fold serve as adequate abductors of the shoulder in the absence of the LD. The donor site can almost always be closed primarily with a resulting longitudinal scar that, with careful planning in a female breast reconstruction, can be hidden by the posterior bra strap.

With its simplicity, versatility, and reliability, the surgeon working in a resource-poor setting will find the LDMF to be a very handy addition to their armamentarium.

Table 1

Indication	No. of Cases	Pathology	Complications
Coverage of anterior chest wall defect	45	Breast malignancy, soft tissue sarcoma	3 minor flap-skin dehiscences due to tight closure
Coverage of posterior chest wall defect	1	Recurrent soft tissue sarcoma	None
Neck contracture	1	Burn	None
Immediate breast reconstruction	1	Breast Cancer	Implant Displacement
Delayed breast reconstruction	2	Breast Cancer	None
Breast augmentation after partial mastectomy	5	Breast Cancer	None

56 latissimus dorsi myocutaneous flaps at Kijabe Hospital, 2000-2014.

Indications

Table 1 shows the various indications for use of the LDMF in 56 consecutive cases at Kijabe Hospital, Kenya, by the author. These had minimal morbidity. The most common use of the LDMF is in the reconstruction of defects resulting from the excision of large breast tumors, usually locally advanced invasive ductal breast carcinomas (LABCs), but also in a variety of sarcomas such as Phyllodes tumors. In high-income countries, LABCs are managed by neoadjuvant therapies that down-size the tumor, so when surgery is performed the surgical defect can usually be closed primarily. In low-income countries, patients often cannot afford, nor have access to, neoadjuvant therapies, so surgery is the only option for treatment with the aim of achieving good local control only. Surgery in these cases must only be done if wide macroscopic tumor clearance can be attained, and this usually means primary wound closure is impossible. The alternative of skin grafting is suboptimal as the axillary dissection, with subsequent seroma formation, may lead to graft loss, in addition to the comparatively more painful donor site. The LDMF is most useful in such cases, although local flaps, such as the Keystone perforator island flap may be used.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Recurrent Phylloides tumor treated with wide excision and reconstruction with a LDMF. Note large defect that required skin grafting.

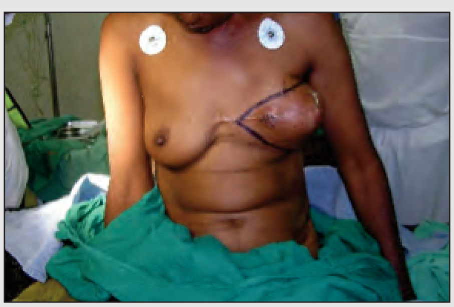

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Figure 7 shows the chest wall defect following a wide excision of the tumor; figure 9 shows mesh sewn in place.

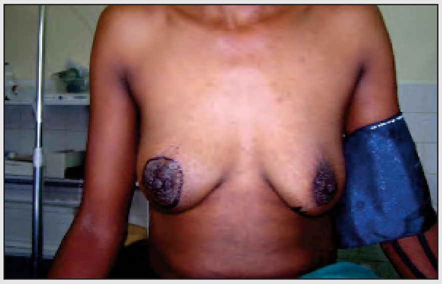

Fig. 11

Fig. 12

Fig. 13

Fig. 14

Fig. 15

Fig. 16

Breast augmentation using LDMF following breast-conserving mastectomy.

Clinical Examples

One very large myocutaneous flap donor site required skin grafting with some graft failure requiring daily dressings (see Figs. 1-5).

Two cases required full thickness anterolateral chest wall excision with mesh repair of the thoracic rib defect (See Figs. 6-10).

The LDMF can also occasionally replace a small breast after mastectomy as an autologous tissue breast reconstruction, with subcutaneous fat also mobilized with the skin. In a whole breast reconstruction, the LDMF volume is often inadequate, and a prosthesis is required to obtain an adequate size match with the contralateral breast.

The LDMF can also be used to augment breast volume after breast conserving surgery, where the cavity is large or the breast small. This is called augmentation mammoplasty and has been used a number of times by the author, including immediate nipple reconstruction using a corner of the skin island otherwise to be discarded (Figs 11-16).

Anterior neck contractures can also be managed with an LDMF (see Figs. 17-18).

Fig. 17

Fig. 18

Neck contracture treated with LDMF.

Other indications:

1 Defects of the humerus can be reconstructed using the lateral scapular border based on the angular artery, a branch of the thoracodorsal artery. This is raised as a chimeric flap; a skin flap can also be raised and used in the humeral reconstruction. The muscle provides excellent cover for the osteomyelitic humerus.

2 The functioning LD is an important muscle following a brachial plexus injury, and can be used to reconstruct elbow flexion by transferring it to the arm and connecting it to the origin and insertion of the biceps brachii.

3 The pre-expanded LD flap can be used for a number of purposes, including resurfacing of extensive shoulder circumferential burn scar to improve both function and cosmesis. The scar was itchy with areas of unstable scar that broke down every few months.

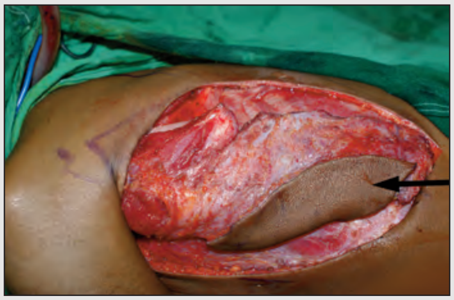

Fig. 19

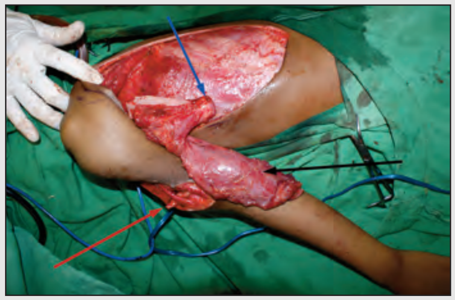

Fig. 20

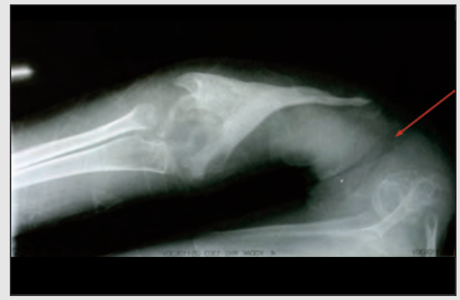

Fig. 21

Defect in humerus covered with LDMF. 19) Black arrow shows skin paddle. 20) Blue arrow shows scapula (bone), black arrow shows LD muscle, and red arrow shows the defect in humerus. 21) The red arrow shows the defect in humerus.

Fig. 22

Fig. 23

Fig. 24

22) A patient with an extensive, tight and itchy scar over the shoulder, with an axillary contracture. 23-24) An LD flap was pre-expanded and used to cover the shoulder defect after scar excision and contracture release.

4 The LD flap can also be used to reconstruct the shoulder after shoulder girdle resection for malignancy and to reconstruct the deltoid for shoulder abduction. When used for a functional deltoid reconstruction, the LD flap is islandized, with the humeral insertion sutured to the site of the deltoid insertion and the origin sutured to the trapezius proximally.

5 Because of the dual blood supply, the LD can be raised on either the dominant pedicle, the thoracodorsal vessels, or on the secondary segmental pedicles at its origin and be used to cover midline defects on the back.

6 The LD is used extensively as a free flap. The long pedicle with large diameter vessels makes it an excellent flap for free flap coverage of almost any defect. The disadvantage is that, for most defects, the patient has to be turned during the procedure to allow for harvesting and then flap insetting. A further disadvantage, of course, is that free flaps are not an option for most resource-poor settings.

Flap Design and Mobilization

The following description will be for the most common indication, using the LDMF to cover a wide mastectomy wound. Usually the LDMF is mobilized first, followed by the mastectomy, so there is only one turn during the case - the patient starts on their side, then is moved onto their back for the mastectomy and flap in-setting.

In some cases, two teams can work at the same time with the patient in a lateral lithotomy position.

Step 1: Planning the Flap Design and Positioning the Patient

Fig. 25

A 7x15cm flap; angle of scapula marked (black arrow).

Critical to successfully using the LDMF is planning the surgery. First, the expected defect size and location must be carefully estimated to ensure the LDMF will reach and cover it. The LD can be mobilized in its entirety, and the pivot point is, therefore, its main vascular pedicle—the thoracodorsal vessels—which lies high in the axilla near its insertion into the humerus. It is crucial to understand the distance the flap must travel, and this means measuring from the pivot point to donor site and the pivot point to the recipient site, like the pendulum of a grandfather clock. The further the flap must travel, the lower the donor site must be on the back. The skin island is usually an elliptical shape, so simple advancement flaps close the donor defect. The ellipse is best aligned transversely to facilitate wound closure, and the resulting scar lies horizontally and can be hidden beneath the bra/bikini strap for good cosmesis. If necessary, the ellipse can be aligned in any direction, but wound closure will be more difficult when the ellipse is oriented other than those that are transverse. Also, less skin width can be taken, and the scar will not be as aesthetically pleasing when not oriented transversely. The width of the skin island can be up to 10cm in a larger frame and older patient.

- Use a ruler and measure first the estimated defect size. Position the patient in a lateral position on the table, much like for a posterolateral thoracotomy—with the ipsilateral arm flexed at 90 degrees, resting on an arm board or Mayo stand across the chest. Note the position of the tip of the scapula, as the upper border of the LD will reach this high (Fig. 25). Do not cross the tip of the scapula with the skin ellipse. and do not cross the midline posteriorly. Draw the flap using a ruler to measure the width of the ellipse. Move the skin in a craniocaudal direction comparing the drawn superior and inferior ellipse lines to a fixed point to make sure the wound can be closed primarily. A tight closure is common but will almost always heal satisfactorily.

Step 2: Lower Flap Mobilization

Apart from the usual retractors, artery forceps, tissue forceps and so on, equipment you will need will include an electrocautery machine (ECM), long-bladed right-angle retractors (for the superior flap dissection), drain tubes (for the inevitable seroma formation), preferably a headlight (especially useful during dissection under the upper flap high in the axilla). Using a seat will make it much easier to dissect below the skin above the superior border of the skin ellipse while seated.

Remember to measure and mark twice to ensure accuracy, as you can only cut once.

- After incising the skin with a scalpel or the cutting switch of the ECM, use the coagulation setting of the ECM for the remainder of the case to minimize bleeding and to keep the operative field clear. Bevel the flaps slightly to aid in-setting the flap later—the skin of the back is much thicker than the anterior chest wall, and an unsightly step in the two skin edges can be avoided with the bevelling. Dissect down to the LD all around the ellipse.

- Next mobilize the skin below the inferior edge of the skin paddle. The amount of LD needed inferior to the ellipse of skin will depend on the indication. Most of the LD will be needed for an immediate breast reconstruction, as the LD will form the muscle pouch for the prosthesis. If just covering a defect of skin and/or chest wall, a smaller distal portion of LD can be taken. Starting inferolateral, find the long, vertical lateral border of the LD. It is surprisingly anterior, and care must be taken not to dissect deep into the intercostal muscles. The thoracodorsal neurovascular bundle is 1-2 cm medial to the anterior margin of the LD muscle. Mobilize the skin flap far enough inferiorly to be able to cut the LD safely (Fig. 26). Find the medial border of the muscle as it merges with the

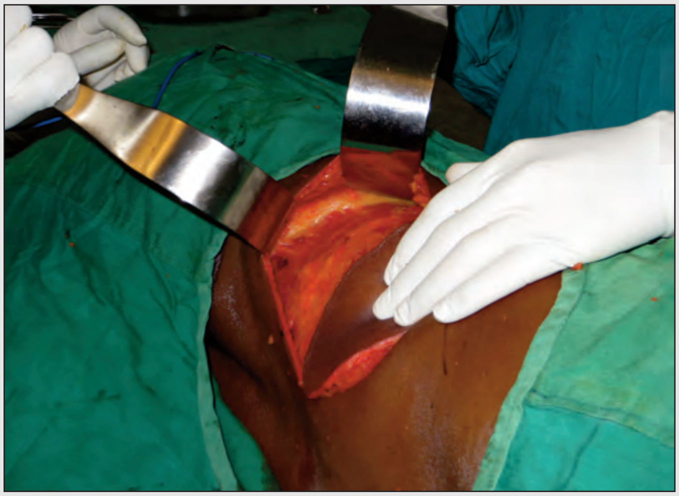

Fig. 26

Caudal end of dissection.

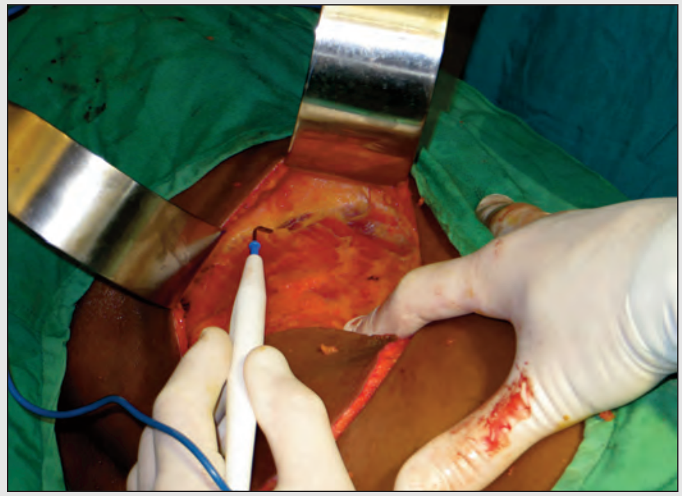

Fig. 27

Dividing the lower edge of the LD with bent cautery tip.

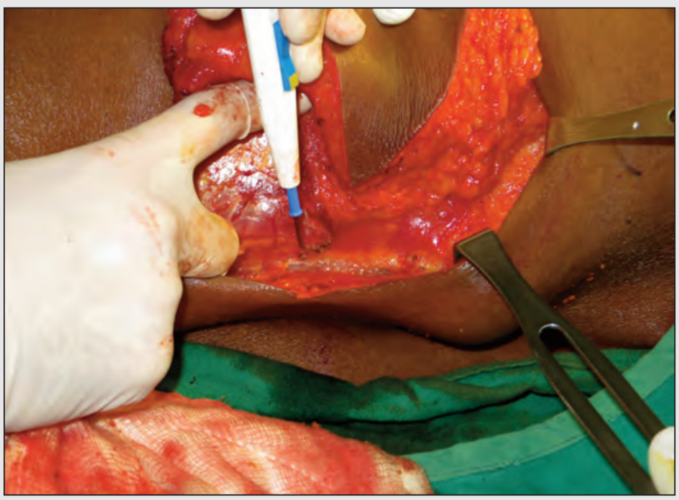

Fig. 28

Dividing the medial edge of LD on the paraspinal muscles.

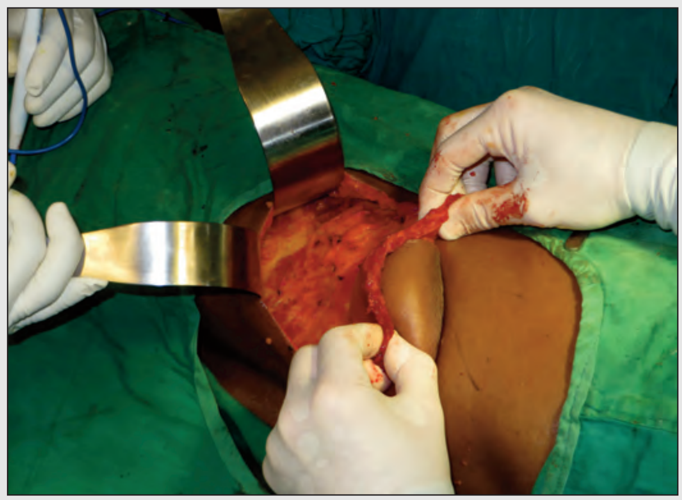

Fig. 29

Completely divided lower LD. Note the proximity of the ribs and intercostals.

paraspinal muscle fascia. It is thin here.

- Move to the upper margin of the flap and mobilize the skin off the muscle. Follow the vertical lateral border of the LD superiorly for 5-10 cm. Find the upper border of the LD as it runs obliquely upwards, medial to lateral, just crossing the tip of the scapula.

- Next, divide the lower edge of the LD. Bend the cautery tip 60° to aid this division. Start laterally and work medially towards the midline posteriorly (Fig. 27). Take care not to divide too deeply and enter the intercostal spaces, as the muscle is very thin here. Lift the muscle cephalad and dissect it off the ribs and intercostals, cauterizing perforating vessels as they are encountered. Only pause to tie off the larger vessels. Do not damage the paraspinal musculature. The LD here is largely fascial but is separable (Fig. 28).

- Continue the flap mobilization superiorly, working along the whole width of the LD simultaneously. One of the dangers of the flap dissection at this point is dissecting beneath the serratus anterior (SA), which now comes into play. There is not a clear plane between the LD

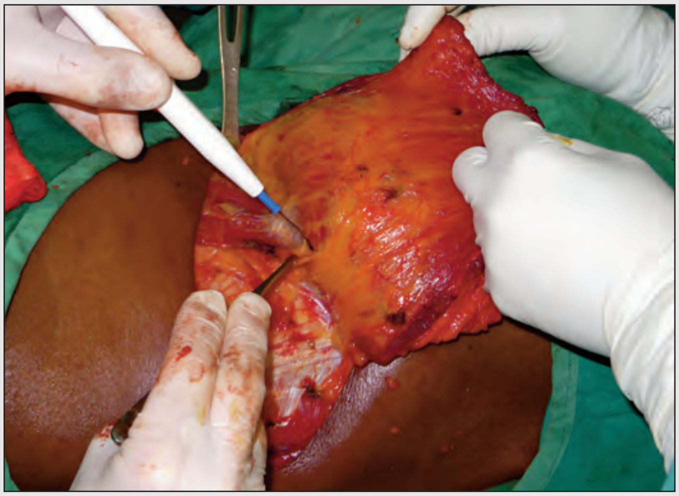

Fig. 30

Finding the plane between serratus anterior and LD.

and the SA, so it must be anticipated. One clue is that the flap starts to get thicker. Trace the origin of SA medially as it travels obliquely upwards toward the angle of the scapula, which can be palpated at any time. Sharp dissection will be needed to enter the plane between these two muscles (Fig. 30).

- From now on, care must be taken during the LD mobilization on its deep surface, as the thoracodorsal vessels enter here high up and can be damaged. The superficial surface of the LD is easy to dissect, as there are no important structures to watch out for.

Step 3: Upper Flap Mobilization

Continue the dissection under the upper skin flap. The assistant will be standing on the opposite side of the table, pulling firmly on the long, right-angled retractors at this stage, with the surgeon seated and working up under the upper flap towards the axilla. The LD will gradually taper to a thick strap of muscle 4-5 cm wide as it spirals around teres major into its insertion on the humerus. The upper, medial aspect of the LD lies adjacent to the teres major, and this must be dissected clear so the LD can be free to rotate to its destination. The vascular pedicle must now be seen and protected as it enters the deep surface of the muscle (Fig. 31). Stop using the cautery at this point, changing to dissecting scissors. The second main blood supply—the SA branch (Serratus Anterior)—can be seen with difficulty, heading towards the medial axillary wall to enter the SA. This rarely needs division, as the LDMF can easily rotate anteriorly with this branch intact; however, if extra mobility is required and the flap seems tethered at this point, this branch can be divided without flap compromise.

- The remainder of the dissection is best accomplished from an axillary approach. This is either done as a separate incision, or, more often, through the mastectomy wound. A space needs to be created anterolaterally under the skin flaps to store the mobilized LDMF temporarily and close the back wound (Fig. 32). Place a 14G suction drain tube with its exit point quite anterior and inferior so the patient doesn't lie on it when on her back. The wound is closed with

Fig. 31

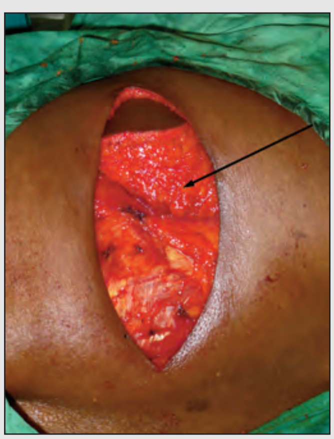

Fig. 32

Fig. 33

Fig. 34

31) Upper flap dissection nearly complete. LD neurovascular bundle not quite visible in this photo, on the deep surface of LD high up, just lateral to teres major (white arrow). 32) Flap tucked under upper wound for closure (black arrow). 33) Closure of wound from end to middle (black arrow). 34) Wound closed over a drain tube (red arrow).

multiple interrupted 2/0 Vicryl® sutures in the subcutaneous layer, starting at the ends of the wound, working towards the center (Fig. 34). The wound closure is tight. A subcuticular suture is used to close the skin (Fig. 35). The dressing must be water-tight so suction is not lost. Roll the patient onto her back for the remainder of the case.

Step 4: Dissection in the Axilla

Once the mastectomy has been completed, often including an axillary dissection, the LDMF can be retrieved, lying in its anterolateral pouch. At this point, a decision needs to be made whether or not maximal flap length is required. If so, the LD can be divided about 5cm below its insertion into the humerus and above where the vascular pedicle enters. From an anterior approach, the vessels are easy to see, especially after an axillary dissection. Extreme care must be exercised at this point, while the LD is encircled with blunt dissection above the vascular pedicle prior to division with cautery. If the LDMF is being used for a breast reconstruction, many breast surgeons will divide the nerve, so the reconstructed breast doesn't move when the patient abducts her shoulder. The divided LDMF, hanging free on its pedicle, must be handled carefully. If rotated anteriorly, the LD "stump" above the pedicle can be sutured to the medial axillary wall just behind and under the pectoralis major anterior axillary fold. This minimizes the additional bulk in the axillary concavity if the LD is left attached and drapes across the axilla.

(**Editor's note**: If the muscle is to be used as a functional muscle flap, then the nerve is not divided. The thoracodorsal artery divides into two branches on the under surface of the LD—a descending and a transverse branch; it is possible to gentle separate the LD into two flaps, based on these two branches. The angular branch is preserved if a bone flap is to be included. If desired, the skin flap can be separated from the muscle and left on one of the large perforators for easy flap insetting.)

Conclusion

The pedicled LDMF is an easy flap to raise and has multiple uses. It is extremely hardy, with a very reliable blood supply, and, with careful planning, can adequately fill defects of up to 15 x 10cm in size with primary closure of the donor site. This flap should be part of the surgical toolbox of every surgeon who operates around the trunk and upper extremities in resource-limited settings.

Further Reading

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Chapter 33
Tendon and Nerve Injuries

Louis L. Carter, Jr. with Jennifer Durham

Important Notice
The authors of this chapter, with extensive experience throughout Africa, will present a different approach to the treatment of flexor tendon injuries to obtain an acceptable range of motion (ROM) for patients who must use their hands to make a living. Invariably fingers end up stiff and immobile after tendon repairs, especially flexor tendon repairs. This chapter will suggest a repair and a therapy protocol that will give your patients the best opportunity to have a functional hand, but you will need to keep the patient in hospital 7-10 days post-op. This applies to farmers as well as office workers who use a computer.

General Considerations
Tendon injuries should be repaired as soon as possible. Wounds are irrigated and debrided, and the tendon ends identified. If the wound is clean, the tendons may be repaired immediately as described below. If the surgeon does not feel comfortable in performing the repair, the wound can be loosely closed and the repair carried out at a later date in a clean wound. See under **Clean Closed Wound Concept** in Chapter 2 on Wound Care. Tendons and nerves can be repaired the following day, or up to two weeks later if the wound is initially irrigated, debrided and loosely closed, as this gives a clean closed wound. An acute clean wound should **never** be left open for a later repair. This will allow the wound to become contaminated.

If the wound is heavily contaminated and the wound cannot be closed initially, tendon repair can be delayed. The wound will require further irrigation and debridement on Days 2, 4, etc., with closure by Day 7 if at all possible. As soon as the wound can be closed the tendons are repaired. Therefore, if the wound is clean at day 3 or 4, the tendons are repaired and the wound closed.

If the wound has been initially closed, tendons may be repaired up to 2 weeks later, but after two weeks, repair will be difficult because of muscle contraction and tendon shortening. Secondary repair later than two weeks post-injury is not recommended.

Delayed Tendon Repair after 2-3 weeks with tendon grafts is possible, but also not recommended in most situations. If there is a gap between the tendon ends, a tendon transfer is best.

Important Surgical Principles
1 Know the function of each tendon.
2 Know how to examine for tendon injuries.
3 Knowledge of muscle/tendon relationships in upper and lower extremities.
4 Know how to dissect and identify tendons at surgery.
5 Technical repair of extensor and flexor tendons at different levels.
6 Splinting and elevation of extremity after tendon repair—positions of extremity and fingers.
7 Length of immobilization in splint or cast after repair.
8 When should therapy and range of motion exercises begin?
9 Once one has examined the patient in casualty, it is good to give the patient a **local wrist block anesthetic** to relieve pain before surgery, since surgery may be delayed several hours (see chapter 5 on Anesthesia).

Before tendons can be repaired, they must be identified, and this requires knowledge of anatomy and muscle/tendon relationships in the upper and lower extremities. Textbooks of anatomy should be in every theatre or operating room for reference. **Surgeons should not be embarrassed to have an anatomy textbook in the theatre!** This chapter will cover the repair of commonly injured tendons in the upper extremity.

Anesthesia and Tourniquet
- Extensor tendon injuries to the dorsum of hand can be repaired under local/wrist or digital block anesthesia. In these cases, it still best to use a tourniquet. Method:
  1 Infiltrate local anesthesia.
  2 Place tourniquet over forearm.
  3 Exsanguinate or elevate hand for few minutes.
  4 Inflate tourniquet for desired time.

  This will give at least 20 minutes of anesthesia time. With sedation, there will be approximately 40 minutes operating time. Ischemic pain does not develop as quickly when the tourniquet is placed over forearm tendons in contrast to over arm muscles.

- Extensor tendon injures at the wrist and above and all flexor tendon injuries require regional or general anesthesia, and a tourniquet should always be used.

Tendon Repair Technique

- Tendon repair must be strong. For **flexor tendons, it is important that one has four suture strands across the tendon repair**. Since one core suture equals two strands, any flexor tendon repair should have two core sutures. (Some new sutures have two strands attached [swedged on] to the needle so that one core suture equals four strands.) The primary core suture should be a weave suture, preferably a Bunnell as described below or a modified Kessler. Ideally it should be a braided suture that holds better. The second suture across the repair should also be a Kessler, though some use a horizontal mattress. It is important also to use a running locked epitendinous suture. Many find it easier to put the posterior or distal wall epitenon suture in first before the core sutures are placed.

- **Extensor tendon** repairs from Zone III into the forearm (see below), should have one core suture—2 strands across the repair site. Many will use a horizontal mattress suture for extensor tendon repairs, and the author has used this technique; however, where there are few physical or occupational therapists to monitor rehabilitation, the weave technique is stronger, and two weave sutures are ideal, as in flexor tendon repair. In Extensor Tendon zones I and II, horizontal mattress or running sutures may be used. Unfortunately, extensor tendons are often treated with skillful neglect.

- **Additional suture**: As stated above, a running locked epitendinous suture of 5-0 nylon or Prolene® should be used for both flexor and extensor tendons. This **adds strength** and provides a smooth surface to **help with better gliding** of the tendon. This is especially true in all flexor zones. Most important it prevents gapping at the repair site.

- **Suture material:** In the West, newer sutures as Supramid® and Fiberwire® are now used for important tendon repairs. What is most important is that a braided suture is used. It ties and holds better. Therefore, **silk**, **Ethibond®** or **Mersilene®** suture if available should be used. If none of these are available, then Prolene® may be used. Prolene® requires multiple knots to hold the tendon ends together and is definitely contraindicated in Flexor Zone II or No Man's Land where the fibro-osseous canal is small. Any suture should be tied down **within** the tendon so that gliding will not be affected.

Specific Tendon Repairs

Biceps Avulsion

- **Mechanism**: This occurs most often in middle age males with forced extension on a maximally flexed elbow.

- **Findings**: Common findings are ecchymosis in antecubital fossa, weakness of elbow flexion and supination, and abnormal contour and bulging

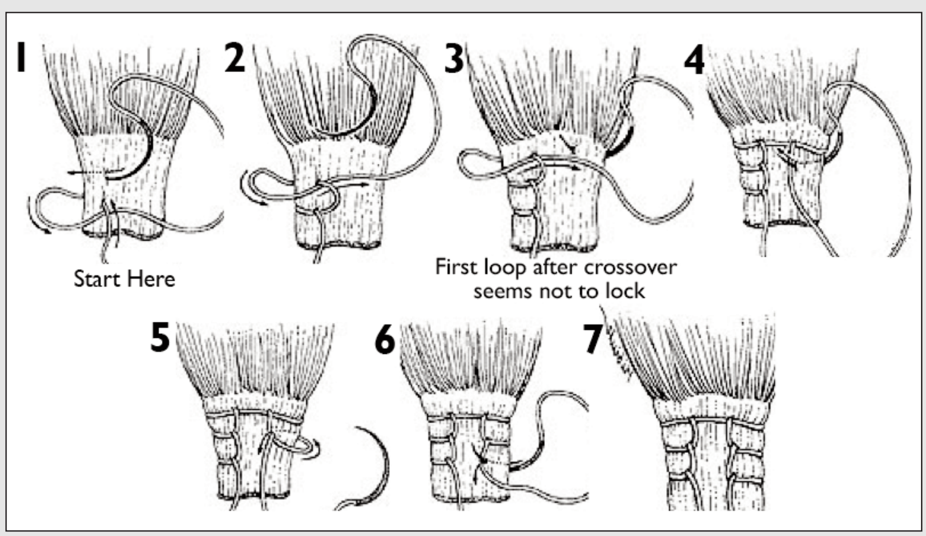


Fig. 1

Krackow whip suture: both ends may be passed through the tuberosity and tied posteriorly. (Courtesy of Kenneth A. Krackow).

of proximal biceps. Biceps rupture may be incomplete or complete, and treatment may be either conservative or operative. Since brachialis, brachioradialis and supinator are still intact, there will be weak flexion (70%) and weak supination (60%) with conservative, non-operative, treatment for complete ruptures.

- **Treatment**: Partial injuries can be easily repaired if found early. Complete avulsions can be repaired early with interference screws or suture anchors, if these are available, to radial tuberosity. If these are unavailable, drill holes may be made in the tuberosity. In each method, a strong core weave suture or two Krackow whip stitches, using # 1 or #2 nonabsorbable suture, should be placed in the proximal tendon. If drill holes are used, the suture ends can be passed through the tuberosity and tied down posteriorly through a separate posterior incision. The forearm should be pronated to identify the tuberosity through a posterior lateral incision. Posterior exposure requires splitting the common extensor and supinator muscles.

- **Post-operative care**: The elbow should be placed in flexion in a cast for four weeks. After four weeks, flexion without resistance may be allowed. Gradual resistance can be added after six weeks. (The surgeon should review a detailed description of this procedure and the anatomy before surgery.)

Hand & Forearm

- **Anatomy, exposure, and relationships**: With injuries in the hand and forearm, **it is important to know the relationship of the muscles and tendons**. After an injury in the hand and forearm, the proximal tendon ends retract proximally and lie within the muscles and hematoma. This makes identification difficult in the forearm. It is common for an inexperienced surgeon to give up trying to identify the proximal tendon ends thinking that there is only muscle there and no tendons. The distal tendon ends may be seen in the wound, but identification of the proximal tendon ends requires proximal extension of the wound in a zigzag fashion, irrigation and removal of the hematoma, and dissection of the tendon ends within the muscles. Wide, extensive exposure is mandatory, both proximally and distally. The apex of each zigzag can be sutured back to the skin for retraction and exposure. Finding each tendon requires knowledge of anatomy and muscle relationships. This surgery requires patience, as this dissection may take time. The location of the tendons both proximally and distally will depend on the position of the fingers and wrist during injury,

Volar

Radial  Ulnar

Dorsal

Fig. 3
Mid-Forearm (from Netter, Courtesy of Elsevier).

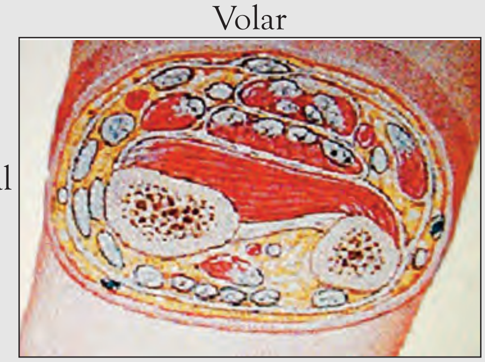
Volar

Radial  Ulnar

Dorsal

Fig. 2
Proximal Forearm (from Netter, Courtesy of Elsevier).

Volar

Radial  Ulnar

Dorsal

Fig. 4
Distal Forearm (from Netter, Courtesy of Elsevier).

Table I

Abductor Pollicis Longus	APL
Abductor Pollicis Brevis	APB
Extensor Carpi Radialis Longus	ECRL
Extensor Carpi Radialis Brevis	ECRB
Extensor Pollicis Longus	EPL
Extensor Digitorum Longus	EDL
Extensor Indicis	EIP
Extensor Digiti Minimi	EDM
Extensor Carpi Ulnaris	ECU

Extensor Tendons and Abbreviations

and also the angle of the wound. Identification of distal tendon ends is easier as the wrist and fingers can be flexed to find flexor tendon ends or extended to find the extensor tendon ends.

It is hard to remember these relationships. An anatomy textbook should be available in every operating room for reference.

Repair of Extensor Tendons

This is not difficult, but it must be done carefully with good exposure. Usually a 3-0 or 4-0 core, weave, braided, non-absorbable suture is required for an extensor in the forearm or wrist (see details under flexor tendons). Many only have Prolene® for these sutures, but a **braided suture** as silk, Ethibond®, or Mersilene® is recommended. If Prolene® or a similar monofilament suture is available, multiple knots must be used to prevent unraveling. One weave suture (see under flexor tendons) or two 4-0 or 5-0 horizontal mattress sutures can be used in tendons over the dorsum of the hand and in the fingers. Even though extensor tendons in the hand do not retract as extensor tendons in the forearm or flexor tendons, **one should extend** the wound proximately and distally to identify the ends and perform an adequate repair. There are zones for tendon injuries, both for extensors as well as flexors. The nine zones for extensor tendon injuries help in determining the proper repair. Below are listed the zones, suggested repairs, splint methods, and rehab methods. The odd number extensor zone is over a joint.

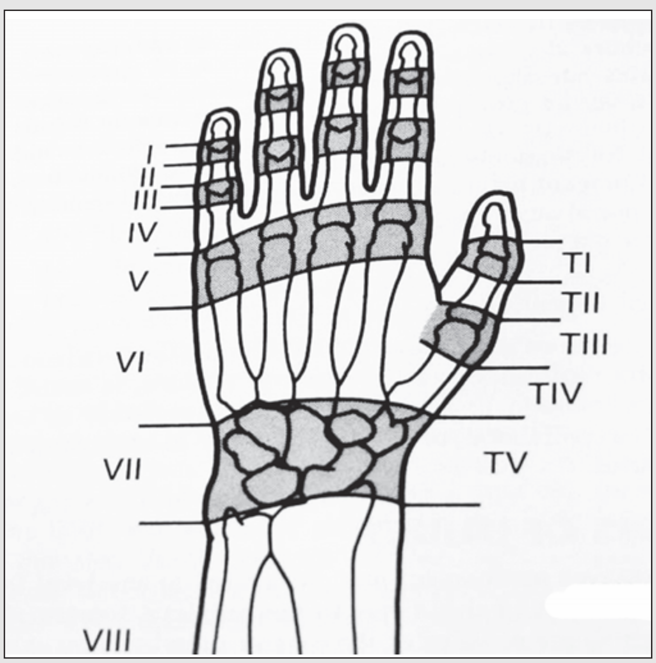


Fig. 5
Extensor Tendon Zones

- **Zone I—Terminal Tendon Injury over Distal Interphalangeal Joint and Mallet Injury**

  Tendons are thin at this level. If after a **laceration**, the ends are clearly seen, primary repair is performed with a running 5-0 or 6-0 monofilament suture. If the ends are difficult to identify, continuous splinting or pinning of the DIPJ at 0 degrees of extension or slight hyperextension for six weeks will work well. **An excellent repair at this level combines the skin and tendon in a horizontal mattress or running suture tied over the skin**. A **Closed Mallet Injury**, involving only the terminal tendon, requires **continuous** splinting for six weeks with gradual tapering after six weeks, allowing progressive exercise periods during the day. Splinting at night is then continued for four more weeks. If there is a bony Mallet, usually a closed fracture at the insertion of the extensor tendon, splinting alone is sufficient for six weeks. **For either open or closed injuries, the author would use a K-wire to hold the DIPJ in extension for six to eight weeks, as this will eliminate the need for compliance in keeping a small splint on continuously**. The K-wire can be bent and pushed under the skin at the tip of the finger so that it is not exposed. Bending the wire also prevents proximal migration. If there is volar subluxation of the volar fragment of the distal phalanx, there are several methods of reducing and holding the reduction with K-wires for six weeks. See Chapter 34 on Hand Fractures. **Bottom line: A K-wire across the joint for 6-8**

weeks is sufficient, and suturing the tendon is not absolutely necessary. Splinting in extension is also sufficient but compliance in wearing the splint may be a concern.

- **Zone II—Between Distal Interphalangeal Joint (DIPJ) and Proximal Interphalangeal Joint (PIPJ)**

  The terminal tendon and lateral bands may both be divided. The tendon is very thin and repair is performed with fine monofilament running or horizontal mattress sutures. Skin may also be combined with the tendon in the repair at this site. A K-wire may also be used as described above.

  Splint and rehab as Zone I.

- **Zone III—over the Proximal Interphalangeal Joint and Central Slip Insertion**

  There should be a high degree of suspicion with any injury over the PIPJ, since the slightest and most insignificant laceration can partially divide the central slip. The patient may initially extend the PIPJ with the lateral bands, but if the injury is missed and untreated, the lateral bands will in time slip to the volar side and become flexors rather than extensors. A boutonniere deformity will result with a PIPJ flexion deformity, with an extensor lag at the PIPJ. The DIPJ will be extended. If the laceration is through the tendon, a core suture—such as a modified Kessler technique—with 4-0 braided suture as discussed under flexor tendon injuries can be used. A monofilament, such as Prolene®, can be used if that is what is available. If the injury is at the insertion into the middle phalanx, the proximal tendon end must be attached to the base of the middle phalanx. This can be done with bone anchors, or by passing a suture through a transverse drill hole in the middle phalanx and then through the tendon with a core suture.

  Technique for anchoring suture to the bone without anchors: With open exposure, use a .035 or .045 inch K-wire to drill transversely through bone where you wish to anchor the tendon. Then pass a 20 gauge hyponeedle through drill hole. Pass a 4-0 suture (monofilament if available) through the needle and remove the needle. Pass suture ends next to the base of middle phalanx, weave the suture through the proximal tendon, and anchor the tendon down to the bone.

  Splint/cast or pin PIPJ in extension for six weeks, allowing DIPJ and MPJ freedom to flex.
  When one treats delayed injuries to the central

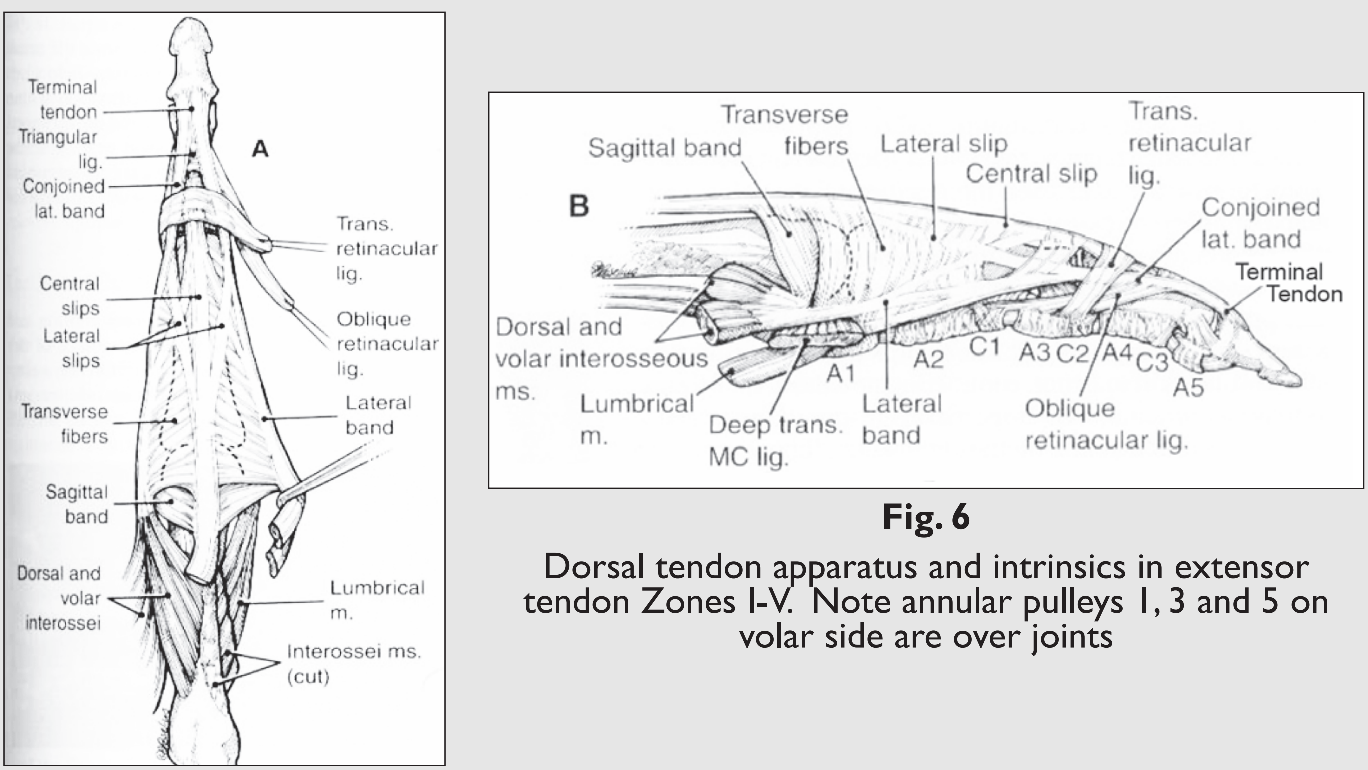


Fig. 6

Dorsal tendon apparatus and intrinsics in extensor tendon Zones I-V. Note annular pulleys 1, 3 and 5 on volar side are over joints slip with extensor lag (incomplete extension of middle phalanx), if the PIPJ can be passively extended, then splinting/casting of PIPJ for 6-12 weeks is usually satisfactory. **To eliminate the need for compliance required in wearing a splint for either acute or delayed injuries, a K-wire across the joint for six weeks may be used in place of a splint.**

The unusual closed rupture of the central slip is treated closed with PIPJ extension and preferably a K-wire across the joint.

- **Zone IV—over Proximal Phalanx**

Repair with multiple horizontal mattress sutures or a modified Kessler core suture. Post-op: Splint the PIPJ in absolute 0 degrees of extension for six weeks and include the DIPJ if the lateral bands were also repaired. Add a continuous locking small monofilament suture on the tendon surface.

- **Zone V—over Metacarpal Phalangeal Joint**

This injury may involve the joint. Modified Kessler core sutures are adequate, with a continuous locking epitenon or surface suture. Index and Small fingers have two tendons, with the EDC always the radial tendon. Repair both tendons. **Beware** of lacerations over MPJ, as these may be from a clenched fist or human bite injury. These may or may not lacerate the tendon, but be aware of possible metacarpal phalangeal joint (MPJ) bacterial inoculation. Unless recognized, this injury may lead to a septic joint and/or severe cellulitis. X-rays are necessary to rule out a foreign body, like a tooth, within the joint. Copious irrigation and antibiotics are required with delayed skin closure.

Post-op: After tendon repair, the MPJ should be held in extension at 0° with the wrist extended 20° for 2-3 weeks. Then begin to allow progressively greater MPJ flexion. After six weeks the splint can be removed, allowing full range of motion. Avoid forceful gripping for 8-12 weeks.

- **Zone VI—over Dorsum of Hand**

Because of juncturae (fascial connections between the extensor tendons) there may be a weak extension of the finger, even if a proximal extensor to the finger is lacerated. In this Zone, tendons retract and proximal extension of wound may be necessary to find the proximal end for repair. Care must also be taken when evaluating EPL injuries, as intrinsic tendons to thumb (APB and AddP) will give a weak extension when the EPL is divided. Repair with a core 4-0 suture, braided if available, and epitenon running suture. Splint the hand and fingers as for Zone V.

If only one or two tendons are lacerated in the zones above, then repair may be carried out under local anesthesia. If there are multiple injuries, then regional or general anesthesia will be necessary. In any case, a forearm tourniquet should be used to give a bloodless field.

- **Zone VII—over Wrist Joint and Extensor Retinaculum**

Knowledge of extensor compartments is

Fig. 7

Fig. 8

7) Extensor tendon compartments; 8) Cross-section from ulnar to radial (Courtesy of Elsevier).

important. There are six compartments with Compartment 1 radial.

- **Compartment 1**—APL and EPB are usually in the same compartment, but may be in two separate compartments. (This is something one must be aware of when treating tenosynovitis of First Dorsal Compartment or de Quervain's Syndrome as one must release both compartments if present.) Leave retinaculum open after repair.

- **Compartment 2**—long extensor tendons to the wrist, ECRL and ECRB: These large tendons will retract when divided. Repair with a 2-0 or 3-0 core suture (a braided suture should be used). Care must be taken to hold wrist joint in extension to take tension off the repair while other injuries and skin are repaired.

- **Compartment 3**—long extensor to the thumb, EPL. It courses around Lister's tubercle with the tubercle as a fulcrum. This tight compartment must be released for repair, and EPL should be left subluxed radially and lying over the second compartment after repair.

- **Compartment 4**—EDC tendons are superficial with the EI (EIP) deep—5 tendons in this compartment. The Extensor Indicis can usually be identified deep to the other tendons, and it has a distal muscle belly. The retinaculum may be opened in a zigzag fashion for later repair so as to prevent bowstringing. Often this is not possible. A core suture with an epitenon suture is used for repair of these tendons.

- **Compartment 5**—EDM: open retinaculum, repair tendon, and leave retinaculum open, repair with horizontal mattress (usually a small tendon).

- **Compartment 6**—ECU: over ulna, requires strong core suture for repair and repair of overlying sheath if possible to prevent subluxation.

Post-op: tendon repairs of the wrist extensors in Zone VII require splinting of the wrist in 20-30° extension for six weeks, continuously. For finger extensor tendon injuries at the wrist, the wrist is held in 45° extension, and the MPJs are splinted (blocked) in 45° flexion for four weeks with a volar splint. The fingers are allowed to begin gentle Active Range of Motion (AROM) at the MPJ after four weeks, but the splint is worn for six weeks post op when not exercising. The IPJs (PIPJ and DIPJ) are not included in the splint, and the patient is encouraged to exercise these joints.

- **Zone VIII—Distal Forearm**

  Anatomical relationships are important to know to identify the injured tendons. Repair may be at the musculotendinous junction. Four extensor tendons originate on the ulna and course from the ulnar to the radial side and deep to the long extensors. Beginning proximally, these are APL, EPB, EPL, and EI. Repair the tendons under a tourniquet and with IV regional, axillary block or general anesthesia. Post-op: splint with the wrist extended 45° and MPJs as under Zone VII.

- **Zone IX—Proximal Forearm**

  Dissect tendons out of muscle for repair. In the proximal forearm, the muscle will need to be approximated.

Extensor Tendons Zones for Thumb

- **Zone I and II** are similar to Zone I and IV in the fingers.

  For **Zone I**, splint the IPJ at 0 or slight hyperextension.

  Non-operative: splint continuously for eight weeks. Operative: splint 5-6 weeks continuously.

  For **Zone II**, splint the MP and IP at 0 degrees, thumb in radial abduction. Begin active flexion at each joint at four weeks; progress in 25-30 degree increments each week. Begin weaning from the splint at week 6.

- **Zone III** is similar to Zone V for the fingers. The EPB inserts to the proximal phalanx base on radial side. There is no sagittal band. EPL is ulnar and inserts at base of distal phalanx (no middle phalanx in thumb). Keep MPJ extended for 6 weeks and then begin gradual flexion as above.

- **Zone IV** is similar to Zone VI: Repair both EPB and EPL.

- **Zone V** is through extensor retinaculum, as described above. The retinaculum over the EPL is released, and the repaired EPL is allowed to sublux radially. The retinaculum over the first compartment is released, the EPB repaired, and the retinaculum left open.

If the thumb tendons are injured, a thumb spica splint is used to hold the thumb and wrist in extension.

Epitenon suture in addition to core suture:
1 Gives additional strength.
2 Provides a smooth surface for gliding.
3 Helps to prevent gaping between tendon ends.

Flexor Tendons

Important facts about flexor tendon injuries:

Table 2

Flexor Carpi Ulnaris	FCU
Flexor Digitorum Superficialis	FDS
Flexor Digitorum Profundus	FDP
Palmaris Longus	PL
Flexor Pollicis Longus	FPL
Flexor Carpi Radialis	FCR
Brachioradialis	BR

Flexor Tendons and Abbreviations


Fig. 9

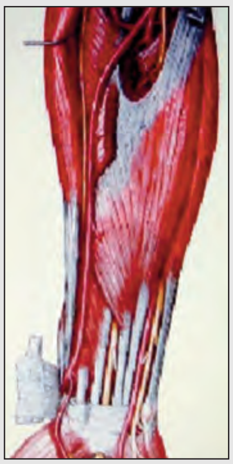


Fig. 10

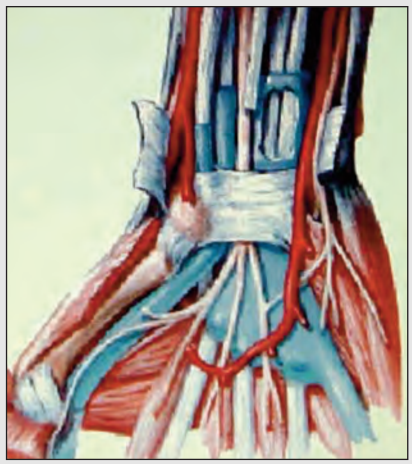


Fig. 11

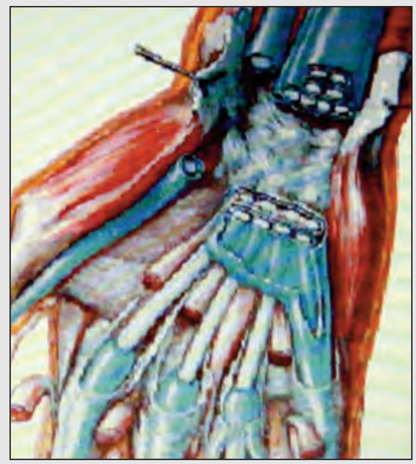


Fig. 12

Anatomy of Volar or Flexor side.
(L-R) Superficial forearm; Deep forearm; Superficial wrist; Deep wrist.

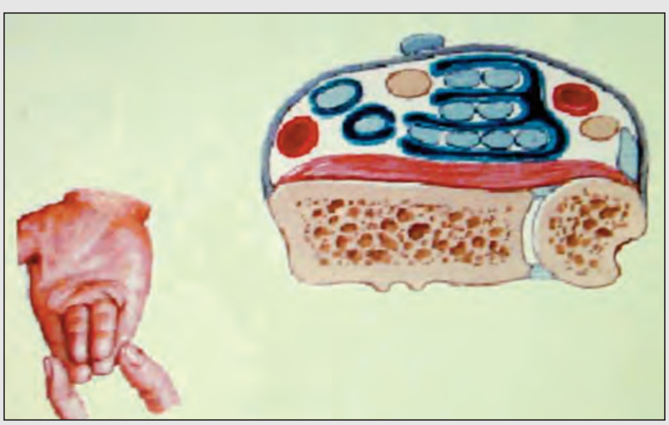


Fig. 13

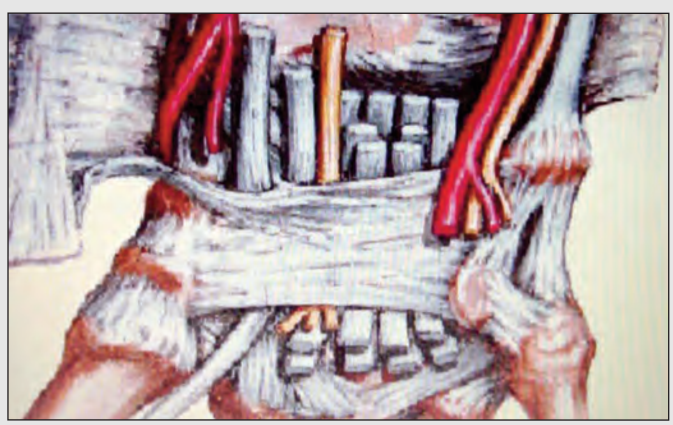


Fig. 14

13) Anatomy and relationship of FDS tendons in the carpal canal; 14) The relationship of FDS and FDP to FPL and Median Nerve in the carpal tunnel (Courtesy of Elsevier).

- Ulnar Artery and Nerve are radial to FCU, with artery volar and nerve dorsal.
- Any injury to FCU and flexor tendons will likely injure these structures.
- There are ten structures in the Carpal Tunnel: All FDS and FDP tendons (8), FPL, and Medial Nerve.
- Approximately 20% of individuals do not have an independent FDS slip to the small finger.
- Approximately 20% of individuals do not have a PL.
- All long flexors to fingers are **ulnar** and dorsal (deep) to Palmaris Longus. Any injury at wrist ulnar to Palmaris Longus may injure all eight flexor tendons to the fingers.
- Flexion of MPJ is through intrinsic tendons and not the long flexors. On exam after injury, be aware of the patient who flexes proximal phalanges only. Distal flexors may be divided.
- The palmar cutaneous branch of median nerve lies superficially between the PL and FCR tendons at the wrist. Repair if injured to prevent neuroma.

Pulley System

Before discussing flexor tendon repairs, it is important to discuss the pulley system. There are five annular pulleys in each finger.

- A-2 and A-4 are over phalanges and **must be preserved for complete finger flexion.**
- A-1—located over MPJ (divided in trigger fingers).
- A-2—located over Proximal Phalanx and **must be preserved for full flexion**.
- A-3—located over PIPJ, usually divided in tendon repairs.
- A-4—located over Middle Phalanx and **must be preserved for full flexion**.
- A-5—located over DIPJ—can be divided in Zone I repairs.

Remember: important pulleys are over phalanges not joints. Cruciate pulleys between annular pulleys allow finger flexion.

The thumb has three pulleys:

- A-1—located over MPJ (divided in trigger thumb).
- A-2 or oblique—located over Proximal Phalanx and must be preserved.
- A-3—located over IPJ.

Pulley Injuries

Pulleys are difficult to repair primarily. It is rare to have a complete injury to A-2. One half of A-2 is sufficient to prevent bowstringing. If either A-2, A-4, or the thumb oblique pulley is completely divided, they should be repaired with a tendon graft (a portion of unrepaired FDS or slip of EDM or PL. Look up repair in major hand text). With A-4 injuries, a slip of distally based FDS can be used to recreate an A-4 pulley injury.

For a complete pulley reconstruction:

- **A-2 reconstruction**, the graft should be wrapped around the entire proximal phalanx but beneath the extensor tendons.
- **A-4 reconstruction**, the graft should be wrapped around the middle phalanx but superficial or dorsal to the extensor tendons.

Since adhesions may form after primary reconstruction, some prefer to perform delayed pulley reconstruction. The author prefers to do this acutely in clean wounds, recognizing that secondary tenolysis may be necessary. Also the protocol below for tendon motion would still be used.

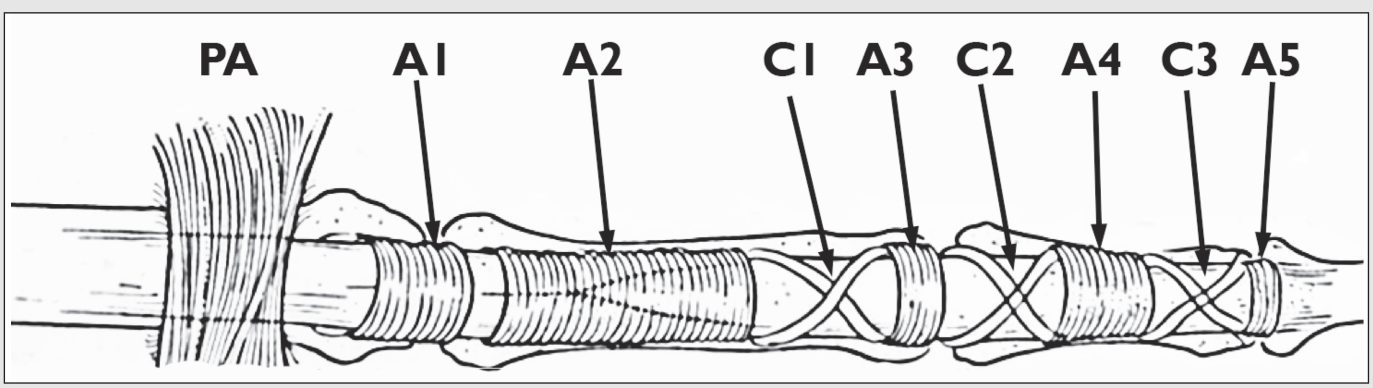


Fig. 15

Pulley System

Recent studies have shown that if all the other pulleys are intact, A-4 may be left unrepaired to allow for better tendon excursion. Invariably with repair of tendon lacerations under A-4, there will be adhesions and loss of excursion after repair. So even with an intact A-4, consideration should be given for excision of A-4 to allow for tendon excursion.

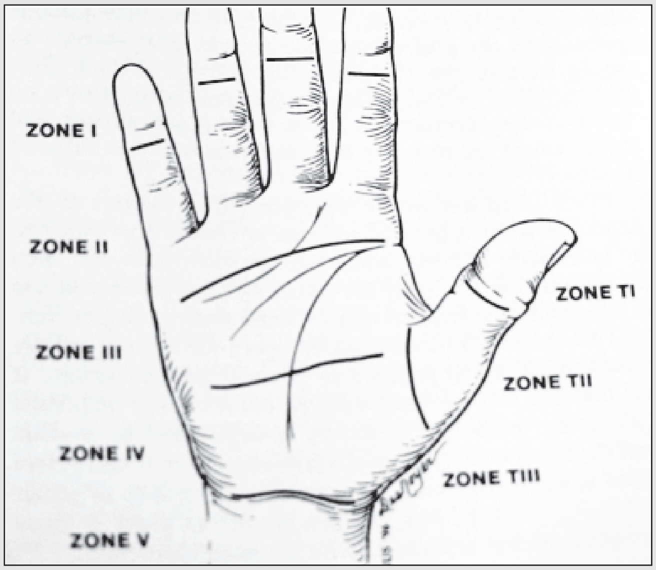


Fig. 16
Flexion Tendon Zones

Flexor Zones in the Fingers and Repair of Tendons in Each Zone.

Radical Advice for Tendon Repairs
Based on suture availability, expected non-compliance, and limited therapists: Braided sutures, either a 3-0 to 4-0 silk/Ethibond®/Mersilene® are recommended for the core suture, plus an additional horizontal mattress to give 4 suture strands across the repair. (One may use 2 weave sutures or a weave suture plus a modified Kessler suture to give the 4 strands across the repair.) Most hospitals have one of these sutures, they are easy to tie with few (3) knots, and they do not slip as Prolene®. Core sutures with an additional 5-0 nylon/Prolene® epitenon running locked suture should allow early range of motion as described below.

- **Zone I**—from A-4 pulley to insertion FDP—repair FDP with core suture. One may need to attach tendon end to the base of distal phalanx with an anchor, or through drill holes, or with sutures passed around the phalanx and through the nail bed on either side. A monofilament suture as Prolene® or wire may be used if the knot is not within the sheath.
- **Zone II**—from A-1 pulley to FDS insertion under A-4 pulley. This is the Fibrous Osseous Canal or "No Man's Land." Repair profundus tendon only if both are lacerated, as there is not sufficient room for excursion if both tendons are repaired. The FDS is excised if injured. (If the FDS is intact and, for some reason, the FDP cannot be repaired and secondary reconstruction will not be performed, then the distal FDP should be sutured to either A-2 or A-4 pulley to decrease the incidence of DIP hyperextension.)

With Zone II injuries, one should explore the injury through a window made in the tendon sheath between A-2 and A-4. A-3 and cruciate pulleys can be sacrificed to provide a "window" for repair. If necessary, the distal half of A-2 and the proximal half of A-4 can be divided in order to retrieve the tendons and perform the repair, but this must be done judiciously, as A-4 is very short.

Many injuries in this Zone occur with the **fingers flexed. The proximal end of FDP may retract into the palm, and the distal end may retract under A-4 pulley**. Exploration in the palm will likely be necessary. One may flex the wrist and MPJ and look for the proximal end of the FDP. **Blind grasping for the tendon end is discouraged!** If the proximal end cannot be readily seen, it is better to identify the tendon in a distal palm incision. A core suture can be placed in the proximal FDP, the suture with the proximal tendon passed under A-2 pulley, and the repair carried out between A-2 and A-4 pulleys. If the FDS is intact, then the proximal end of the FDP should be passed distally through the split in the FDS if possible. If the FDS has been lacerated, it is excised. If one slip of the FDS is intact, it may be left and the lacerated slip excised. The distal FDP end may be retrieved distal to A-4. A core suture may be placed distal to A-4, and the end passed proximally under A-4 for repair in the "window" described above, between A-2 and A-4. The pulleys may be dilated gently with a hemostat or small urethral dilator to allow tendons to pass through easily. As mentioned above, A-4 may be excised for better tendon excursion, especially if all the other pulleys are intact.

- **Zone III**—from distal end of Transverse Carpal Ligament to A-1 pulley, the area of lumbrical muscles—one may repair both tendons if both are injured though many will repair only the FDP.

  The proximal tendon may or may not retract, according to whether or not the lumbricals are divided. Usually, the lumbricals are divided, and the laceration will need to be extended proximately through the Transverse Carpal Ligament and into the distal forearm. The proximal end may retract into the forearm and into a hematoma adjacent to the muscle belly where careful dissection is required to identify it in the hematoma. (Note: divide Transverse Carpal Ligament on the ulnar side in line with the 4th ray, so that the motor branch of the Median Nerve is not injured.)

- **Zone IV**—beneath Transverse Carpal Ligament—divide ligament and repair only the profundus tendon if both FDS and FDP are divided. If the surgeon anticipates good compliance with good therapy after surgery, then both tendons may be repaired. This ideal situation is unlikely in most remote hospitals.

- **Zone V**—proximal to Transverse Carpal Ligament in forearm—may repair both if a sharp, clean laceration, but repair of the FDP alone is adequate. It is important to know muscle relationships and remove hematomas so that proximal tendon ends can be identified.

Incisions in the Hand and Fingers
Incisions for tendon exploration in the fingers can either be a Bruner zigzag incision (small finger in Fig. 17), a mid-lateral incision, or a combination of both. The Bruner incision extends from the end of one crease to the opposite end of the next adjacent crease. These zigzag incisions can be continued into the palm. The author feels a Bruner incision gives the best and easiest exposure for a non-hand surgeon.

Flexor Tendon Repair Technique
Repair flexor tendons with core or weave suture using 2-0 to 4-0 braided non-absorbable suture—**we recommend silk, Mersilene® or Ethibond® if available**. A braided suture holds best and does not slip. Kessler or Modified Kessler suture core techniques are the easiest to use. **IMPORTANT SUGGESTIONS**: It is best to tie the suture inside the repair, as in the modified Kessler repair, so that the knot does not interfere with excursion. An additional horizontal mattress suture or modified Kessler suture increases the strength of the repair and gives four strands across the repair site, as in the Indianapolis repair In Fig. 18. The epitenon should be repaired with a running locked suture of 4-0 to 6-0 monofilament suture. This suture increases the strength of the repair and reduces gapping and bulk. Different techniques have been used, but a running locked suture is easy and works well (See Fig. 19).

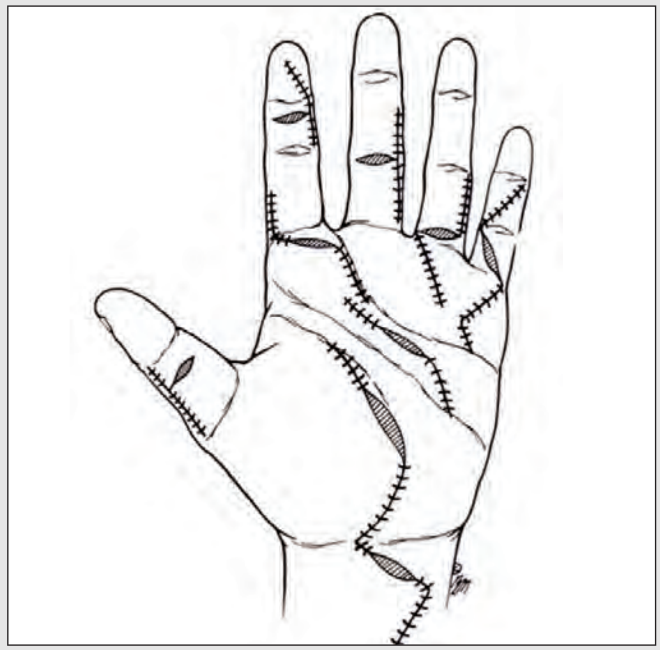
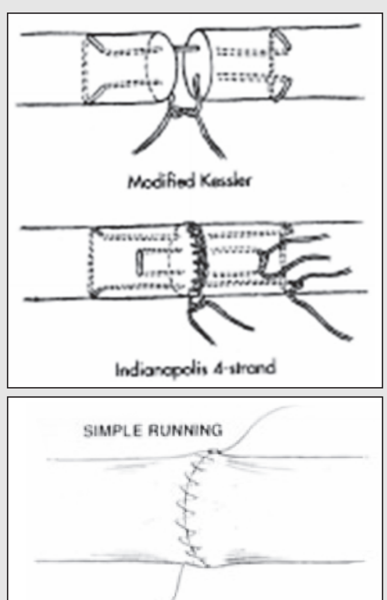


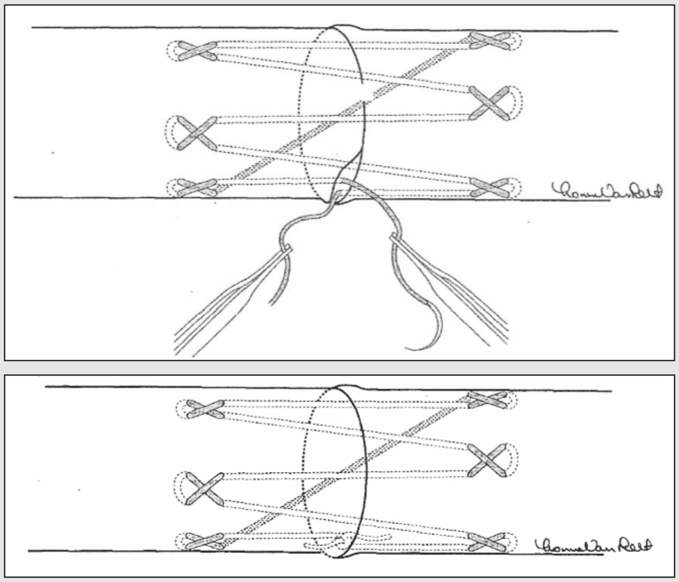
Fig. 17
Finger and Hand Incisions



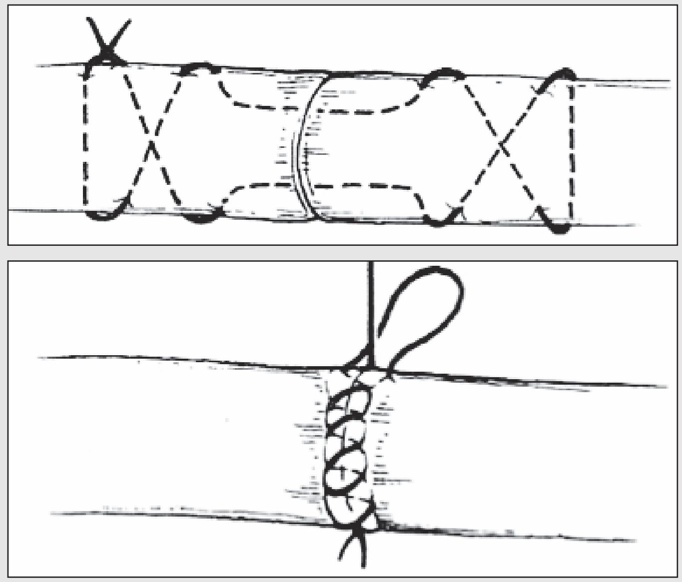
Figs. 18, 19

Modified Kessler puts the suture inside the repair site.

Additional horizontal mattress suture and epitendinous suture add considerable strength to the repair. A locking epitendinous repair is recommended.



Figs. 20, 21
Sandow modification of the
Savage weave repair



Figs. 22, 23
22) Bunnell weave.
23) Epitendinous suture.

During repair, the tendon surface/epitenon should not be grasped, as this leads to adhesions. The tendons are held by grasping inside the end of the tendon with small toothed forceps. Once the tendon ends are pulled into position and approximated in preparation for repair, one may pass hypodermic needles through the tendons and into surrounding soft tissue so that the ends are touching and ready for repair. This prevents the tendon ends from retracting and allows tendon repair without the need to grasp and pull on the tendon.

Important Suggestions: Though a four-strand repair using the Modified Kessler suture and additional horizontal mattress suture as described above may be sufficient for extensor tendon, the author suggests a stronger repair for the early range of motion protocol described below. One may use the Savage/Sandow weave technique (as shown in Figs. 20-21) or the old Bunnell weave for a core suture, followed by another core suture and then an epitendinous repair. The Savage/Sandow weave technique is technically demanding, requiring practice and additional operating time. (Some sutures are now made with two strands attached to one needle for tendon reconstruction. If these are used, one has four strands across the repair site with one core suture, and an additional horizontal mattress suture adds two more strands.) Most hospitals have silk or Ethibond® and **the author suggests you use the older Bunnell weave** for the core suture with an additional modified Kessler or horizontal mattress suture—this gives four strands across the repair. If the silk or Ethibond® core sutures are buried, then there will less chance for adhesions. An epitendinous suture is always added for the reasons given above. Below we will describe early motion that will not only reduce adhesions but improve tensile strength at the repair site.

This is a great suture, but may not be practical for the average general surgeon in the district hospital. The Bunnell suture shown in Figs. 22-23 is recommended (with an additional core suture—either a Modified Kessler or horizontal mattress to give 4 strands). The Bunnell is an old repair and has not been widely used in recent years because of the tendency to bunch up the tendon. If only one tendon is repaired and an epitendinous suture is used to smooth out the repair site, the author feels this is the best repair to allow the early motion protocol.

Recommended Flexor Tendon Repair

1. Bunnell Suture—Would begin suture from inside as shown in the modified Kessler suture in Fig. 18, so that knot is on inside.
2. Additional horizontal mattress or modified Kessler suture will give four strands across the repair.
3. Epitendinous repair as seen in Fig. 23. The author would use a running locked suture.

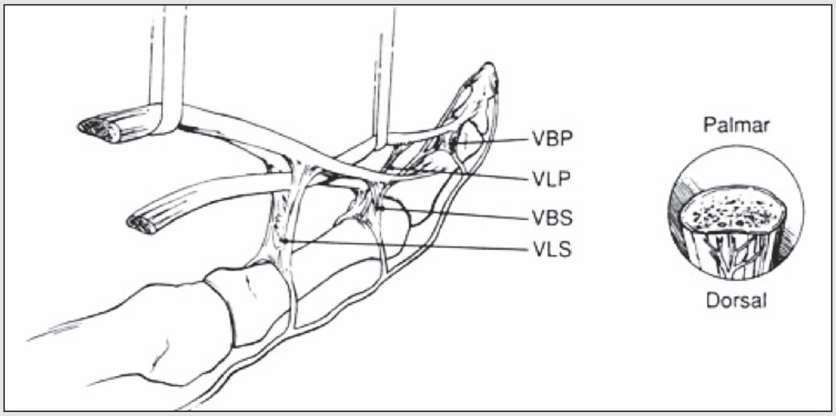


Fig. 24

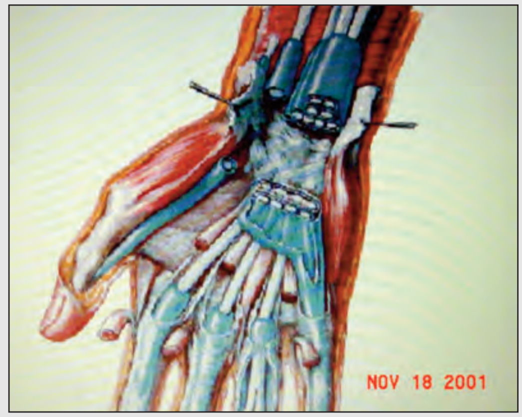


Fig. 25

Blood supply from vincula and bony attachments, and diffusion from synovial sheath (in blue above). Vincula should be preserved if possible during tendon repair (Courtesy of Elsevier).

Tendon Healing

Tendons heal through direct vascular supply at musculotendinous junctions, their vinculae, and through synovial diffusion. They can also receive blood supply through adhesions, but these are not desirable.

Splinting and Exercises: A Different Approach for the District Hospital

For uncomplicated Zone 1 and 2 flexor tendon repairs.

Post-op: In the OR, the patient is placed in a dorsal slab cast that allows 45 degrees wrist extension, MP's flexed to 30 degrees, IP's at 0.

Day 3-4: Passive Range of Motion (PROM) is begun to the fingers at day 3-4 post-op.

- **Ideally, PROM** is done hourly by the patient during waking hours while in the splint. **Practically, one should attempt to do these passive exercises twice daily with ten repetitions for each finger** or whatever is required to achieve a mobile finger prior to active motion. The plaster cast is changed at five days if necessary for dressing changes.
- Active Range of Motion (AROM) in the DIP's is allowed in the cast (gentle wiggles).

Day 4: Once the patient has full PROM, AROM exercises can be initiated in the cast. Under the supervision of the surgeon or therapist, the patient is shown how to actively initiate active flexion of the fingers by flexing the DIPJ's. The uninvolved hand is placed across the mid-palm so that the injured fingers can just touch the other hand(see picture below). The patient is encouraged to slide or **scratch** the fingertips down to the index finger and then

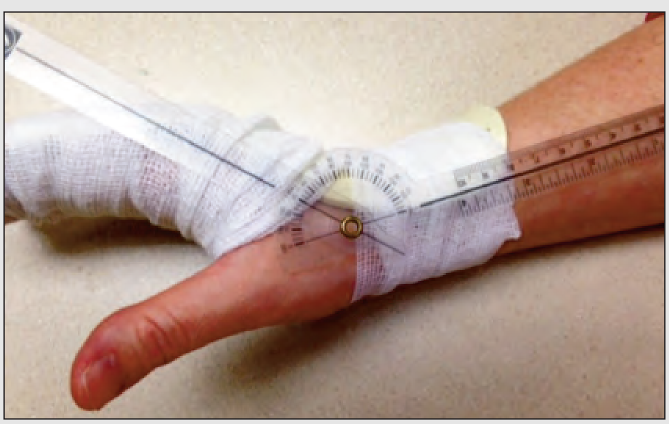


Fig. 26

Fig. 27

Position of wrist joint and MCP joints in the post-op splint after flexor tendon repair in Zones I and II.

Fig. 28

Fig. 29

28) Starting at 4-5 days post-op (when there is full PROM), actively flex finger(s) twice daily down to index finger, and then slide (flex) down to interspace (crease) between fingers.

29) One week later, flex down to long finger, and then slide (flex) down to crease between long and ring fingers.

Fig. 30

Fig. 31

30) At the third week, flex down to ring finger, and then slide (flex) down to the crease.

31) At the fourth week, flex down to small finger, and then slide (flex) down to one's palm.

down to the interspace between the index and long fingers, using the DIP and PIP joints for flexion rather than just the PIP and MCP joints.

Each week the patient is directed to go down or scratch down one more finger until by week four (week five post-op) the patient is flexing the fingers into nearly full flexion down to the small finger and palm.

NOTE

1. Ideally, at least four exercise sessions each day with ten repetitions and PROM must be done before AROM.
2. Early full **active** range of motion (flexion) is not necessary or safe.
3. The patient must understand that they cannot resume normal activities with the hand during the first 6 weeks to prevent rupture.
4. A night volar extension splint may be added to the splint/cast to obtain full finger extension at the IP joints.
5. The initial goal it NOT to make a complete fist, but to learn to initiate movement in the fingers beginning at the tips (DIP's).
6. A few days after sutures are removed and there are no open areas, instruct the patient in scar massage.

If the surgeon and therapist are satisfied with the patient's progress and if the patient lives far away, the patient can be seen back at 4-5 weeks post-op. Otherwise, if there are any concerns about the patient's understanding of the required therapy or concerns about the wound, the patient should be seen at least weekly on an out-patient basis.

4 Weeks Post-op: At four weeks, the patient can come out of the dorsal block splint/cast **under the guidance of the therapist** and begin coordinated wrist/hand movements. Begin flexing the wrist while actively extending the fingers. Allow the fingers to bend as the wrist extends. Functional activities (to be done under the supervision of the therapist/MD) might include picking up cotton balls or other lightweight objects using wrist flexion/extension to help with the finger movement. There is to be NO resistance at this point. These exercises are to be done in addition to the other exercises above. Continue to wear the splint/cast between exercise sessions (See Fig. 32).

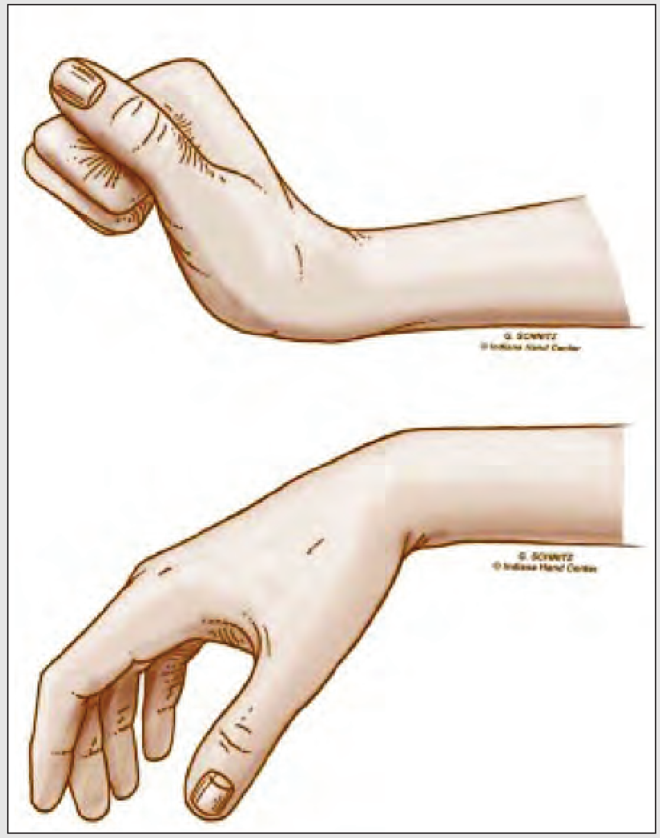


Fig. 32
(From Rehabilitation of the Hand and Upper Extremity, 6th edition: Used by permission from Elsevier)

6 Weeks Post-op:
- At six weeks post op, discontinue the dorsal blocking splint. Begin light activities of daily living (ADL's), while continuing the exercises above.
- Do lumbrical stretches to allow greater FDP flexion.
- Have the patient practice carrying a light weight object using a hook grasp (shopping bag, light weight purse) to encourage flexion at the IP's.

8 Weeks Post-op:
- At eight weeks, light resistive exercises are included, like picking up 1-2 pound objects, and activities of daily living are increased.
- Splinting and therapy may be individualized according to age, intelligence, compliance, location of patient's home, and opportunity for follow-up. When the patient will not be seen for weeks, a realistic approach is necessary.
- Children should be splinted or casted for four weeks without active or passive range of motion. Children will usually recover full range of motion.

This is a radical approach for tendon therapy and ideally should only be done under the supervision of a therapist trained in hand therapy or the surgeon. Unfortunately, most flexor tendon injuries in Zone 2 will lead to adhesions, contractures, and little active motion. This is the reason the author suggested repairing only one flexor tendon if both are injured. Ruptures may occur if the patient is not supervised.

Staged Tendon Reconstruction

This 2-3 stage technique is a secondary procedure and is used when the tendons are damaged beyond repair or when there are severe adhesions after a previous repair. This technique requires the use of a silastic rod (Hunter Rod) for the first stage. The reader is referred to hand surgery textbooks for further information. This technique requires close follow-up, an excellent therapist, and is **not** recommended in most situations. If a functional FDS is uninjured, staged reconstruction is contraindicated.

Tendon Ruptures

Occasionally a tendon repair will rupture accidentally a few days after repair, or when dealing with a non-compliant patient. If this was an accidental rupture, these ruptures could be repaired immediately with reasonably good results. After a few

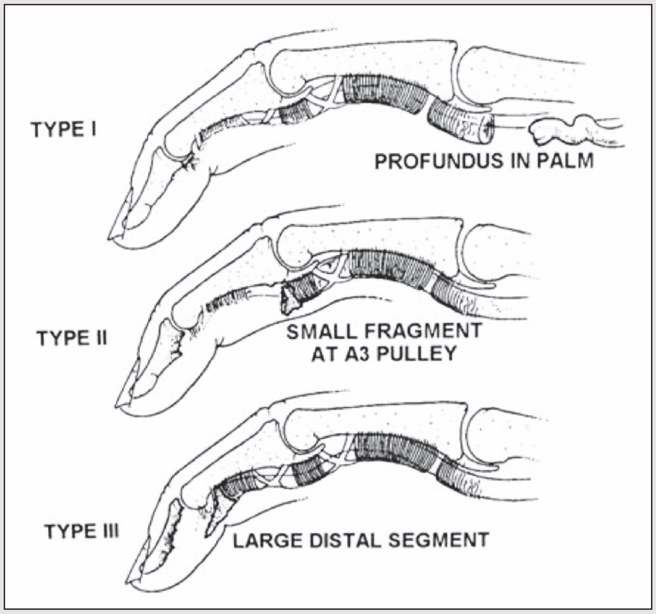


Fig. 33
Avulsion injuries: Types I-III.

days, repair will be difficult, as the tendons will retract.

Partial Tendon Laceration

Occasionally, a patient may present with a partial tendon laceration. This is likely if flexion is weak, painful or incomplete. If the tendon laceration is greater than 50% of the diameter, routine repair with core sutures should be done. If less than 50%, nothing is required, other than trimming or tacking down the cut edges with 5-0 or 6-0 epitendinous suture to prevent catching or triggering on the edge of a pulley. Exercises are begun sooner in these injuries, depending on the extent of the laceration. (Recent studies show only a small percentage of the flexor tendon is necessary for good function.)

Reconstruction of Specific Areas

This is a closed injury with avulsion of the Flexor Digitorum Profundus at its insertion at the base of the distal phalanx. This is suspected with any enlarged and tender finger after a rugby match or rock climbing. This is often called a “jersey injury” from catching a finger, often ring finger, on a jersey with forced extension of the distal phalanx while there is maximum FDP flexion. This is suspected with a swollen finger after closed trauma, and it is important to diagnose this soon after injury. There are four types:

I—FDP retracts into palm: early recognition is important, repair within 1 week.

II—FDP retracts to PIPJ or distal edge of A2 pulley with or without a small bone fragment (may have vincula still intact), may still be able to repair at 4-6 weeks.

III—FDP with larger fragment of distal phalanx retracts to A4 pulley, may be able to repair at 6-8 weeks.

IV—FDP and small fragment of distal phalanx retract, but separately, and both need repair urgently as FDP may retract into palm—unusual injury.

Achilles Tendon Injuries

Acute open injuries can be repaired with several core weave sutures, as in flexor tendon injuries, or a Krackow whip stitch with a large braided non-absorbable suture—probably the largest available in the hospital (usually silk or Ethibond®). It is best to expose the tendon through a medial incision. The ankle may then be casted in plantar flexion for 6-8 weeks. If the Achilles is avulsed off the calcaneus, it can be repaired using large bone anchors or with sutures passed through drill holes. A drill is used to

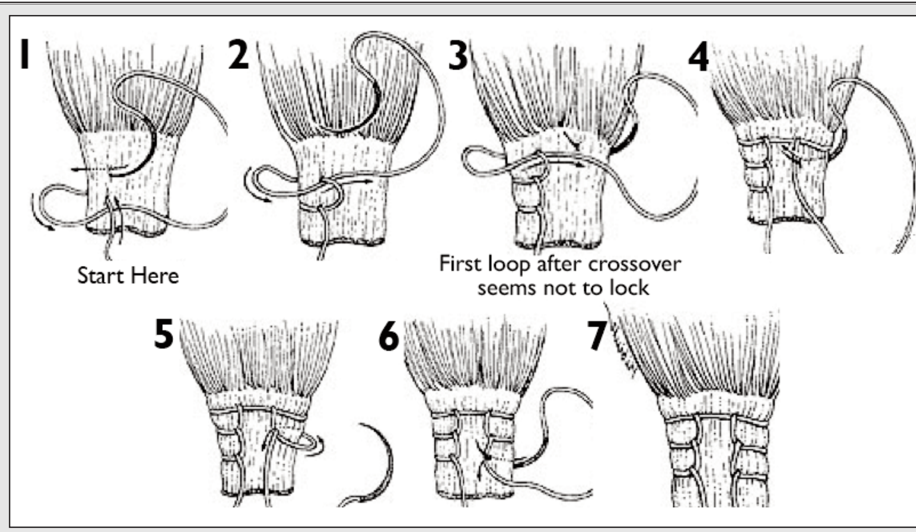


Fig. 34
Krackow suture for Achilles and Biceps (Courtesy of Kenneth A. Krackow).

make horizontal/transverse/ holes at the normal tendon insertion in the calcaneus. Sutures are passed through these holes and then through the distal tendon. Acute closed ruptures can be treated open or closed with equally good results in recent literature studies.

Krackow suture is shown in Fig. 34. Many now add a second suture to give four strands for both Achilles tendon and biceps tendon repairs.

Summary

Tendon injuries require early identification and repair. Even in major centers, excellent results are difficult to achieve with flexor tendon injuries in the hand—these require special and frequent therapy sessions and exceptional patient compliance. Any severe trauma or crushing type injury further compromises the final result. If therapists are not available to follow the patient on a bi-weekly or weekly basis, the surgeon must learn basic therapy techniques described above to care for his patients.

Because of the poor results with a limited range of motion after tendon injuries in remote locations, the authors feel the suture technique and therapy described above gives the best chance for the patient to regain a functional hand. This includes using four strands across the repair with silk or Ethibond® sutures, plus an epitendinous suture. Using the therapy protocol above for one week in the hospital has the best chance of giving the patient a functional hand. The patient should not be discharged within the first week no matter how well the wound is healing.

Nerve Injuries

All major nerves that can be identified should be repaired. Identification requires knowledge of anatomy, and as mentioned before, **it is important that the surgeon always has an anatomy book in the operating theatre**. Immediate direct repair or repair with nerve grafts is best. Even after a few days, dissection of nerve ends may be difficult. If one must delay repairing a nerve because of severe contamination, severe crushing injury, nerve avulsion or loss, or inadequate surgical skills, the ends should be tagged with 2-0 or 3-0 non-absorbable suture, as Prolene® or nylon, and ends left long. Ideally this should be with a blue, black or green suture that will be easily recognized during a second stage. Nerve repairs can easily be disrupted after repair and during repair of other structures. Therefore, the author repairs these after tendons have been repaired, unless they are deep in the wound.

The surgeon must perform a careful exam with each injury. Glass injuries are especially deceiving as the direction glass penetrates is sometimes difficult to determine. A glass injury on the radial side may still damage the ulnar nerve.

Table 3 shows the last muscle innervated by each nerve and the exam to determine the function of that muscle. The autonomous sensory zone—where there is no overlapping of sensory innervation—is shown. There are other ways to exam each muscle, but the pointing of the index finger—radial nerve, snapping of thumb and fingers—median nerve and crossing of fingers—ulnar nerve gives an easy and quick motor exam.

Table 3

Nerve	Last Muscle Innervated	Autonomous Sensory Zone
Radial	Extensor Indicis (EIP). Point w/Index	Dorsal First Web Space
Medial	Abd. Pollicis Brevis (AbPB). Snap Fingers	Volar Surface Index
Ulnar	First Dorsal Interosseous (1st DI). Cross Fingers	Volar Surface Small

Tables 4-6 present the findings when each nerve is injured at each level in the upper extremity.

Table 4

Level	Motor Loss	Sensory Loss
Above Elbow	Wrist/finger extension	Dorsum of hand, radial side
Elbow	Finger extension; weak wrist ext.	Same
Mid-Forearm	None	Same
Wrist	None	Same

Findings when the Radial Nerve is Injured

Radial nerve injuries at and above the elbow will result in a wrist drop and inability to extend the fingers at the MPJ. No muscles in the hand are

Table 5

Level	Motor Loss	Sensory Loss
Above Elbow	T, I, L flexion; Weak pronation; Thumb abduction	Volar T, I, L; 1/2 of R; Thenar eminence
Mid-Forearm	Thumb abduction	Same
Wrist	Thumb abduction; (thenar wasting)	T, I, L; 1/2 of R

Findings when the Median Nerve is Injured

innervated by the radial nerve.

It is unusual just to have nerve injuries without muscle or tendon injuries. Often the surgeon will determine at exploration if the loss of function is due to a nerve or muscle injury.

The nerves in the upper extremity that should be repaired are the median, ulnar, radial, superficial radial, superficial ulnar, and digital nerves.

Table 6

Level	Motor Loss	Sensory Loss
Above Elbow	FDP; S, R; Intrinsics; No claw	Volar surface; S; 1/2 of R
Mid-Forearm	Intrinsics; Claw	Same
Wrist	Same; Froment's Sign	Same

Findings when the Ulnar Nerve is Injured

Repair Technique

Epineural repair is recommended. It is important to align the nerve as near normal as possible. This is not always easy, but in larger nerves one can align by:

- the direction of the cut.
- the location of blood vessels and align these to the other end.
- fascicular size and pattern.

Often the nerve ends need sharp trimming, **but only after one has determined the alignment**. (For example, it is easy to determine the alignment of an obliquely cut nerve when it is first inspected rather than later when it has been divided transversely for repair.) This is best done by a new sharp blade against a sterile wooden tongue depressor, but any flat surface will do. Herniating, protruding fascicles must also be trimmed back. Larger nerves should be repaired with 6-8 interrupted sutures. Smaller nerves are repaired with 2-4 sutures, and digital nerves with 1 or 2 sutures. In the larger nerves, the first sutures are best placed 180° from each other and left long for manipulation of the nerve. It is often easiest to flip the nerve over and repair the deep surface first. After repair it is important to splint the extremity so that tension may be taken off the repair. Three weeks immobilization is usually sufficient. It is ideal if these repairs can be carried out under loupe magnification, but it is understood that many rural hospitals do not have these. Larger nerves may be repaired with 4-0 to 6-0 monofilament non-absorbable suture. Digital nerves should be repaired with the smallest non-absorbable suture available, i.e. 4-0 to 8-0.

Specific Nerves

Median, Ulnar and Radial Nerves in the Arm or Upper Forearm

- These nerves should be aligned as best as possible using the guidelines above.
- With the radial nerve around the elbow, one should try and identify the sensory portion of the nerve above and below the laceration so that the motor fascicles may be approximated. This will likely not be possible in most locations. The radial sensory nerve at this level provides sensation to the dorsum of the hand on the radial side, but the radial motor fascicles innervate all the extensor muscles of the hand and fingers.
- The ulnar nerve may need to be transposed anterior to the medial epicondyle to remove tension on the repair. This is almost always necessary with ulnar nerve injuries near the elbow. Though the nerves are divided into definite and specific fascicles at this level, not random as once thought, still it is best just to do one's best in aligning the nerve, especially without magnification.

At the Wrist

- The superficial radial and ulnar nerves and palmar cutaneous branch of the median nerve should be repaired to prevent neuromas. These are small and difficult to see without loupes.
- The ulnar nerve topography at the wrist has two distinct fascicular groups, with the motor group ulnar to the sensory group until Guyon's canal,

where it passes deep or dorsal to the sensory fascicular group. Attempt should be made to approximate the motor fascicular group.
- The median nerve topography is a little more complex with the motor fascicles. In the mid-forearm, the anterior interosseous nerve is posterior or dorsal and is usually distinct. At the wrist, the motor branch to the thenar muscles is volar and radial. The motor branch should be carefully identified distally and then dissected proximally to the injury site. By first identifying the motor branch distally, the motor fascicles in the proximal nerve end can be better identified. If one has a nerve stimulator, this will help identify the distal motor fascicles. The distal muscles will respond to stimulation for 48-72 hours.

Hand
- Digital nerves should be repaired, especially on the radial side of each finger and both sides of the thumb. These are repaired after tendons are repaired with 1-2 sutures of the smallest monofilament non-absorbable suture you have and can see.

Nerve Palsy
Injuries with resulting paralysis of the major nerves to the hand are common. Often the diagnosis is missed at the time of the injury. When patients present late with upper extremity nerve palsy, it is usually easy to determine which nerve is involved. On the other hand, when there has been severe damage to muscles as well as nerves, the diagnosis is not as clear.

Radial nerve injuries above the elbow will have a classic wrist drop, whereas those below the elbow will not have a wrist drop; however, they will have weakness in MPJ extension of the thumb and fingers. Median nerve injuries at any level will lead to thenar wasting and loss of thumb palmar abduction and opposition. Ulnar nerve injuries above the elbow will not produce the typical "claw" deformity since the long flexors of the small and ring fingers are also paralyzed. When the injury is in the mid-forearm or wrist, there is typical claw deformity of the small and ring but not of the index and long since the lumbrical muscles to the index and long are innervated by the median nerve and protect these fingers from clawing by flexing the MPJs. A complete claw deformity is seen in injuries to the median and ulnar nerves in the distal forearm and wrist—since the long flexors are intact. Ulnar nerve injuries at any level will lead to muscle wasting between the fingers and in the first web space, first dorsal interosseous. There are other findings, and tests are found in the major textbooks.

Late Repair of Nerves
Nerves may be repaired directly or with nerve grafts. For muscle reinnervation, the sooner the better. Delayed repair will still give protective sensation. Except in the very young, reinnervation of intrinsic muscles rarely occurs unless the injury is sharp and near the site of innervation in the hand. Also, the repair must be performed soon after injury. Late nerve repairs should be carried out, but with the understanding that muscle function will not return with a delay of 6 months unless the injury is very close to the site of innervation. Radial nerve injuries at the elbow have been repaired late, with the return of some motor function since the site of innervation for some extensor muscles is close to the elbow. It is recommended that tendon transfers also be done at the same time when a radial nerve is repaired late, greater than six months. Late repair of the median and ulnar nerves may be done for protective sensation.

The treatment for nerve palsies with tendon transfers is beyond the scope of this book. Major textbooks have detailed descriptions of the various types of reconstruction. The motor losses that require tendon transfers include the following:

- Radial nerve—wrist drop and thumb/finger extension at MPJ.
- Median nerve—thumb opposition.
- Ulnar nerve—finger extension at IPJs with correction of claw and thumb/index pinch.

Vascular Injuries
Brachial artery injuries should be repaired. Injuries to the radial and ulnar arteries should be repaired if there is any evidence of ischemia. Certainly when both arteries are divided, at least one should be repaired. Repair with 5-0 or 6-0 monofilament suture. If one artery is divided, then it should be repaired if there is any evidence of ischemia. One can verify collateral flow through the palmar arch by appearance and using a Doppler to determine if there is arterial flow throughout the hand. Visualizing capillary refill is often the only method of determining flow if one does not have a Doppler. Use of the Allen's test is helpful.

Chapter 34
Hand Fractures and Dislocations

Bill Rhodes and Louis L. Carter, Jr.

Preface

This chapter is for those surgeons who have the time, knowledge, expertise and equipment to handle hand fractures. Many general surgeons in remote hospitals have not had the necessary training to treat hand fractures. Some who have been trained under an orthopaedic surgeon in the use of a C-arm, closed and open reduction, and internal fixation of small fractures will not have this equipment and instrumentation in their mission or district hospitals. A C-arm is necessary for accurate closed reduction and fixation of hand fractures. Closed fractures should not be opened in most cases. Dislocations may need open reduction.

Without a C-arm, closed manipulation and splinting or casting is all that should be done, and in most cases this is adequate and allows for rapid healing.

This chapter is written to give basic guidelines for the treatment of the closed fractures that are grossly displaced, angulated, or rotated, and for the treatment of open fractures. The treatment for common dislocations will also be discussed.

Hand anatomy books should be available every operating room, and the surgeon should not feel embarrassed referring to these before and during surgery.

A few who have had training by an orthopaedic surgeon and have a C-arm available may be able to reduce and fix these fractures and dislocations, and guidelines are included in this chapter as well.

Introduction

Traumatic injuries to the hand present a significant challenge to the general surgeon because of the complex anatomy and the endless number of possible traumatic scenarios. Injuries can range from simple closed fractures to complex open wounds that involve not only fractures but injuries to tendons, neurovascular structures, and soft tissue. The goal of this chapter will be to describe the treatment options for these injuries within a clinical setting that has limited diagnostic and treatment capabilities.

Several factors are especially relevant when treating these injuries in remote areas:

1. Has there been a delay in seeking medical attention?
2. Are there other life or limb threatening injuries?
3. Non-compliance in postoperative follow-up for wound care and physical therapy.
4. The lack of trained therapists for rehabilitation after hand injuries.

Even the best surgical intervention can be undermined by the non-compliance of the patient during the post-operative phase, as well the inability to provide timely and effective hand therapy to restore function. The surgeon must take a realistic approach to the management of hand fractures to deliver the best result possible. While there are only a few actual hand therapists in Sub-Saharan Africa, there are many physical and occupational therapists. Unfortunately, few of these have hands-on experience in hand therapy, and even fewer work in district hospitals. Thus, often the doctor must also be his own therapist for the patient to regain a functional hand.

(**Editor's Note:** Open reduction and internal fixation should only be carried out for the most severe of **closed** hand fractures. Open reduction will often leave the patient's hand stiff and non-functional. A poorly reduced but functional hand will be better than a reduced but stiff hand. If the wound is already open, then one should go ahead and fix these open fractures and dislocations.)

Initial Evaluation

All fractures and dislocations involving the metacarpals and phalanges should be assessed in a thorough and thoughtful manner. An appropriate history and physical exam must be performed. Concerns include:

- The time since the injury occurred: hours, days, weeks, or even months.
- Specific site of pain, tenderness, swelling, deformity, and if there is an open wound.
- Determine if lack of movement is secondary to pain, fracture, tendon or nerve injury.

Fig. 1

Fig. 2

Importance of oblique views—see base of proximal phalanx of ring finger. Fracture is difficult to see on PA view but obvious on oblique.

- Determine if there are other associated upper extremity injuries involving elbow or shoulder.
- Review appropriate x-rays to evaluate any fracture/dislocation.
- The basic hand views are AP, lateral and oblique. Often oblique x- rays omitted but some oblique, spiral, and small intra- articular fractures may be missed **unless oblique views are taken**.
- X-ray technicians must learn to take x-rays of an **individual finger** alone and not the entire hand when only a single finger is injured. A full hand x-ray often does not show the finger deformity clearly.
- There are **special x-rays** to help diagnose certain fractures when clinical exam suggests a fracture and routine x-rays fail to demonstrate an abnormality. These will be mentioned below.

Initial Care

Prompt attention to cleaning all wounds and open fracture sites is a priority. This may require sedation with local or regional anesthesia or even general anesthesia. Hand and upper extremity wounds can be debrided and closed if less than 24 hours old. Ideally tendon, nerve, and bony injuries will be treated acutely. If someone with the expertise to repair these structures is not available, then debridement and copious irrigation should be followed by loose closure (see the "Clean Closed Wound Concept" in Chapter 2 on Wound Care). The hand should be elevated at all times post-op. Definitive repair can be performed later, as this is now a clean closed wound. DO NOT simply dress an open wound with the thought of definitive surgery the following day. It is always best to loosely close the wound immediately if adequate debridement has been carried out, since no one can predict the operating room schedule the following day. Ideally, delayed repair should be done as soon as possible, but a delay of 7-10 days is not harmful as long as the wound is closed. Systemic antibiotics should be given in cases of open fractures and where there is contamination.

With injuries presenting after 24 hours, repeated debridements may be necessary for several days before the wound can be safely closed. Sometimes the use of a VAC, if available, will be necessary. Since the soft tissues of the hand are well vascularized, minimal debridement is sufficient, along with the removal of all obviously necrotic tissue and foreign bodies. In the rare case that a wound cannot be closed directly or with a skin graft or flap, then it is important to keep the wound moist, and the extremity elevated between debridements (see again Chapter 2).

Basic Nomenclature of Fracturs and Dislocations

- **Angulation**: The position of the apex of the fracture determines whether the angulation is dorsal or volar. Metacarpal fractures often have an apex dorsal angulation, whereas proximal phalanx fractures have an apex volar angulation due to muscle forces.

- **Rotation**: Common in oblique and spiral fractures, and can be diagnosed by actively or passively flexing the fingers into the palm. Overlap of the fingers is seen. Rotation can also be identified by comparing the plane of adjacent fingernails. Rotation must be corrected, as 5° of rotation at the metacarpal level can result in 1.5 cm of overlap of the fingers.

- **Dislocation**: The position of the distal bone determines whether the dislocation is dorsal or volar.

- **Displacement**: When the bony fragments on each side of the fracture are not in alignment with each other.

- **Comminuted**: When there are multiple fracture fragments.

Anesthesia

The choice of anesthesia depends on what is available in your hospital. For adults, an axillary block or Bier block is adequate for most hand injuries. A wrist or digital block will be satisfactory for finger injuries. Ketamine is also sufficient for closed reductions, especially in children. A tourniquet should be used with any open fracture or open procedure. General anesthesia may sometimes be required.

Once x-rays have been taken and the diagnosis confirmed, a **hematoma block** with lidocaine in the casualty department or operating room will give good anesthesia for a reduction, casting or splinting of some fractures.

Resources

Keep an anatomy book in your OR at all times and refer to it as needed. One should never be ashamed to refer to these books when taking care of your patients.

Metacarpal Base (CMCJ) Fractures and Dislocations

Thumb

Special x-ray view of Thumb CMCJ: Robert's view—forearm pronated, shoulder internally rotated and thumb abducted against the film.

- **CMCJ dislocation** of the thumb without a fracture on AP, lateral and oblique views of the thumb: An isolated CMCJ dislocation is usually dorsal. If closed reduction is successful, a thumb spica splint should be applied for six weeks. Then range of motion is initiated. If closed reduction is unsuccessful, then an incision can be made along the radial border of the thumb, with a palmar extension along the distal wrist crease (Wagner), and open reduction and pinning with K-wires carried out. One must preserve the dorsal branches of the radial nerve in this incision. The thenar muscles are reflected volarly off the metacarpal to better visualize the joint.

- **Bennett's fracture** is an oblique intra-articular fracture of the metacarpal base, with the undisplaced ulnar fragment attached to the anterior oblique ligament or metacarpotrapezial ligament. The large radial shaft fragment is displaced dorsally, proximally, and radially with the pull of the abductor pollicis longus tendon. Though this is an unstable fracture pattern, closed reduction may be attempted by traction on the thumb with adduction and pressure over the

Fig. 3

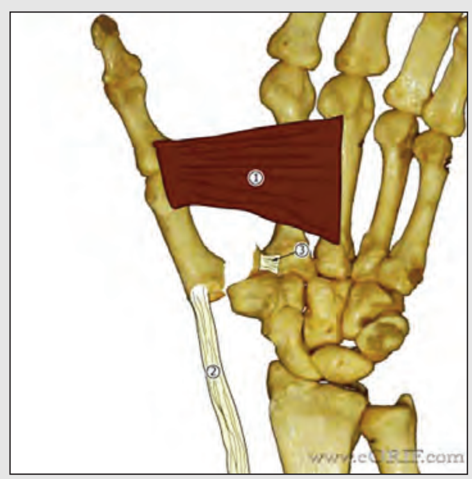
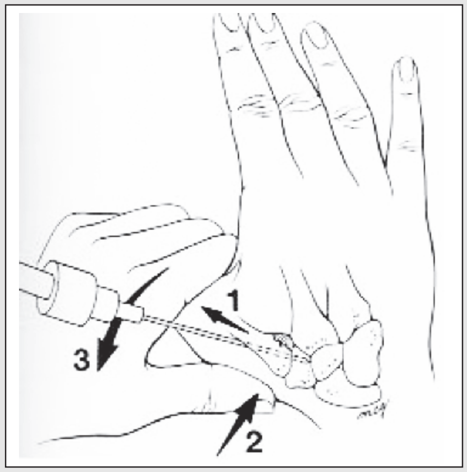


Fig. 4

Bennett's Fracture showing pull of adductor ulnarly and APL proximally (Courtesy of eORIF.com).

radial side of the thumb base, while applying a thumb spica cast which includes the wrist joint and the thumb MP joint. If it is difficult to hold reduction, one or two K-wires may be passed from the thumb metacarpal base blindly into the carpus before the spica cast is applied.



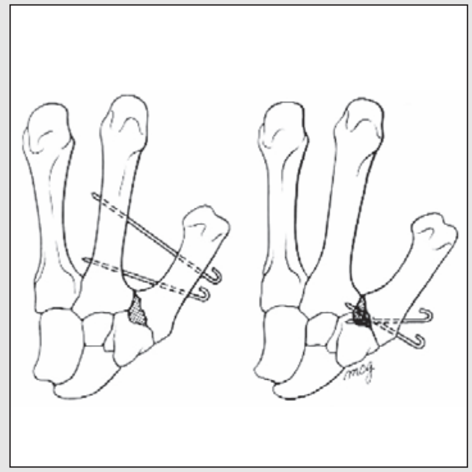


Fig. 5 **Fig. 6**

5) Method to reduce Bennett's fracture: traction, abduction, pressure at the base. 6) Other methods of fixation. (Courtesy of eORIF.com)

Fig. 7 **Fig. 8**

Rolando Fracture PA and Lateral views. (Courtesy of eORIF.com)

- If followup x-rays show reduction, the patient should be followed weekly to ensure reduction is maintained.

  If the fracture cannot be reduced, or reduction maintained, an incision as described above is used. The fracture site is exposed, the metacarpal reduced, and two .045-inch Kirschner wires are inserted from the radial thumb metacarpal shaft into the ulnar fragment or proximal trapezium and carpal bones. If the ulnar fracture fragment is large enough, direct pinning into it with two K-wires can be done. A thumb spica radial gutter splint is applied. The pins are removed at three weeks. Active range of motion exercises are then begun, and the splint is worn when not exercising for an additional three weeks.

- **Rolando fracture** is a rare comminuted, intra-articular, V-shaped fracture of the metacarpal base. Closed reduction with or without pinning is rarely successful. Open reduction and pinning is difficult but can be attempted if there are large displaced fragments. External fixation with traction on a distal pin may be best—pins are placed through the trapezium or carpus and a distal pin through the distal metacarpal or proximal phalanx. Skeletal traction can be performed while placing these K-wires, and then incorporating the wires in a thumb spica cast. If these techniques are not possible, the thumb should be placed in a thumb spica splint or cast for three weeks. Then range of motion exercises may be started, and the splint worn for an additional three weeks when not exercising.

  (**Editor's Note:** It cannot be overemphasized that closed reduction with splinting or casting is best if one does not have experience with this surgery and is not certain of hand anatomy. Immobilization for 3 weeks followed by early exercises will often result in a functional hand.)

- **Open fractures** of the thumb CMCJ will be

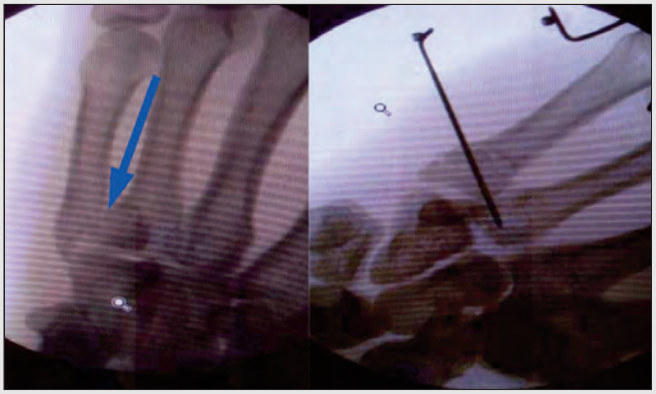


Fig. 9

Fracture dislocation small CMC joint.
(Courtesy Dr. Jason Rehm)

Fig.10

Fig.11

Fracture dislocation at base small finger. If severely displaced, treat with pins as above, but casting will work in most cases if one lacks experience and x-ray control.

treated the same way after adequate cleansing and debridement.

Metacarpal Dislocations of Other Digits

- The most common **CMC joint fracture/dislocation is a dorsal dislocation of either the ring or small finger** or both. **The best x-ray to ascertain these fracture dislocations is an AP view with the hand pronated 30° from a fully supinated position. Another good view is a lateral view with the hand pronated 30° from neutral**. This view shows the amount of subluxation at the CMC joint of the ring or the small finger. The fracture dislocation of the small finger is similar to the Bennett's fracture of the thumb. The distal fragment is dislocated dorsally and proximally by the pull of the extensor carpi ulnaris tendon—small finger. Stabilization of these fractures may be difficult to maintain with just closed reduction and splinting or casting. Two K-wires can be passed blindly after reduction into the carpus and/or ring finger, but only if swelling is minimal. If this is not possible, it is acceptable to treat these with splinting and range of motion after three weeks rather than an open reduction and pinning.
-
- **CMC fracture/dislocation** involving the index, long, ring, or small finger can be suspected by significant swelling over the dorsum of the hand. These are due to high energy injuries. **These are usually dorsal and often involve multiple fingers**. The **best x-ray to ascertain these fracture-dislocations is an AP view with the hand held 30 degrees pronated from a fully supinated position**. With these fracture-dislocations, it is difficult to maintain stabilization with closed reduction. Blind retrograde pinning from the metacarpal into the carpus is possible once the swelling has subsided. The sure option is by open reduction through a dorsal incision, with direct visualization and

Fig. 12

Fig. 13

Carpometacarpal fracture dislocations are rare and usually dorsal. Both dorsal and volar are due to high energy forces, and are often associated with other severe injuries. There is significant soft tissue swelling, and surgery should be delayed until swelling subsides with elevation.
(Courtesy of eORIF.com)



Fig.14 **Fig.15** **Fig.16**

Non-intra-articular fracture of metacarpal base. Treat closed unless open fracture. If significant angulation, this pinning method is an excellent method of stabilization. One will need x-ray control for pinning.

insertion of K-wires in a retrograde manner. If these are open dislocations, reduction and pinning as above can more easily be performed. K-wire fixation helps reduce the severe pain associated with these injuries, but when one lacks experience, these may be splinted three weeks, and range of motion begun. When not exercising, a splint should be worn for six weeks.

- **Volar dislocations** result from significant force and are rare and frequently missed. Open reduction is indicated after swelling has subsided. In any CMCJ dislocation, associated fractures may result in rotation. Before and after pinning, great care should be taken to rule out rotation by flexing the fingers into the palm.

  (**Editor's Note**: These are severe injuries with significant swelling. They are frequently missed. There is very little motion at these joints, so splinting, elevation and early range of motion is acceptable.

Metacarpal Fractures

- **Metacarpal fractures** may be at the base, in the shaft or at the neck. They can occur in transverse, spiral, or oblique fracture patterns. Shortening at an isolated fracture site of up to one centimeter may be acceptable if there is no rotational deformity. **Angulation** may be accepted if the angulation is less than 10° in the index and long, less than 20° in the ring and less than 25° in small. Rotational deformity of even a few degrees is unacceptable. If closed reduction is performed, great care must be taken to ensure stability without rotational deformity. Many shaft fractures can managed by closed reduction and casting for four weeks with the wrist extended 20-30° and MP joints flexed. The cast is extended out to but not including the PIP joints so they are free to move. Fingers can be buddy-taped together to help correct and prevent rotation. Transverse fractures are often angulated with the apex dorsal. Reduction is accomplished by traction, flexion of MP joints and dorsal pressure over the metacarpal shaft while applying the cast (Jahss Maneuver).

- A single metacarpal fracture should be treated with closed reduction and casting. **Rarely will it**



Fig.17 **Fig.18** **Fig.19**

Metacarpal shaft fracture with 60 degrees apex dorsal angulation. (Courtesy of eORIF.com)

be necessary to open a single metacarpal fracture. If closed, reduction is possible, but maintenance of stabilization is not possible in a border metacarpal, percutaneous closed pinning may be attempted but it is difficult without a C-arm. This can be accomplished by maintaining reduction and placing several K-wires transversely across the metacarpals pinning the fractured metacarpal to a normal one above and below the fracture site—see Fig. 20.

- **Open reduction may be needed in the following situations:**
  - There are multiple fractures.
  - The fracture(s) is significantly displaced, and bony approximation cannot be corrected by closed reduction.
  - Rotation cannot be corrected.
  - Open displaced or rotated fractures.
  - Spiral, oblique central metacarpal (long and ring) fractures require closed correction of rotation and buddy-taping of the fingers—see Figs. 23 and 24. Shortening in these metacarpals will not be significant and does not require open reduction.

For all hand fractures, if a C-arm is NOT available, a portable x-ray in the theatre can be used. If a portable x-ray is unavailable, then the patient can be given a regional block and taken to x-ray where serial x –rays can be taken after each attempt at reduction. The patient should be closely monitored by anesthesia personnel. If pinning is performed in the x-ray department, great care must be taken to maintain a sterile environment.

Realistically, it is rare for closed metacarpal fractures to be opened at our hospitals without an orthopaedic surgeon present. Most are splinted and early range of motion started at three weeks. **A deformity may result, but the hand will be functional**.

- **Methods of ORIF-open reduction and internal fixation:**
  1. Transverse K-wires above and below fracture into normal metacarpals (percutaneous and closed if possible—recommended). See Fig. 20.
  2. Crossed K-wires, bent, inserted antegrade from base of metacarpal (this will be difficult without experience).
  3. Crossed K-wires passed retrograde through

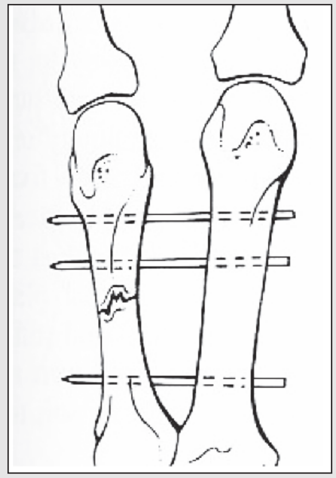


Fig. 20

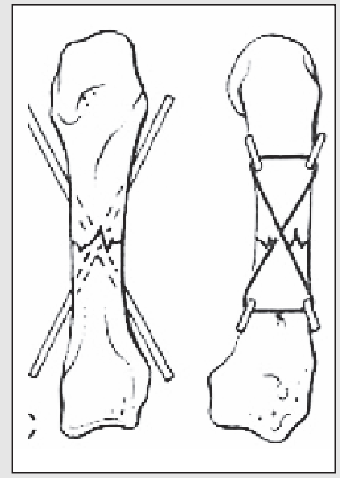


Fig. 21

20) K-wires above and below the fracture and into adjacent normal metacarpal.
21) Crossed K-wires and with Fig. of eight wiring ORIF—only if fracture open.
(Courtesy of eORIF.com)

Fig. 22

Spiral metacarpal fractures. Index fracture appears stable in this view. There is likely minimal shortening of the ring and long. If closed but angulated, these fractures would be best treated with K-wires from small to the ring and long under x-ray control. If this is not possible or if angulation is minimal, closed treatment with casting in position of protection is best—MPJs flexed and IPJs extended. If there is malrotation, the fingers can be buddy-taped together—see Figs. 23 and 24. If these fractures are open, then they may be treated with interosseous wires, cerclage wires, or small interfragmentary compression screws, if available.

MC head (usually requires x-ray control and experience).

4 Crossed K-wires passed antegrade from the fracture site through the distal fragment until they emerge through the distal cortex, then passed retrograde into the proximal fragment—possible only with open reduction, best used with an open fracture (see Fig. 21).

5 One K-wire through the fracture, and one or two interosseous 24 gauge steel wire for oblique border metacarpals.

6 One K-wire through the fracture and cerclage steel wires—if the fracture is oblique or spiral.

7 90:90 stainless steel 24-gauge wire sutures provide excellent stabilization, if one must open a fracture or if the fracture is open. Use K-wires to make **horizontal and vertical** drill holes through both ends, 5 mm from the fracture. (K-wire is passed from 3 to 9 and 12 to 6 at each end.) A 19-gauge needle is passed through the drill holes, and a wire suture or stainless steel wire is passed through the needle. The wire is pulled through on the opposite side, the needle removed, and then the wire is passed back through another needle in the opposite fragment drill hole. The sutures can then be twisted down. This method is ideal for an unstable transverse fracture, and especially an open fracture.

- If there is rotation of a transverse fracture, the first or last two techniques will likely be necessary.
- Towel clips are excellent to temporarily stabilize the spiral or oblique fracture.
- Open, rotated spiral fractures may be treated with K-wires into adjacent stable metacarpals, or K-wires or interosseous wires across the fragments.

Pinning methods above should be carried out with .028, .035, or .045 K-wires, according to the size of the metacarpal. If possible, K-wires should be left just outside the skin so they can be removed at three weeks. If not, they can be left beneath the skin without difficulty.

Casting these fractures in the “protective position” is necessary, as none of the above techniques will give rigid fixation except the 90:90 wiring.

Exposure for metacarpal fracture fixation is through the laceration, or through a longitudinal incision along one side of an extensor tendon. Adjacent metacarpals can be approached by an incision midway between them.

Protective position: Wrist slight extended, MPJ flexed 80-90° and IPJ extended.

(**Editor’s Note**: The above techniques are for those with expertise and time to treat these fractures. Most will not have expertise in this surgery or the operating room time. Metacarpal fractures can be treated closed with casting. Just be sure that rotation has been corrected, and motion is started after 3–4 weeks. A volar splint or gutter splint is worn when not exercising during the next three weeks. **Rotation** can be determined by flexing the fingers into a fist to ensure there is no overlap and by ensuring the

Fig. 23

Fig. 24

Casted in protective position. Note buddy-taping between ring and long to help prevent rotation. (Courtesy of eORIF.com)

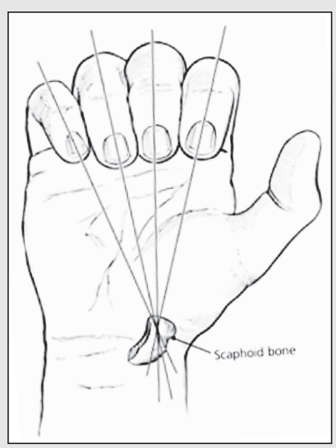


Fig. 25

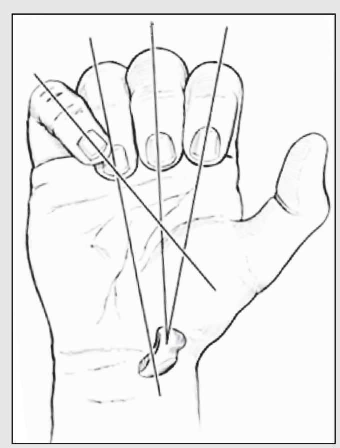


Fig. 26

Finger tips should point to scaphoid. Note overlapping between the small and ring finger tips on the right.

fingernails are parallel. All the fingers tips should point to the scaphoid—see Figs. 25-26.)

- **Comminuted fractures** or those with segmental loss are best treated with transmetacarpal K-wires above and below the comminution (Fig. 27) and into normal metacarpals, as described above, or using a mini-external fixator if only one metacarpal is involved. Home-made external fixators can be constructed using two K-wires above and below the fracture and held together with plaster or methylmethacrylate. An endotracheal tube filled with methylmethacrylate is a good "external fixator." As the methylmethacrylate is hardening, the K-wires are stuck through the tube as the fracture is distracted and aligned. If a there is a segmental loss, bone grafting can be carried out as a second stage. If open with segmental loss, a K-wire can also be used as an intramedullary pin to hold the metacarpal out to length. Two right angle turns are made at each end and placed in both fractured ends of the bone—see below. Severely crushed metacarpals can be casted and early motion started at 3-4 weeks.

  (**Editor's Note**: Fortunately these are rare injuries. When there is segmental loss, there will be an open wound. These should be debrided and irrigated and closed as soon as possible. The patients should then be referred to a center where adequate treatment can be carried out if they have adequate finances.)

- **Metacarpal neck or Boxer's fractures** are one of the more common hand fractures resulting from the person striking an object in a longitudinal fashion with a closed fist. These result in apex-dorsal angulation. The amount of acceptable angulation is dependent upon the digit involved. As a general rule, the index and long finger can only tolerate 10 to 20 degrees of angulation. The commonly involved ring and small fingers can tolerate up to 50-60 degrees of angulation in metacarpal neck fractures. These fractures warrant an attempt at a closed reduction in the acute setting with a hematoma block. **The Jahss maneuver** is used: Flex the MP joint while applying upward pressure through the proximal phalanx directed toward the metacarpal head. This can more easily be accomplished by flexing the PIPJ and pushing dorsal through the PIPJ. Care must be taken to prevent rotation of the metacarpal. This can be clinically achieved by comparing the plane of the fingernails. There are two casting methods, and these should include the wrist in slight extension: **First**, the MP joints are flexed to 90° and the PIPJ extended. The PIPJ can be held in extension for two to three weeks and then allowed to flex—see Figs. 27-30. **Second**, with pressure under the fifth metacarpal head from the palmar aspect, and dorsal pressure over the shaft of the fifth metacarpal, this can provide good stabilization of the fracture. The cast can be applied with the MP joints in 0° or no flexion with adequate pressure under the palmar head of the metacarpal, and adequate dorsal pressure over the fifth finger metacarpal shaft. Care has

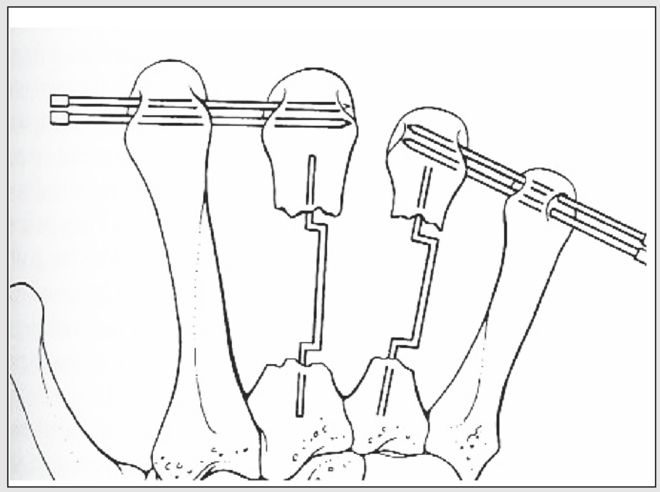


Fig. 27

K-wires with right angle turns to maintain length when there is a segmental loss. K-wires can be placed above and below with an "external fixator" as described above.

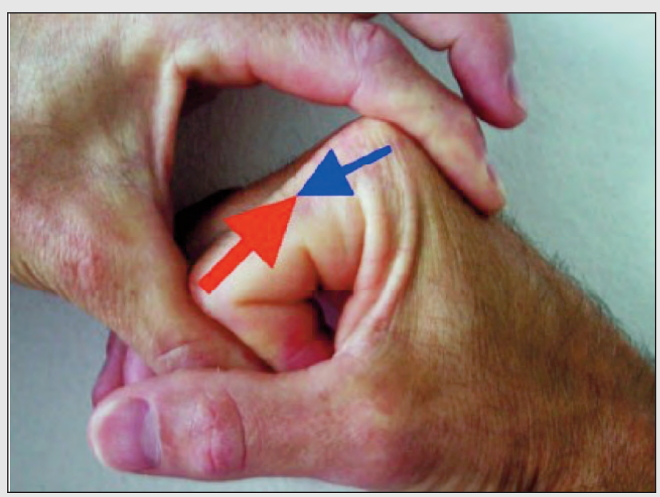


Fig. 28

The Jahss Maneuver.

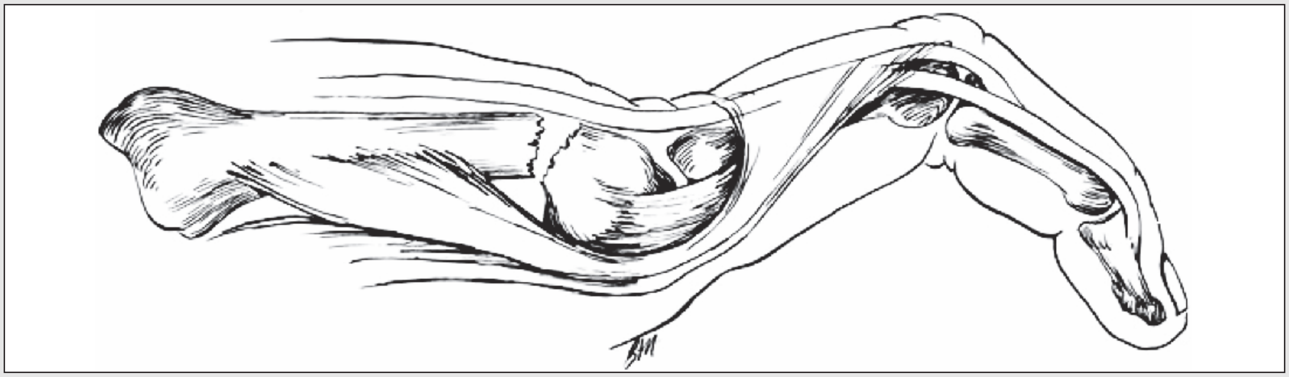


Fig. 29

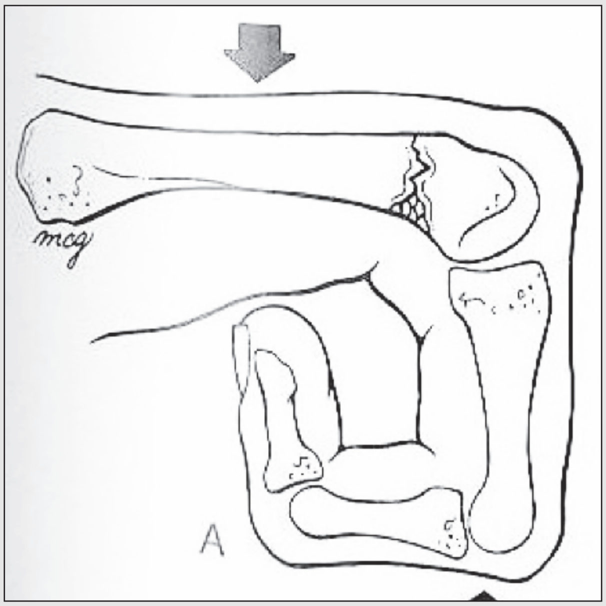


Fig. 30

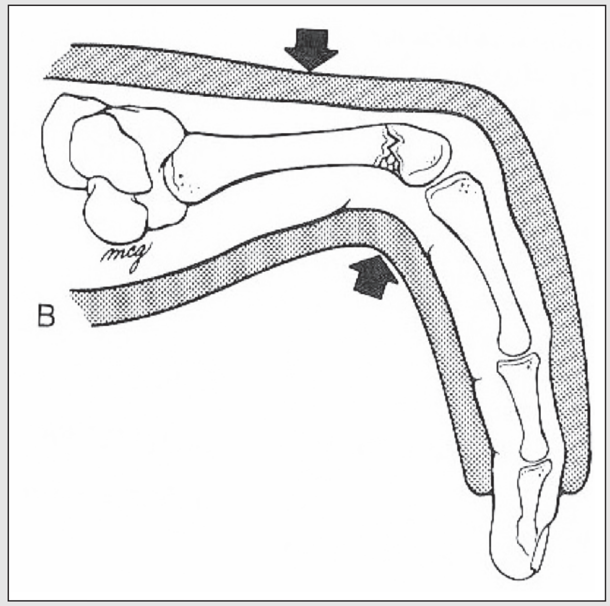


Fig. 31

Metacarpal neck fracture. Note dorsal angulation with head in the palm. Reduced by Jahss Maneuver and casted in position of protection with MPJ flexed and IPJs extended.

to be taken not to apply too much pressure, in that this can cause skin necrosis. This does allow the PIP joint to be totally free. X-rays should be repeated at weekly intervals as these fractures are unstable.

- If the fracture is severely angulated (see Editor's Note below) and cannot be held in reduction with the cast, then closed fixation with crossed K-wires through the MC head may be attempted (see Fig. 33). The K-wires are placed from the either side of the head down into the proximal fragment. Alternatively, the K-wires may be placed from the MC head into an adjacent stable MC head (see Fig. 34). A gutter splint is applied, with the MPJs flexed and the PIPJs extended for three weeks, at which time the K-wires are removed and range of motion is begun. Protective splinting is continued for two to three more weeks. **Closed pinning will be difficult without fluoroscopy**.

(**Editor's Note:** Important Information—Some would only reduce these if the MC head was palpable in the palm or if there was pseudo-clawing deformity with extension of the proximal phalanx at the MP joint. Sometimes an angulation up to 75° can be accepted.)

- (**Gutter splint**: a curved, half-circle splint, from dorsal to palmar around a border and adjacent digit)

- **If the metacarpal neck fractures cannot be successfully reduced** and stabilized by closed methods, open reduction and percutaneous pinning may be necessary for significantly displaced/angulated fractures. **This will be unusual**, but significantly angulated neck fractures in the index and long fingers that are left unreduced may cause significant pain in the palm when grasping objects. Open reduction is achieved through a longitudinal incision over the dorsal aspect of the affected metacarpal, retraction of the extensor tendon, and longitudinal retrograde pinning through the metacarpal head. Pins are removed at three weeks, and exercises begun. (The extensor tendons, EDC and EDM may be separated in the midline to gain exposure, but this may lead to adhesions.) **Open reduction will rarely be necessary**.

- With open injuries, **care must be taken to rule out an open fracture from a human bite wound**. Patients will often deny this happened.

Fig. 32

Fig. 33

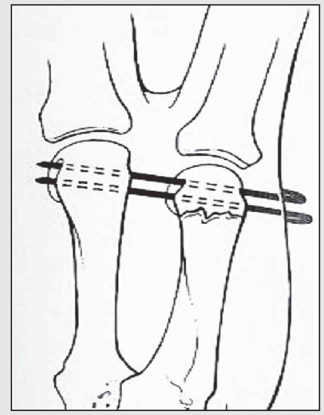


Fig. 34

Metacarpal Neck Fractures. If necessary to pin, these are two methods: 1) Crossed K-wires through the MC head, or 2) K-wires from the fractured MC into the normal metacarpal, while reducing the fracture with the Jahss maneuver. These methods are best done with a C-arm or portable x-ray.

Fig. 35

Fig. 36

Fig. 37

Angulation of third MC neck fracture with retrograde pinning. Pinning was performed in this case, since it was in the third metacarpal where the head in the palm is not as well tolerated. (Courtesy of eORIF.com)

Position of Protection: wrist slightly extended, MPJs flexed 80-90° and IPJs extended. This will prevent extension contractures of MPJ and flexion contractures of PIPJ.

- **Intra-articular fractures of the metacarpal head** should be treated conservatively with splinting in position of protection for three weeks, followed by active range of motion exercises. Ideally, displaced fracture fragments require reduction and fixation to maintain the metacarpal phalangeal joint; however, this is impractical in most of our hospitals. (If one has the expertise and small wires, plates and screws, open reduction can be accomplished via a curvilinear incision made over the MCP joint. A careful incision through the sagittal band, leaving a cuff for later repair, will provide good exposure to the joint surface. On occasion, the saggital band and extensor tendon may be retracted with percutaneous pinning of the articular surface, with small K-wires to achieve satisfactory stabilization. The MCP joint should be held in position of protection to maintain maximum collateral ligament length.)

(**Editor's note**: The above recommendations are somewhat theoretical. General surgeons in most district hospitals will find this open surgery difficult, if not impossible. Therefore closed reduction and splinting in the position of protection is best with early range of motion exercises at 2-3 weeks. Splinting is continued for six weeks when not exercising. **Stability and proper alignment of these fractures at the MPJ has been found to be more important than perfect articular reduction**. This is also true for open fractures after debridement and irrigation.)

- **Special x-ray view: Brewerton for metacarpal head fractures**. Fingers are placed on the film with palm up, MCP flexed 65°, and the x-ray taken from 15° ulnar to the vertical.

Metacarpal Phalangeal Joint Dislocation

Thumb

- **Ulnar collateral ligament injury**

  This is the most common type of dislocation at the thumb MPJ, and is secondary to a sudden radial deviation of the thumb at the metacarpal phalangeal joint, with a tear of the ulnar collateral ligament. The ligament usually avulses from the base of the proximal phalanx. This injury is seen acutely, but more often it is seen late and is known as a Gamekeeper's thumb. When seen late, it is often associated with a Stener's lesion—where the completely ruptured ulnar collateral ligament is found proximal to the adductor pollicis aponeurosis. When the aponeurosis is interposed between the ligament and the base of the proximal phalanx, the ligament cannot heal.

  On exam, there is swelling and, if seen acutely, there is tenderness and ecchymosis. When the joint is stressed radially, the joint is considerably more lax than the contralateral thumb. This test is best done with the MPJ flexed 30-40 degrees, which eliminates the stabilizing effect of the volar plate in extension. When testing is done acutely, a local digital anesthetic block is helpful to relieve pain and allow a better evaluation, both for the clinical exam and for stress x-rays—see below.

  X-rays should be taken to rule out a fracture at the base of the proximal phalanx, and it is important to compare findings to the normal thumb.

- **Indications for Surgery:**
  If less than 30° laxity or less than 15° differential from the contralateral thumb when stressed, then acute injuries may be treated conservatively with a thumb spica cast with the MPJ slightly flexed for four weeks (see Fig. 39).

  If greater than 30° laxity or greater than a 15° differential from the contralateral thumb, then

Fig. 38
Stress view showing significant laxity of the thumb UCL. Note 40-45° angle. (Courtesy of eORIF.com)

Fig. 39
Avulsion ulnar base of thumb proximal phalanx. Treatment as described if a C-arm is available.

operative repair is recommended.

- Several surgical techniques have been described.
- If there is only a ligament injury, then direct repair or repair using a bone anchor is possible.
- Fractures at the base of the proximal phalanx will usually heal if not widely displaced, and if casted for six weeks or placed in a thumb spica splint.
- If a C-arm is available and a Stener lesion is not suspected, the fracture can be penetrated with a .035 K-wire, and the small fracture fragment manipulated back into proper position (see Fig. 38). Then the K-wire is advanced across the fracture site, exiting the radial aspect of the thumb. A drill is then applied to the pin outside the radial side of the thumb and withdrawn distally until the tip of the pin is just at the edge of the fracture fragment on the ulnar side of the thumb.
- Otherwise, open reduction is necessary with pins or preferably small screws.
    - Chronic injuries can be repaired with either adductor advancement or a tendon graft.
    - **One is referred to operative textbooks for a description of these procedures.**

(**Editor's Note**: It is recognized that in many of our hospitals these injuries, if diagnosed, will be treated with casting or splinting. If there is not a Stener lesion, the ligament or fracture will likely heal back. If one feels a mass over the proximal ulnar side of the MPJ, then a Stener lesion is probable, and adequate healing of the ligament will not occur with splinting alone.)

Fingers

- **Metacarpal phalangeal joint dislocations** can occur either in a dorsal or volar direction. Dorsal dislocations are much more common from forceful hyperextension, and can be divided into simple and complex. These occur commonly in thumb and index finger.

- A **simple dorsal dislocation** is reducible when the phalanx remains in contact with the metacarpal head, and the volar plate is not trapped within the joint.
    - These simple dislocations are usually quite obvious, with significant angulation—more prominent than a complex dislocation.

Fig. 40
Simple Dislocation of MPJ.
(Courtesy of eORIF.com)

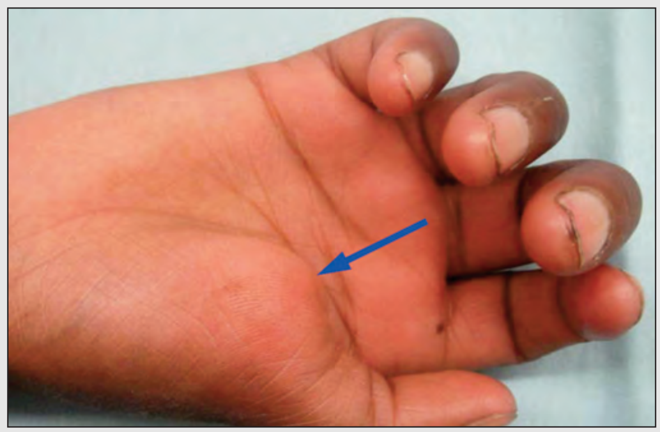


Fig. 41
Complex Dislocation of Thumb MPJ.
Note puckering (blue arrow).

Fig. 42
Complex dislocation of index MPJ with bayonet appearance. Required open reduction. This dislocation could be easily missed.

Fig. 43 **Fig. 44**

Chronic dislocation of thumb MPJ. Required volar and dorsal approach.

- Reduction is achieved by maintaining contact of the MCP joint while pushing the base of the proximal phalanx distally along the dorsum of the metacarpal, direction of black arrow below.
- **Hyperextension or traction is not useful, and is contraindicated**.

- **A complex dislocation** occurs when the volar plate ruptures from the metacarpal and becomes entrapped between the head of the metacarpal and base of the proximal phalanx.
  - Puckering of the volar skin may be seen at the level of the metacarpal neck, and this always indicates a complex dislocation.
  - The proximal phalanx lies dorsally in the same direction as the metacarpal—"bayonet appearance."
  - The metacarpal head is caught in a "noose" between the flexor tendons and the lumbrical muscles in the index and the flexor tendons and thenar muscles in the thumb.
  - The volar plate is avulsed from the metacarpal and often trapped in the joint
  - **X-rays** may show the sesamoid bones in a widened joint.
  - **Closed reduction is rarely successful, especially when the patient presents late**.

These complex dislocations can be approached either from the volar or dorsal side. The author uses the volar approach on early dislocations.

- Open reduction should be carried out from a **volar approach**.
  - This allows identification and protection of the radial digital nerve that is tented up next to the skin by the metacarpal head.
  - The flexor tendons are identified on the **ulnar** side of the metacarpal head and the A-1 pulley is divided. Usually, this allows reduction.
  - **In chronic cases which present late**, a **dorsal approach** may also be needed to release the collateral ligaments from the metacarpal head and **reduce the volar plate by splitting it** in the midline and passing each side back around the metacarpal head.
  - The ligaments will reattach and do not need to be repaired.
  - The MPJ is held in 20-30° flexion for two weeks, and then exercises are begun while the last 10° of extension is blocked.

Phalangeal Fractures and Dislocations

- These are always serious injuries in those who use their hands for work. The flexor and extensor tendons lie close to the bone, and are susceptible to injury and later stiffness.

- **Intra-articular fractures at the base of the proximal phalanx** that are closed and minimally displaced can often be treated with manipulation, buddy-taping, and a dorsal splint,

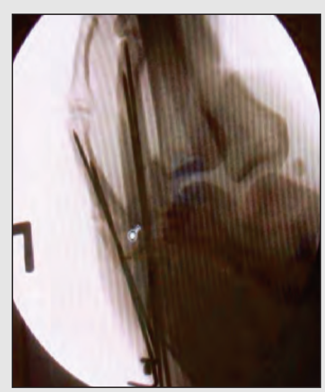


Fig. 45 **Fig. 46** **Fig. 47**

Base of proximal phalanx fractures. Treated by Eaton-Belsky technique. (Courtesy of Dr. Jason Rehm) with the MP joints flexed and early range of motion at three weeks. Significantly displaced (with a 3 mm. step off) or open intra-articular fractures (uncommon) can be opened through the dorsal midline and pinned with small K-wires. However, **stability, alignment and future mobility are more important than a perfect articular reduction**.

- (If necessary, and if one has experience operating in this area, the extensor tendon is divided longitudinally in the midline or through the open injury. Approaching these laterally is possible if the fracture extends distally, but a lateral approach is difficult for fractures at the base of the proximal phalanx because of the lateral bands. One lateral band may be divided for exposure and then repaired at the end of surgery or sacrificed, but this is difficult surgery for the non-hand surgeon.) If there is severe comminution, then a K-wire can be placed through the distal proximal phalanx or the distal phalanx, and traction applied. This pin can be incorporated into a cast while traction is placed on the MPJ. Traction should be discontinued and exercises begun at three weeks.

- **Closed or open transverse fractures through the base or shaft of the proximal phalanx**: Proximal phalanx shaft fractures most often have an **apex volar angulation**, secondary to the volar flexion of the phalanx base by the intrinsic tendons, and extension of the distal end by the extensors at the central slip insertion (see Fig. 49). These can be best stabilized with flexion of the distal fragment and volar-to-dorsal pressure over the site of angulation so that it will line up with the flexed proximal fragment. If closed reduction is not stable with a cast, then the **Eaton-Belsky** pinning technique should be used. After the fracture fragments are reduced and aligned as best as possible, two K-wires are passed through the metacarpal head and into the proximal phalanx with the MPJ flexed (see Fig. 48). The pins are inserted until resistance is reached at the distal cortex of the proximal phalanx. This is an excellent fixation for these fractures that should be attempted even if one does not have a C-arm. This procedure requires patience, as one passes the K-wire through the metacarpal head and up to the fracture site, then into the distal fragment while manipulating it into reduction. When resistance is felt, the wire has reached the distal

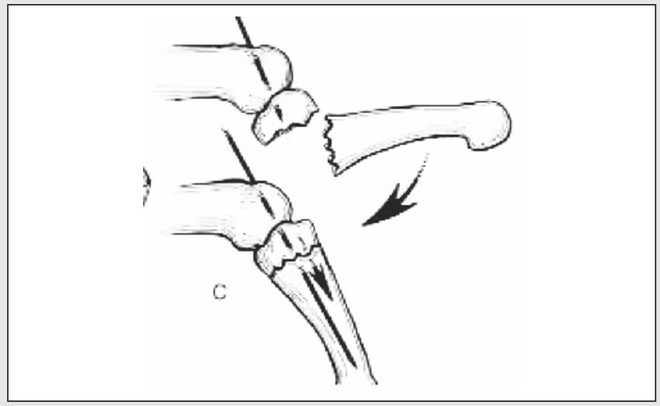


Fig. 48
Eaton-Belsky technique. Pin through metacarpal head, fracture alignment, and pin passed to distal cortex of proximal phalanx.

Fig. 49
Base fracture—best treated with the Eaton-Belsky technique.

Fig. 50 **Fig. 51**
Shaft fracture—note apex volar angulation—attempt Eaton-Belsky technique, otherwise treat closed in position of protection.

cortex of the phalanx. This technique gives rigid fixation, as the fracture is stabilized proximately (with the pin through the metacarpal head) and distally (by the pin engaging the distal cortex), but not into the PIP joint. If there is significant displacement, possibly from intervening soft tissue, or if the fracture is open, the Eaton-Belsky technique can be easily carried out under direct vision. These pins are removed at three weeks and motion begun. The PIPJ should never be splinted or casted in the flexed position. Proximal phalanx shaft fractures frequently lead to tendon adhesions and a stiff finger, due to the close proximity of the tendons and bone.

- If a closed shaft fracture is displaced or rotated, then traction with manipulation, MPJ flexion, volar-to-dorsal pressure at the fracture site to correct the angulation, and then splinting or casting with the PIPJ extended will help align the fractures. The affected finger can be splinted together with the adjacent normal finger.

  (**Editor's note:** If the Eaton-Belsky technique is not possible, and closed reduction and casting or splinting does not result in perfect alignment, further exploration with open pinning or wiring of the fracture is **NOT recommended** unless the fracture is already open. See below.)

- **Closed oblique or spiral fractures** of the proximal phalanx should NOT be opened unless severely displaced or open. If a closed fracture is displaced or rotated, then traction with manipulation, MPJ flexion, and volar-to-dorsal pressure at the fracture site will help align the fractures. Also, the affected finger can be buddy taped and splinted together with the adjacent normal finger. These fractures often lead to both flexor and extensor tendon adhesions, as the tendons lie close to the bone. If there is shortening at the fracture site, an extensor lag at the PIPJ may result, but opening these injuries, even with the ability to rigidly fix and with excellent post-op therapy, will still lead to stiffness and loss of motion. **Never open unless already open**.

- **Open proximal phalanx fractures** should be irrigated and debrided, and an attempt to stabilize with the Eaton-Belsky technique. This may be possible even with oblique and spiral fractures. With the pins in place, the hand should be casted in the position of protection, with MPJ flexion and PIP joints extended. If this is not possible for transverse fractures, two small K-wires may be passed antegrade and obliquely from the fracture site through the medullary canal until they emerge laterally at the MC neck. When they penetrate the skin, they may be passed retrograde into the proximal fragment to hold the fracture. The wires are left through the skin distally for easy removal at three weeks. If stabilization of open spiral fractures is not possible with the above techniques, two or three K-wires may be placed transversely across fracture, with or without a cerclage wire. **Early motion with proximal phalanx fractures is more important than rigid fixation**. If the fracture is comminuted, external fixation as described above may be attempted.

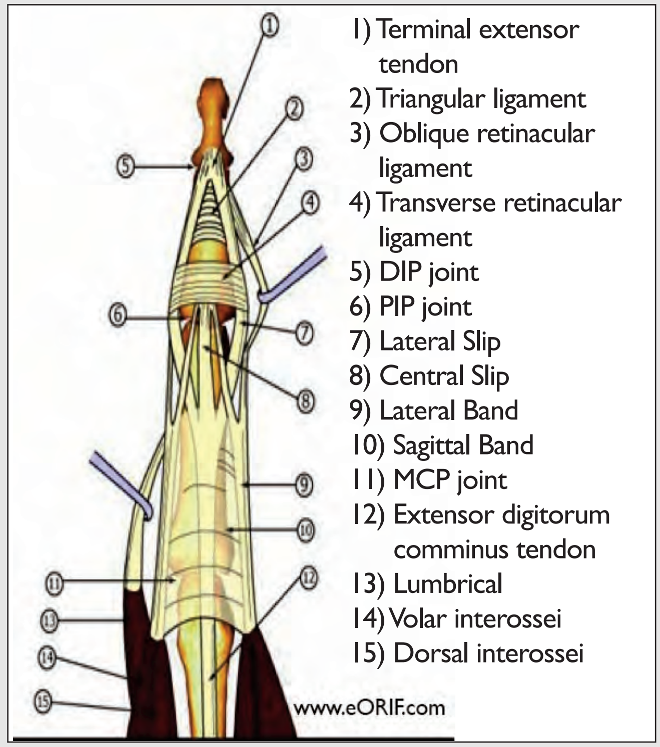


Fig. 52
Note the close association of the tendons and the phalanges—this is the cause for adhesions and stiffness post-operatively, especially if the fracture is open or if open reduction is carried out.
(Courtesy of eORIF.com)

- **Distal transverse condylar neck fractures in proximal or middle phalanges** are especially seen in children. These are dorsally displaced, and sometimes rotated 90° with the articular surface



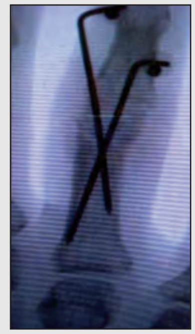



Fig. 53 **Fig. 54** **Fig. 55** **Fig. 56**
Condylar neck fracture, initially missed. Required ORIF.

pointing dorsally. These are frequently missed, especially if a good lateral finger x-ray is not taken. Closed reduction can occasionally be accomplished early with traction and downward and distal pressure applied over the distal fragment. Since these fractures are unstable, once the fragments are reduced, K-wires should be placed through the head of the proximal phalanx into the shaft and left four weeks to maintain reduction. **Because these fractures have little chance to remodel, even in a child**, open reduction may be necessary if closed reduction is not successful. A dorsal incision is made, and the fracture approached from below or volar to the lateral band. **If the fracture involves the middle phalanx**, after reduction a K-wire can be placed from the tip of the finger through distal phalanx, DIP joint, and into the middle phalanx to hold the fragment reduced. The author has found 18-21 gauge hypodermic needles especially useful to pin these in children. The needles can be easily twisted down the shafts of the bones for stabilization, and one is usually sufficient.

- **Distal oblique intra-articular condylar proximal phalanx fractures** are difficult to treat when closed without a C-arm. While it is important to reduce and stabilize intra-articular fractures when there is a significant step off of 2-3 mm, rigid fixation is difficult without small screws. One potential closed method when there is a significant step off at the articular surface is to use one or more towel clips to attempt reduction. Method: after x-rays are taken, a digital block is given **in the x-ray department** (or in the OR with a portable x-ray machine) and a towel clip is used to grasp each fragment and attempt to reduce the fracture fragments. Repeat x-rays are taken to visualize the reduction. Several attempts can be taken before opening the joint. If it must be opened, a dorsal incision is made, and the articular surface visualized though an incision between the lateral band and extensor tendon (central slip). A small towel clip can now be used under direct vision to approximate the fracture fragments. Once reduced closed or open, the fracture can be pinned percutaneously with two or three small 0.028 K-wires, depending on the length of the fracture. PIPJ surgery is not without complications, whether opened or closed. If closed reduction and fixation can be accomplished with manipulation, application of a towel clip and insertion of K-wires, then this fracture may be casted or splinted closed with the MPJ in flexion and PIPJ in extension. These fractures can be opened, but post-op stiffness will inevitably result, even with the best post-op hand therapy. Comminuted fractures should be treated in traction as described below.

PIP Joint Dislocations

Fig. 57
Dorsal PIPJ Dislocation.

- These are commonly seen and often poorly cared for. The most frequent dislocation is a **dorsal dislocation** with the middle phalanx dorsal to the proximal phalanx. They occur by hyperextension and axial loading.

- If the there is a volar plate disruption at the base of the middle phalanx—without a fracture—then the dislocation can be reduced and held in 30° flexion for three weeks with a dorsal block splint, and then 15° flexion for an additional two to three weeks. PIP joint flexion is allowed during dorsal block splinting.

- These dislocations may include a fracture of the volar lip of the middle phalanx that is attached to the volar plate.

- If this intra-articular fracture involves less than 40% of the articular surface, dorsal block splinting is used. The collateral ligaments are still attached to the distal dorsal fragment and reduction is possible. This hand based splint holds the MPJ in flexion and the PIPJ in sufficient flexion to reduce the fragment—in up to but ideally not more than 40°.

- Patients must be closely followed and x-rays taken on a regular basis to ensure the reduction is not lost.

- The reduction should result in congruent dorsal articular surfaces of the phalanges. If there is a dorsal "V" shaped deformity on lateral views, then the reduction is not adequate.

  (Editor's note: An excellent technique is described here (and shown in Fig. 58), courtesy of Dr. Bill Bourland—this technique will require some x-ray control, either a C- arm or portable x-ray. "Hyperextend the PIP and drive a 0.035 K-wire under the volar fracture lip fragment (from the volar side) through the proximal phalanx, and withdraw it dorsally until the volar pin just blocks the volar lip fragment. Then flex the PIP joint until the dorsal fragment reduces with the volar pin preventing the volar lip fragment from moving. Then drive a 0.035 K-wire dorsal to the dorsal lip of the middle phalanx into the proximal phalanx. Cut the pins beneath the skin. Splint for three weeks. Remove the pins under local anesthesia and begin protected ROM with a dorsal blocking splint."

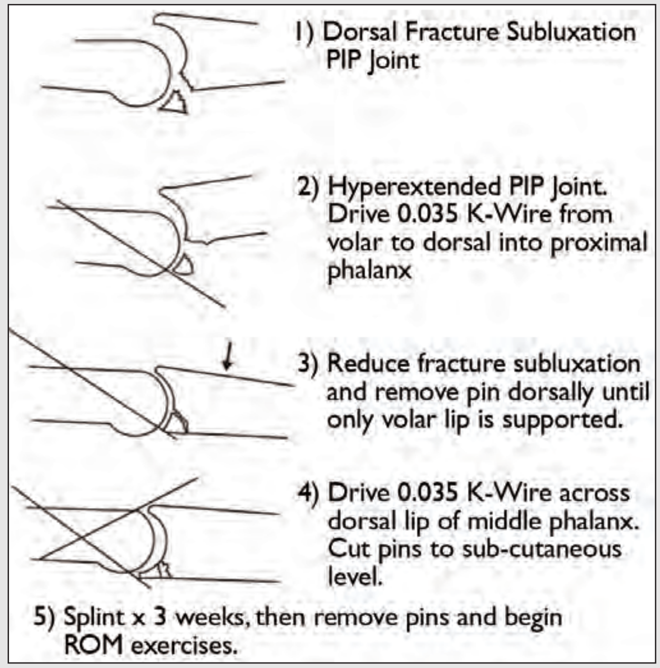


Fig. 58

Treatment for fracture-dislocation of PIPJ. (Courtesy of Dr. Bill Bourland)

- When the **middle phalanx fracture fragment involves greater than 40- 50% of the articular surface**, dorsal block splinting will likely not work. The collateral ligaments are no longer attached to the dorsal distal fragment, and closed reduction will not be stable. The angle of the dorsal block would have to be increased, and this would likely lead to a stiff, flexed PIPJ.

  In these situations, when a dorsal block splint is unsatisfactory, then open reduction or an external traction is necessary. The editor would attempt the technique above.
  - A volar (and sometimes a "shotgun"—see below) approach is best, as it gives good visualization of the fracture fragment and attached volar plate. **This technique requires significant experience and knowledge of anatomy around the PIPJ.**
  - A volar zigzag incision (Bruner) is made across the PIPJ. Care is taken to identify and not damage the neurovascular bundle on each side. The A-3 pulley is divided and the flexor sheath opened from A-2 to A-4 pulleys. The flexor tendons are retracted to one side and the joint inspected.
  - If better exposure is necessary, the collateral ligaments may be divided at their origin, and

the joint opened with hyperextension of the middle phalanx ("shotgun" approach). Once the volar fragment is reduced, small K- wires may be placed obliquely across the fragment into the middle phalanx. If the fragment is small or comminuted, another technique involves passing a two sutures/small steel wires through the volar plate at its insertion into the avulsed fragment, then passing the sutures/wires through two drill holes in the middle phalanx, and twisting the wires down on the dorsal surface of the middle phalanx.

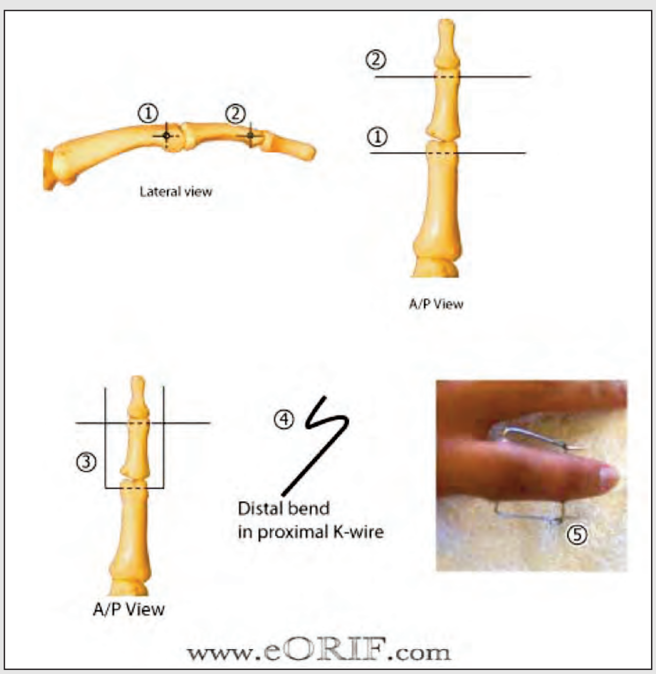
Fig. 59 **Fig. 60**

Pilon fracture dislocation of PIPJ. (Courtesy eORIF.com)

With either technique, the joint should be immobilized in slight flexion for three weeks. K-wires should be removed at three weeks, and gentle ROM exercises carried out. The collateral ligaments will reattach and do not need to be repaired.

(**Editor's note**: PIPJ surgery is complicated. I recommend splinting and early range of motion or traction, with pins above and below the PIPJ for fracture-dislocations involving > 40% of the articular surface. The "shotgun" approach above is difficult even for the accomplished hand surgeon, and stiffness results no matter the how accurate the reduction and fixation.)

- **Volar dislocations** are the result of a rupture of the central slip, or a dorsal lip fracture with the central slip attached to the fragment. If an extensor tendon/central slip avulsion, this may be treated closed or open with repair of the central slip insertion. The **easiest treatment** is placing a pin through the PIPJ to hold it in extension for six weeks. If the fragment is large, and the reduction is not stable, then an open approach may be carried out, pinning the fragment to the middle phalanx with one or two small K-wires, and with an additional K-wire through the PIPJ to ensure compliance in



Treated with dynamic PIP joint external fixation (Badia A, J Hand Surg 2005; 30A:154).

1) 0.045in K-wire placed transversely through center of the head of the proximal phalanx.

2) 0.045in K-wire placed through center of the head of the middle phalanx.

3) Proximal K-wire is bent 90 degrees to be parallel to middle phalanx.

4) End of proximal phalanx K-wire is bent >90 degrees dorsally and again >90 degrees volarly to make S configuration at tip.

5) Traction applied and distal K-wire is engaged and bent 90 degrees.

Fig. 61

Method of dynamic PIPJ external fixation for traction. (Courtesy eORIF.com)
(For dynamic fixator technique: see Ruland RT, J Hand Surg 2008; 33:19)

keeping the PIPJ extended at 0°.

- **Rotatory dislocations** are rare but also possible. These may be looked up in a major text.

- **Comminuted fractures** in jammed fingers at the base of the middle phalanx are also frequently seen—a **pilon** fracture. These occur with significant axial loading, and include both dorsal and volar lip fractures with a destroyed middle phalanx articular surface. In district hospitals these injuries should be treated with splinting and early range of motion. If one has significant experience in hand surgery, one may try the dynamic PIPJ traction method shown in Fig. 61.

Unfortunately, no matter what the treatment is for these PIPJ injuries, arthritis and stiffness will likely be a final result. Therefore, early range of motion exercises may be best.

Middle Phalanx Fractures

- Closed shaft fractures are rare, and most will be treated closed with early range of motion. If opened and fixed significant stiffness will result. These should only be treated open when there is an open injury. Intra-articular fractures through the head of the middle phalanx may be treated as for the proximal phalanx, but a stiff joint will likely result regardless of the technique.

Distal Phalanx Fractures/Dislocations

- Most common among these are apex dorsal dislocations of the DIPJ—**Mallet finger**. These can be tendinous (with an avulsion of the extensor tendon) or bony (with a fragment of the dorsal lip of the distal phalanx avulsed off with the tendon). Tendinous injuries are best treated with a K-wire to hold the DIPJ in extension for six weeks, followed by splinting in extension for another six weeks while allowing gradual increase in exercises during the day but constant splinting in extension at night. Bony avulsions, if less than 50 % of the joint surface, may be treated the same way. Some would pin the dorsal lip fragment for >50% of the joint surface involved, while many would continue with the closed pinning in extension. An excellent technique to reduce and hold this dorsal lip fracture is the insertion of the K-wire through the distal extensor apparatus into the distal dorsal articular surface of the middle phalanx while the DIPJ is held in flexion (see Figs. 62-63.) The distal phalanx is then extended and pinned in extension. The "extensor block pinning" allows the fragment to be reduced and held in reduction by the pins. This avoids causing potential comminution of the fragile fracture fragment when attempting to insert a K-wire directly into the fracture fragment. These dorsal lip fractures may be comminuted. Splinting the DIPJ alone

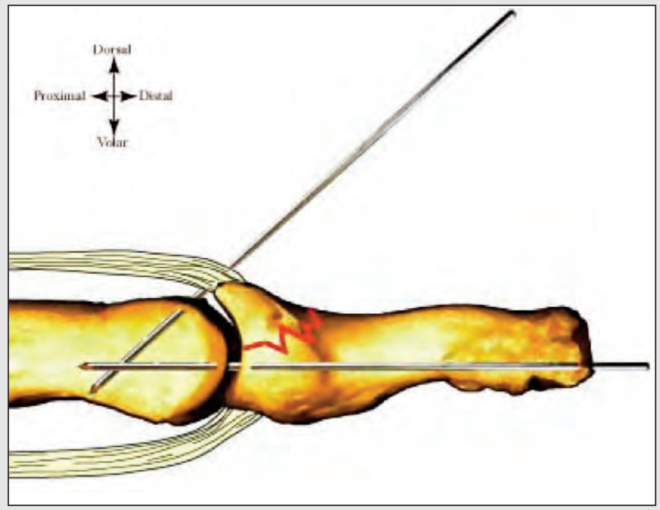


Fig. 62

Mallet Fracture. See technique in Fig. 63

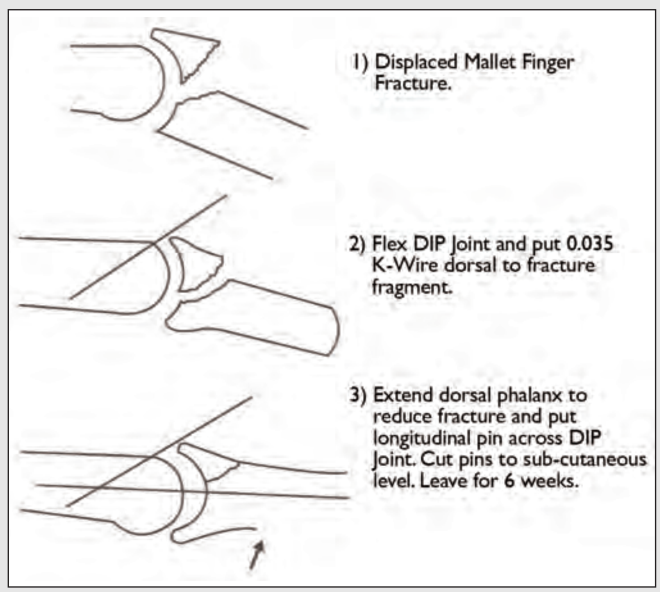


Fig. 63

Extensor block splinting for bony Mallet fracture-dislocations. The pin through the middle phalanx is inserted first with DIPJ in flexion. Distal phalanx is then extended and a pin passed from the distal tip of the distal phalanx into the middle phalanx. (Courtesy of Dr. Bill Bourland)

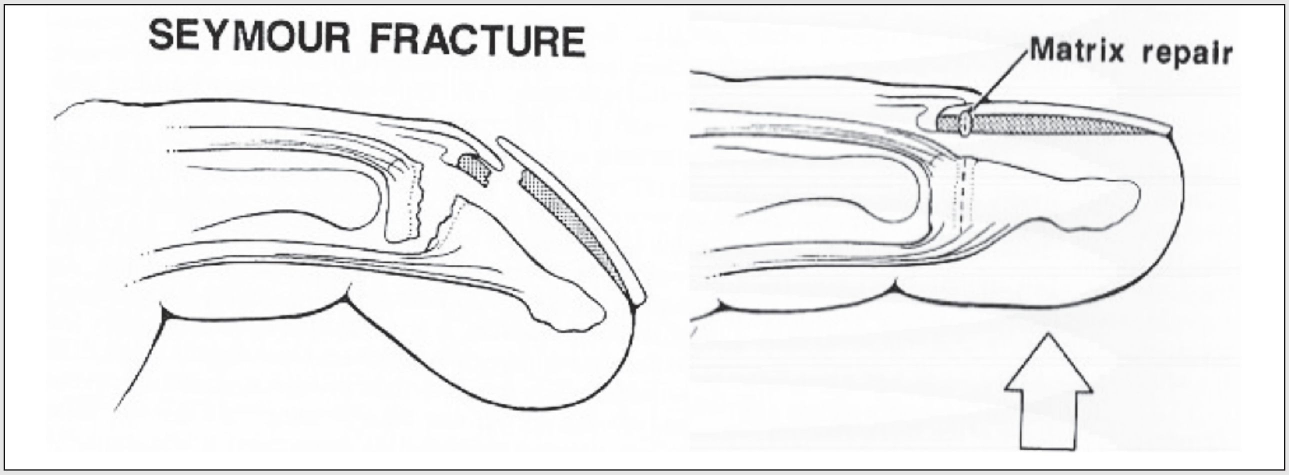


Fig. 64
Seymour fracture through epiphysis of distal phalanx.

may be used, but compliance is a major factor. Without treatment, there will be an extensor lag with subluxation of the volar fragment, but this is only of cosmetic importance and will only rarely affect function.

Epiphyseal Fractures

- These occur in 5 types, and the classification can be found in major texts. The author would treat all these closed with fracture manipulation and reduction, except the grossly displaced or angulated fractures. If acceptable reduction cannot be accomplished, then open reduction and pinning can be carried out. In children, reduction and pinning with a portable x-ray machine in surgery or the x-ray department, if possible, would be better than opening these fractures. Open epiphyseal fractures are rare. One important epiphyseal fracture not to be missed is the dorsal angulation fracture at the base of the distal phalanx, so-called **Seymour fracture**. This occurs through the nail bed, which should be repaired after the fracture is reduced and pinned. One must ensure that the nail bed is not trapped in the fracture site. An #18 - #21 hypodermic needle may be used to pin this fracture, with the pin passed from the tip of the finger into the middle phalanx.

Chapter 35

Carpal Bone Fractures and Dislocations

Tertius H. J. Venter

Editor's Preface

This chapter will discuss these fractures and dislocations for the surgeon in district hospitals. It is understood that many will not have the experience to handle these problems. In addition, they require good x-rays, knowledge of anatomy, K-wires, often a C-arm, anelectric pin driver, and loupe magnification.

Carpal Bone Fractures

The wrist joint is the most complex joint of the body. It includes the distal radius and ulna, the proximal surfaces of the 5 metacarpal bones, and the 8 carpal bones articulating with these 7 bones and each other. The wrist and finger tendons traverse this joint, and are an integral part of the joint anatomy and function, along with numerous ligaments and other soft tissue structures. The diverse components of the wrist have an exact relationship to each, and its complexity results in tremendous mobility.

Wrist injuries are common and, unfortunately, often missed; this results in degenerative arthritis, chronic pain, and limitation of motion. Prompt recognition and proper treatment of the acute wrist injury is paramount in preventing these disabling consequences.

The most common injuries are sprains, scaphoid fractures, and scapholunate ligament injuries. This chapter will focus primarily on these.

Scaphoid Fractures

Scaphoid fractures are the most common carpal fractures, constituting approximately 60-70% of all carpal injuries. The fracture is more

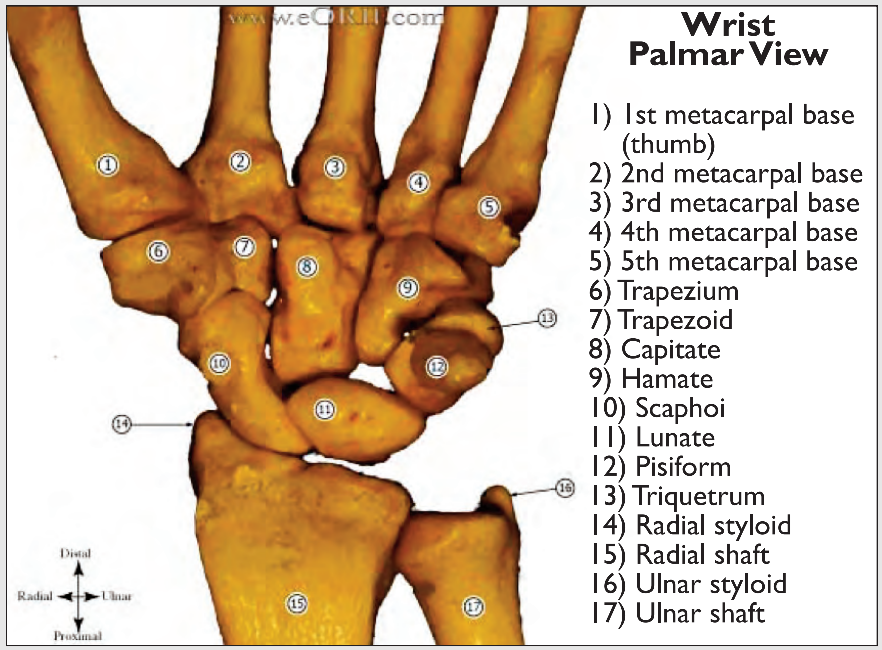


Fig. 1

Note the position of ulnar styloid on ulnar side of ulna. (From www.ORIF.com, used by permission)

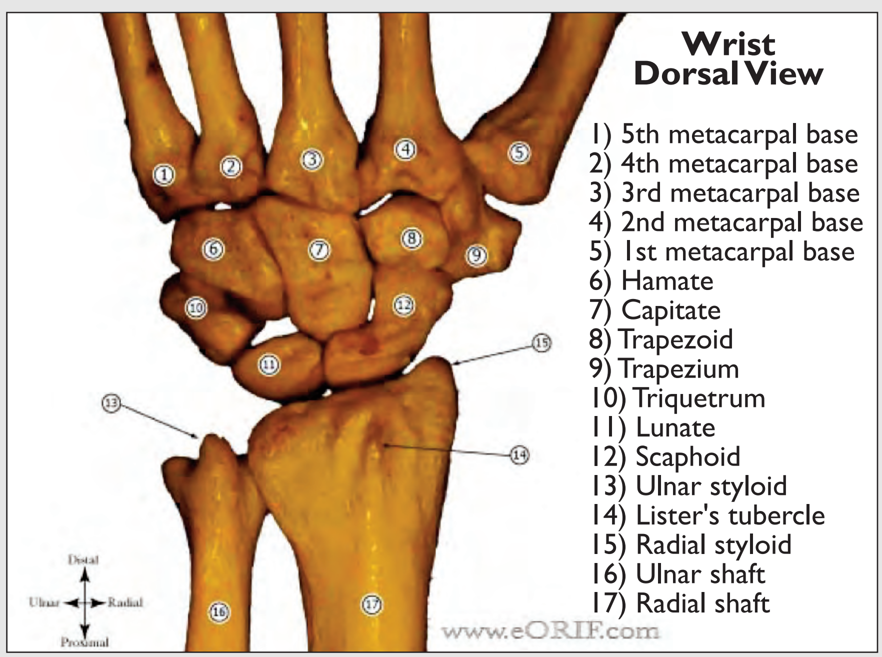


Fig. 2

Note styloid process in center of distal ulna on dorsal view. (From www.ORIF.com, used by permission)

Fig. 3

Adult Scaphoid Fracture

common in the young adult male, but rare in children because the distal radius physis usually fails first in an axial load to the outstretched hand. A similar injury in older people often results in a distal radius fracture, such as a Colles' fracture.

Mechanism of Injury

The scaphoid crosses both carpal rows, and this makes it is more susceptible to injury than other carpal bones (see Figs. 1 and 2). The injury occurs when the hyper-extended wrist is subjected to an axial load (Fig. 4).

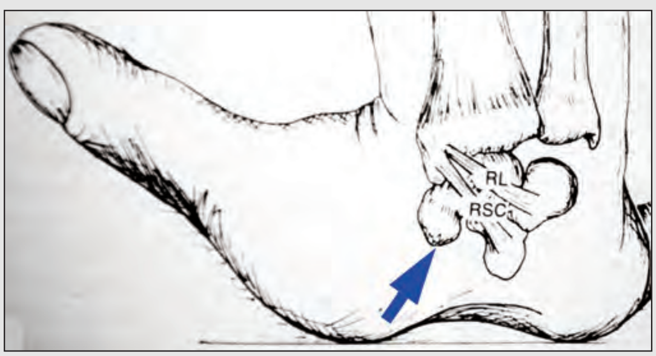


Fig. 4

Mechanism of fracture of the Scaphoid according to Weber and Chao. Force applied to the radial half of the palm (blue arrow) with the wrist in 95° to 100° of dorsiflexion produces bending loads to the unprotected distal half of the scaphoid. The proximal half is protected by the radius and the radiopalmar ligaments (RL=radiolunate, RCS=radioscaphocapitate). (from Weber ER, Choa EYS J Hand Surg 1978, 3:143-148. Used by permission)

Blood Supply to the Scaphoid Bone

The scaphoid bone is shaped like a twisted peanut, and 80% of its surface is covered in articular cartilage. The majority of the scaphoid blood supply, up to 80%, is through dorsal ridge vessels that enter the bone distal to the waist, accounting for its retrograde blood flow (Fig. 5). This leads to a high incidence of avascular necrosis, especially in proximal pole fractures.

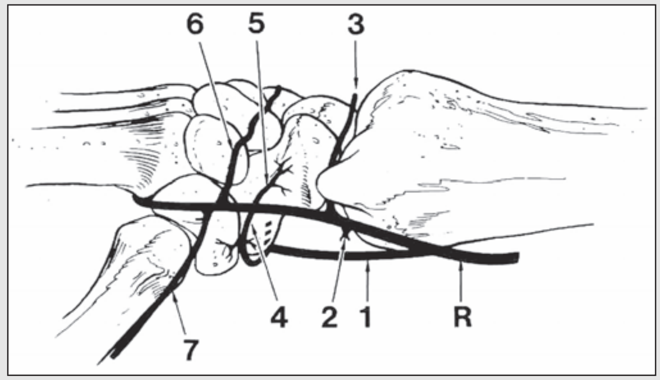


Fig. 5

Schematic drawing of the arterial supply of the lateral aspect of the wrist. R=Radial artery; Note: 4 is branch to scaphoid tubercle and trapezium. (From Gelberman RH J Hand Surg 1983; 8:367. Used by permission)

Scaphoid Fracture Classification: Anatomical

- Middle third—most fractures (70-80%) occur in the central third or "waist" of the scaphoid because of the force transmitted by the radio-scaphocapitate ligament in this region (Fig. 4).
- Proximal third—approximately 20% involve the proximal pole.
- Distal third—10% the distal pole.

The clinical reason for differentiating between the types is the variation in healing ability.

Recently, more emphasis has been placed on the stability of the fractures. Displacement implies instability, and fracture stability is necessary for union, but also for preservation of normal wrist mechanics.

Cooney et al. define a displaced fracture as having:

- more than 1 mm offset, or
- more than 15° of lunocapitate angulation, or
- more than 60° of scapholunate angulation.

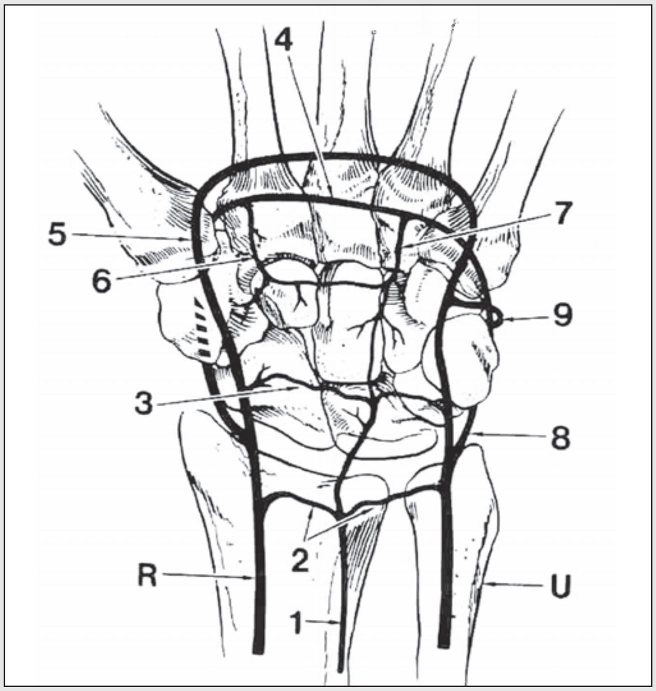


Fig. 6

Arterial supply of the palmar aspect of the wrist from the radial and ulnar arteries. 1) Palmar branch, anterior interosseous artery. 2)Palmar arch. 3) Palmar intercarpal arch. 4) Deep palmer arch. 5) Superficial palmar arch. 6)Radial recurrent artery. 7) Ulnar recurrent artery. 8) Medial branch, ulnar artery. 9) Branch of ulnar artery contributing to dorsal intercarpal arch. (From Gelberman RH J Hand Surg 1983; 8:367. Used by permission)

Diagnosis
The diagnosis of acute scaphoid fractures still continues to be missed. A scaphoid fracture is likely if the clinical examination demonstrates:

- snuffbox tenderness.
- axial load pain.
- palmar tubercle tenderness.
- pain with resisted pronation.

X-ray Examination
Clinical examination can often suggest a scaphoid fracture with normal radiograph appearance.

In addition to the standard posteroanterior, pronated oblique and lateral views of the wrist, the radial and ulnar deviation studies (scaphoid views)—especially with ulnar deviation while making a fist—will exert a distraction force on the scaphoid fragments. The **PA ulnar-deviated view** is a simple x-ray that is very helpful, extending the scaphoid and bringing it more completely into view. (If the examination findings suggest a scaphoid fracture, but radiographs are normal, magnetic resonance imaging has 100% sensitivity,but this is only available in a few major centers in Africa at this time). Ultrasonography and computed tomography are not as useful in the diagnosis of acute scaphoid fractures.

Fig. 7

Scaphoid Middle Third Fracture.

Precise radiographs are also essential to adequately assess fracture and carpal stability (see section on Carpal Ligament injuries below). Seemingly stable fractures have been known to displace as late as six weeks after the injury.

When there is a high degree of suspicion for a scaphoid fracture, but x-rays are normal, one should splint the wrist and repeat the x-ray in 2 weeks.

Treatment

Non-Operative
Most non-displaced scaphoid fractures will heal with 12-16 weeks of thumb spica cast immobilization. Proximal pole fractures may take longer to heal, sometimes requiring up to 6 months of immobilization.

Non-displaced fractures have a union rate of more than 95% when diagnosed promptly and properly immobilized.

The **position of immobilization** for these fractures should be the reverse of the mechanism of production; a short arm thumb spica cast with the wrist in slight palmar flexion and radial deviation. This position approximates the fracture fragments, and the radial deviation may prevent or correct the dorsal tilt of the lunate associated with displaced or unstable fractures. The thumb is placed in palmar abduction with the distal joint left free. Some studies suggest a long arm cast for six weeks, and an additional short arm cast for six weeks. These studies suggest a greater incidence of non-union when short arm casts are used. **There is no consensus on the best position of the wrist.**

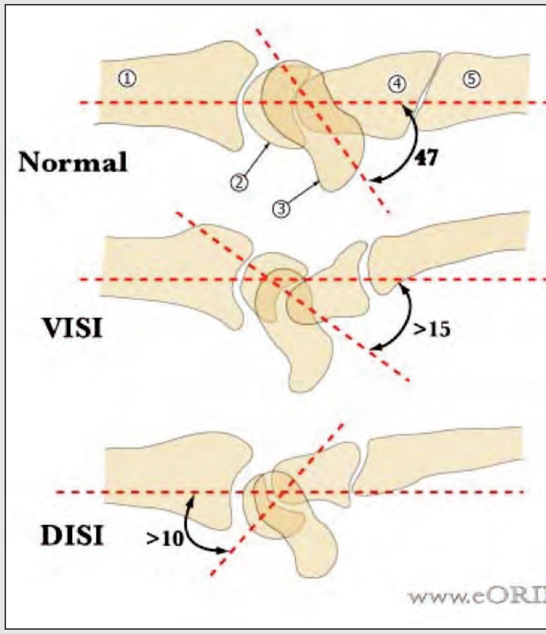


Fig. 8

Wrist Measurements, as seen on neutral lateral views. 1) Distal Radius. 2) Lunate. 3) Scaphoid. 4) Capitate. 5) 3rd metacarpal base. (From www.ORIF.com, used by permission)

Criteria for bony union are a demonstration of trabeculation across the fracture site and obliteration of the fracture line on all radiographic views.

The patient is seen every three weeks; the X-rays repeated without the spica. The thumb spica is reapplied and only permanently removed when radiographic healing is certain.

Operative

Accurate diagnosis of even the slightest displacement is important, for healing depends on precise reduction and immobilization.

Eddeland reported a non-union rate of almost 92% when fractures with displacement of 1mm or more were treated conservatively.

A) Displaced Fractures
Indications (theoretical) for operative treatment of acute scaphoid waist fractures include:

- more than 1 mm of displacement.
- comminution—likely not an indication in district/mission hospitals.
- open fractures.
- associated carpal instability.

Displaced fractures **ideally** require accurate reduction, usually must be open in our hospitals, and secure internal fixation using K-wires.

Technique

1 Waist fractures in which operative fixation is indicated are best approached volarly to better preserve the critical dorsal blood supply. The incision is along the FCR tendon. The tendon is retracted ulnarly (medially) and radial artery to the radial side. The incision is then carried down to the radiocarpal joint and then up to the trapezium. The scaphotrapezial joint is opened. Dorsiflexion of the wrist allows a clear view of this joint so that K- wires can be passed from distal to proximal through the scaphoid.

2 Direct vision of both joints will enable one to pass the K-wires accurately and not leave the end of the K-wire in the radiocarpal joint. Wide exposure is necessary, since most will not have a C- arm.

3 The fracture is accurately reduced by pushing the two fragments together—periosteal elevators can be very useful—and while being held together, transfixed with K-wires; usually two wires, 0.045 or 0.035. Leave the ends of the K-wires subcutaneous so they can be pulled out when the fracture is completely healed.

4 Full radial deviation of the wrist will correct the lunate dorsiflexion, if present, and this bone can be fixed to the scaphoid and/or a capitate with

additional K-wires.

5 Dissection proximal to the radiocarpal joint will expose the distal radius so that one can harvest a bone graft, if necessary.

6 **Displaced scaphoid fractures with significant scapholunate instability are best approached dorsally for accurate reduction and fixation of the lunate instability and the scaphoid fracture.**

7 Apply a thumb spica as described above for the non-operative management of undisplaced scaphoid fractures.

8 See every three weeks with repeat X-rays on every visit.

9 Cast and pins are removed when complete radiological healing is evident: trabeculation across the fracture site and obliteration of the fracture line on all radiographic views.

The above technique can be effectively done without a C-arm. Even if a C-arm is available, however, this described technique is probably still preferable, as insertion of percutaneous K-wires under the C-arm is extremely difficult if the surgeon is inexperienced with its use.

The use of a compression screw is indicated (Fig. 9), if screw and a C-arm are available, but **it is technically more difficult to insert, and, if incorrectly placed, can cause considerable damage.**

(**Editor's Note:** For those inexperienced in wrist surgery, a dorsal approach will be easiest, as the volar approach is difficult. The wrist is approached by a conventional longitudinal dorsal incision between the third and fourth dorsal compartments or just ulnar to Lister's tubercle. The EPL is freed from tendon sheath and retracted radially. The fourth compartment tendons, EDC and EIP, are retracted ulnarly and the wrist joint opened vertically. The scaphoid and scaphoid fracture are identified, reduced and held together with hooks or periosteal elevators. Two K-wires are passed dorsal to volar to fix the fragments reduced.)

Bone grafting may be indicated if there is significant comminution. The distal radius is a nearby source for bone (see above).

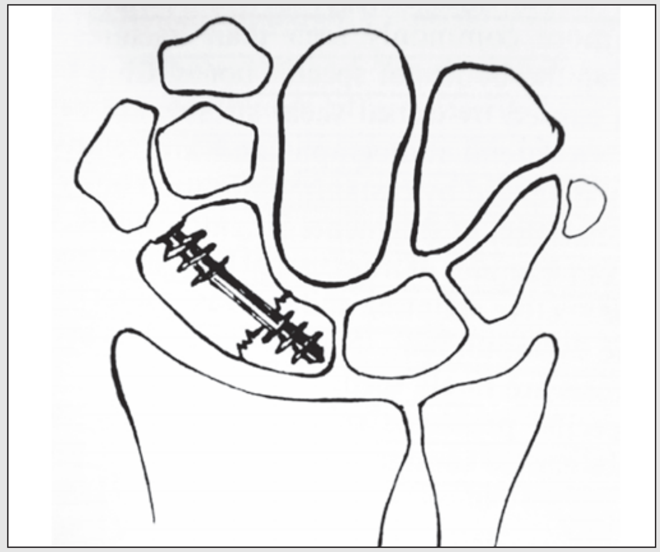


Fig. 9

The Herbert bone screw is designed to produce compression and rigid fixation of small cancellous bone fragments.
(After Herbert TJ. Clin Orthop 1986; 202: 79-92. Used by permission)

B) Delayed and Non-union
Bone-grafting should be given consideration if signs of union are not seen at eight weeks after injury after adequate treatment. Some authors advise a trial period out of plaster or the radiological demonstration of fracture instability before advising surgery, as many delayed or non-unions are essentially symptom-free.

Indications for Surgery
Surgical treatment is indicated for all **painful** delayed and painful non- unions regardless of the presence of degenerative, avascular or cystic changes.

The choice of the procedure will depend on the type of the fracture, the patient's age, and the presence of carpal degenerative changes.

Bone grafting is the basic treatment for all non-unions except those with carpal arthritis, avascular necrosis, and carpal collapse. A popular technique is the Matti-Russe bone graft technique: removal of the centers of the two fragments (hollowing out of the open ends) and filling of the created cavity with a single piece of cancellous bone. See pictures in orthopaedic or hand texts. **This is the best technique for most of our hospitals**.

Cooley found an 85% union with bone grafting whether by the dorsal or volar approach. Avascular necrosis improved in all cases where union occurred. There was a greater incidence of failure after bone grafting in displaced fractures (35%) than in undisplaced fractures (90%). Post-fracture arthritis was also more common in the displaced group. Therefore, we feel that internal fixation should be considered early when the fracture is significantly displaced or unstable.

If there is any avascular necrosis, arthritis, or collapse, a proximal row carpectomy or total wrist fusion is recommended. These operations are predictable, do not require much technology or advanced rehabilitation, and give very functional results.

(**Editors' notes**: It is realized that it is unlikely that these fractures in your environment will be handled this way. Splinting or casting should be done for six weeks. This is followed by intermittent range of motion exercises for six weeks while the wrist is still splinted between the exercises.)

The **SNAC (scaphoid nonunion advanced collapse) wrist** refers to the progressive arthrosis seen in scaphoid non-unions.

Surgical treatment can help prevent the development of a SNAC wrist if treatment is **instituted before the onset of arthrosis**. Surgical fixation with pins or screws, with or without bone graft, is typically preferred. When there is an associated humpback deformity of the scaphoid nonunion, a volar intercalated (inserted) graft is useful to correct the flexion deformity, usually through a volar approach.

Once the arthritic process has begun, the goal shifts from achieving union at the fracture site to maximizing strength and providing pain relief by some salvage procedure. If the associated degenerative arthritis is limited, options include scaphoid proximal pole excision, radial styloidectomy with wrist denervation, scaphoid excision and four-corner fusion or Proximal Row Carpectomy (PRC). PRC is usually not indicated if there is any lunocapitate arthritic involvement, but this is usually the easiest procedure to perform for the non-hand surgeon. If the wrist arthritis is advanced, total wrist arthrodesis is indicated. See available orthopaedic or hand surgery books.

A difference of opinion exists regarding the development of osteoarthritis in cases of longstanding nonunion, whether symptomatic or not. Most authors feel that unstable fracture non-unions will progress to increased carpal instability, collapse and osteoarthritis.

Unless there is evidence of osteoarthritis, such procedures as radial styloidectomy, carpectomy or arthrodesis should not be considered. Limited arthrodesis could be useful in failed bone graft procedures, in heavy laborers or the very active.

Proximal Third Scaphoid Fractures

Acute proximal pole fractures deserve special mention in that they have a high rate of avascular necrosis and may be best treated with operative fixation. These fractures are more easily **approached dorsally**, allowing exposure and fixation of the proximal pole, with or without primary bone grafting.

If prolonged healing time is suspected, due to the nature of the fracture, primary bone grafting should be considered. Due to the absence of sufficient vascular foramina, 30% of these fractures could develop avascular necrosis of the proximal fragment or even fracture nonunion.

Although avascular necrosis may delay union, it is not necessarily a sign of impending nonunion. Fresh, non-displaced fractures can be treated by cast immobilization, but the time of immobilization is controversial. Although the time of healing is known to be prolonged, prolonging immobilization beyond 12 weeks does not seem justified. The surgical method of treatment depends on the size of the proximal fragment. When this comprises one-third of the scaphoid, bone grafting by Russe's method with K-wire fixation may be successful. In smaller fragments, Math's technique, with K-wire fixation across the fracture and the scapholunate joint, is preferable. In cases of symptomatic nonunion or very small fragments, the fragment can be excised, the space filled by a tendon graft (**rolled up palmaris longus or other tendon**) and possibly a triscaphe fusion used to stop carpal migration. **The latter procedure is difficult and not recommended in our hospitals without experience**.

Fractures of Other Carpal Bones

Isolated fractures of the other carpal bones are less frequent than those found in combination with other carpal injuries. Dorsal chip fractures are also more commonly seen than fractures involving the bodies of specific bones. Chip fractures, especially of the triquetrum, caused by dorsal shear stresses are easily seen on lateral radiographs and are relatively easily managed by cast immobilization or by the later excision of fragments if symptomatic.

Most acute fractures of carpal bones are treated by protective splinting for six weeks. Non-unions and avascular necrosis are rarely seen.

Specific problems related to specific carpal bones can be summarized as follows:

Pisiform
In cases with persistent pain and those with degenerative changes in the pisotriquetral joint, excision of the pisiform is a gratifying procedure.

Trapezium
Fractures of the ridge that continue to be symptomatic after splinting, or threaten the median nerve, may be treated by excision of the fragment.

Capitate
Strictly isolated fractures are rare. The capitate is more susceptible to fractures through the neck, frequently in association with fracture- dislocations of the scaphoid and carpus. Avascular necrosis in isolated fractures is unusual, but non-unions may occur.

Hamate
Hook-fractures result from a fall or the direct force from the handle of a work tool or sports' implement, like a golf club. The chronic case is diagnosed with a carpal tunnel view radiograph, and in the acutely painful case, an oblique view with the forearm in mid-supination and the wrist in dorsiflexion will reveal the fracture. Neuropathy of the deep branch of the ulnar nerve can occur. Healing of the acute fracture with cast immobilization is uncommon, and excision of the ununited volar fragment is indicated for persistent pain or symptoms suggestive of ulnar neuropathy.

Triquetrum
Uncommon, but chip fractures are seen after direct blows or extreme dorsiflexion of the hand. There is swelling of the wrist and tenderness over the triquetrum with radial deviation. Usually seen with standard PA, lateral and oblique x-rays. Splint immobilization for 2-3 weeks is usually sufficient.

Carpal Ligaments

Fig. 10
Triquetral fracture
(From www.ORIF.com. used by permission)

Scapholunate ligament tears and perilunate dislocations are the most common and the most important ligamentous injuries of the wrist. Understanding of the underlying anatomy, mechanism of injury causing the tears, and dislocations of these structures are essential to arrive at the exact diagnosis in order to treat each injury specifically and effectively.

Ligamentous Anatomy

The ligaments of the wrist are divided into two major groups.

- **Extrinsic**, which course between the carpal bones and the radius, ulna, and the metacarpals; e.g. radiocarpal and ulnocarpal ligaments.
- **Intrinsic**, which originate and insert on the carpal bones.
    - Long: volar intercarpal.
    - Intermediate: Lunate-triquetral, **Scapholunate**, Scapho-trapezium.
    - Short: bind the four bones of the distal row together The Intrinsic and Extrinsic Volar Wrist Ligaments:

Sprains

A "sprained" wrist is one of the most common diagnoses made in the upper extremity. Sprains are injuries to ligaments and can be divided into three grades:

- Grade I is a ligament injury with a minor tear.
- Grade II is a partial tear or stretch.
- Grade III is a complete tear.

Intrinsic and Extrinsic Volar Wrist Ligaments

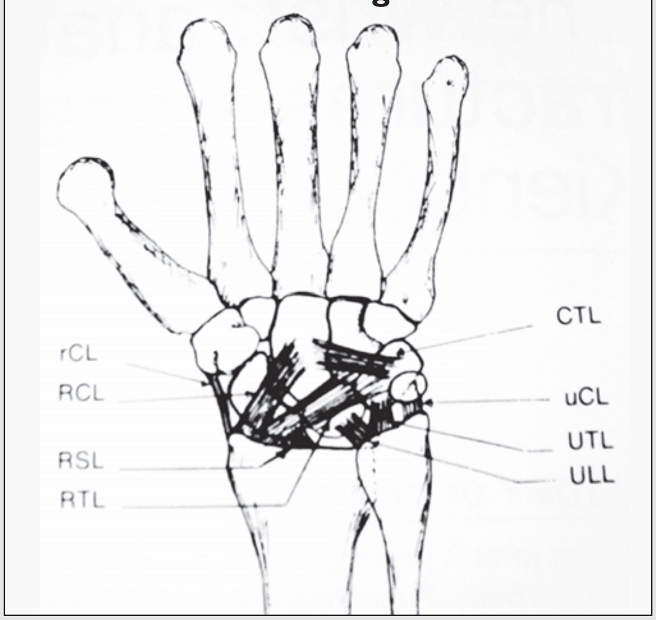


Fig. 11

Volar wrist ligament anatomy. rCL=radial collateral ligament; RCL= radiocapitate ligament; RSL=radioscaphoid ligament; RTL=radiotriquetral ligament; ULL=ulnolunate ligament; UTL= ulnotriquetral ligament; uCL=ulnar collateral ligament; CTL=capitotriquetral ligament.
(From Mayfield JK. Clin Orthop 1980, 149: 45-54.)

Extrinsic Dorsal and Collateral Wrist Ligaments

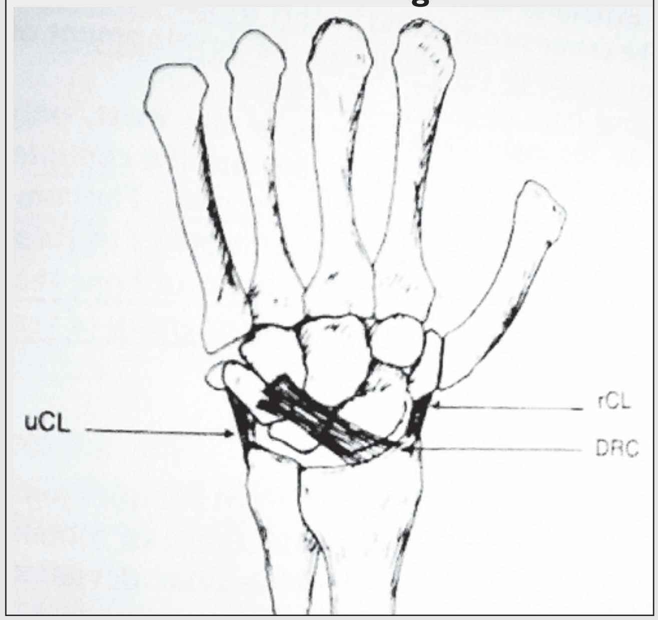


Fig. 12

Dorsal radiocarpal and collateral ligaments. DRC=dorsal radiocarpal ligament; rCL= radial collateral ligament; uCL=ulnar collateral ligament.
(After Mayfield JK, et al Anat Rec 1976; 186: (3) 417, with permission)

Grade I and grade II injuries (also referred to as **pre-dynamic injuries**—see below) can be treated non-operatively and are discussed here; grade III injuries of the wrist may require surgical repair and are discussed in the next section.

It is important in the diagnosis of a wrist strain to keep the possibility of a more severe injury in mind. Significant initial symptoms, persistent signs and symptoms, and the lack of response to appropriate treatment should always raise suspicion of a more serious tear.

Clinical history and presentation: Wrist sprains commonly occur from a fall on an outstretched hand. Patients present with pain and swelling in the wrist.

Physical examination may pinpoint the area of injury; however, the pain is often diffuse. **Stress tests should be normal** both on exam and on x-ray.

Radiographs should be taken and special stress tests performed if the physical examination suggests a more serious injury (see below).

Treatment is summarized with the acronym RICE and includes:

- Rest (immobilization, activity modifications).
- Ice (20 minutes every 2 hours).
- Compression (gentle compression).
- Elevation.

This may involve a brace or a cast for 2-6 weeks, minimizing activity that causes pain, such a tight gripping or pushing, and anti-inflammatory medications such as ibuprofen. Then a removable brace may be used for activities, as gradual strengthening and stretching is added. For sports-related injuries, return to normal activities depends on the severity of the symptoms and the type of sport, as well as if the athlete can participate in the sport with a cast or brace.

The patient should be re-evaluated for improvement after a period of treatment (2 to 4 weeks).

- If the patient's symptoms improve, immobilization should be weaned, and a progressive return to activities commenced.
- A failure of treatment should prompt further evaluation for occult serious injury. Patients who improve but have lingering symptoms should be re-evaluated after several months to avoid the situation in which the patient with a diagnosis of wrist sprain is found years later to have scapholunate advanced collapse (SLAC wrist).

(**Editor's Note**: simple wrist sprains are quite rare in our patients, and most of these injuries will involve a **definite ligament tear** and these must be carefully looked for. Ligament tears are best treated early. **Stress views** must be taken to rule out dynamic instability. This would include an A-P view of the wrist with a clenched fist to rule out tears in the scapholunate ligament.)

Carpal Instability (Unstable Wrist Injury)

Most authors divide intercalated (meaning between carpal bones or rows of bones) carpal instability into that which occurs within a row, termed **dissociative**, and that which occurs between rows, termed **non-dissociative**.

Intercalated segment instability, that is instability resulting from injury either between or within the carpal bone rows, are divided into dorsal and volar patterns depending on whether:

- The scaphoid flexes and the lunate extends (dorsal intercalated segment instability=DISI), or
- The scaphoid extends and the lunate flexes (volar intercalated segment instability=VISI) (see Fig. 13, which repeats Fig. 8).

Anatomy of Scapholunate Ligament Tears: This is the most common wrist ligament injury and involves, as the name suggests, the connecting ligament between the scaphoid and lunate bones.

(**Editor's note**: When repeat x-rays 2-4 weeks after an injury fail to show the suspected scaphoid fracture, one must look for a scapholunate ligament tear as the cause for persistent pain.)

This ligament is the most important intrinsic ligament of the wrist binding the scaphoid and lunate bones of the wrist together. It is divided into three areas, dorsal, proximal, and palmar, with the **dorsal** segment being the strongest portion. It is the main stabilizer of the scaphoid.

Normally, the scaphoid and the lunate move together with the intact scapholunate ligament holding them together—an important factor in the stability of the wrist.

When a scapholunate ligament tear occurs, the scaphoid flexes and the lunate extends—distal intercalated segment instability (DISI), and a gap may form between the bones (Fig. 13). With the **volar intercalated segment instability (VISI)**, the lunate flexes volarly and the scaphoid extends (in Fig. 13, notice the position of the lunate and the line perpendicular through the lunate). This occurs with a combination of a lunotriquetral ligament tears, volar radiolunotriquetral tears, and (in addition) some degree of dorsal radiotriquetral ligament tears—and **not just an isolated lunotriquetral ligament tear**.

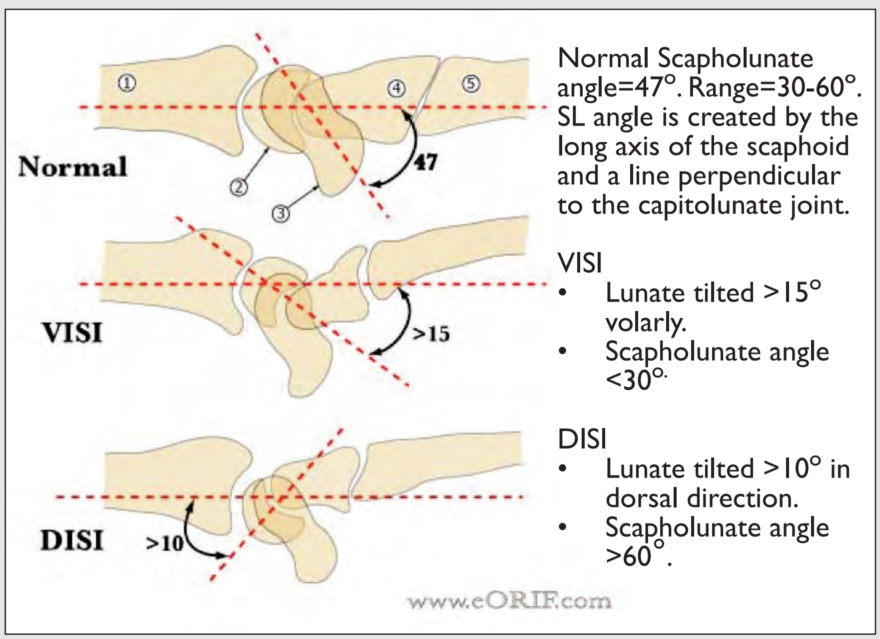


Fig. 13

Wrist Measurements, as seen on neutral lateral views. 1) Distal Radius. 2) Lunate. 3) Scaphoid. 4) Capitate. 5) 3rd metacarpal base.
(From www.ORIF.com, used by permission)

A scapholunate ligament tear can vary from mild sprains (partial tears, Grade I) to complete tears (Grade III), with or without other ligaments torn. They may also be accompanied by other injuries such as a scaphoid fracture or a lunate dislocation (see below).

The scapholunate ligament tear is divided into four categories from mild to severe: pre-dynamic, dynamic, static, and scapholunate advanced collapse.

Stable Wrist Injury (Grade I or II)

- **Predynamic, or occult, injury**; the mildest form of the scapholunate ligament tears. It is a partial tear of the ligament. X-rays are normal but the partial tear may be visualized by an MRI or by looking in the joint with an arthroscope at the time of surgery.

  (**Editor's Note**: This will not be diagnosed in most of our hospitals, but may be the cause of persistent wrist pain with a negative x- ray.)

  Therefore, this is the recommended sequence of care:

  1 Original x-rays—if negative for fracture or obvious dislocation, splint or cast wrist for 2 weeks.
  2 After 2 weeks, repeat x-ray. If fracture or dislocation, treat appropriately as discussed in this chapter.
  3 If the repeat x-ray is negative:
     - If there is definite improvement, allow patient to begin daily activities and continue splinting as necessary.
     - If patient still has pain and swelling or returns later with persistent pain, then this may be a dynamic scapholunate dislocation or other dynamic injury—see below.
  4 Stress views must be taken.
     - If negative, then continue splinting.
     - If patient is unimproved after 2-4 more weeks, then re- evaluate, repeat x-rays and consider referring if this is possible.

Unstable Wrist Injuries (Grade III)

- Dynamic injury; the ligament is completely torn or stretched to the point that it is non-functional. There may also be some mild injury to other surrounding ligaments. **Regular x-rays** are normal but **stress x- rays show a gap** between the scaphoid and the lunate.
- **Static injury**; the ligament is completely torn and some of the surrounding ligaments are also injured. **Routine x-rays** show a gap between the scaphoid and the lunate.
- **Scapholunate advanced collapse (SLAC) injury**, the ligament is completely torn, and the injury has been there a long time (years), **causing arthritis** or evidence of cartilage damage. It is seen on regular PA x-ray with gapping between the scaphoid and the lunate. This is a predictable pattern of arthritis that develops with longstanding, untreated ligament injuries. (This is different than the SNAC wrist seen after scaphoid non-unions.)

Symptoms

A scapholunate ligament tear is usually caused by a fall or by a sudden load on the wrist as with the sprain injury. Sometimes the patient may not recall the fall because they didn't seek treatment immediately, but only sought treatment weeks later when they continued to have pain. There may be pain in the center or on the radial side of the wrist, especially with activities that load the wrist. There may also be grip weakness, snapping, swelling, or popping.

With examination, the scapholunate interval may be tender and swollen. The **Watson scaphoid shift test** can be helpful. This is done by having the patient ulnar deviate the wrist, and then examiner applies dorsally directed pressure to the scaphoid from the palm as the wrist is radially deviated. The dislocated scaphoid will protrude dorsally and then relief of pressure will allow the scaphoid to slip back into place with a clunk. However, this test may be positive in many normal wrists, so it must be interpreted with caution and compared to the opposite side.

Differential Diagnoses of persistent wrist pain:

- Occult ganglion cyst.
- Posterior interosseous nerve neuroma.
- Ulnar translocation.
- Physiologic scapholunate separation such as lunotriquetral coalition (compare to other hand).

There are several imaging studies that may be used: standard x-rays, stress x-rays, and MRI.

Standard x-rays rule out other problems such as fractures. If the patient has a **static injury** (ligament is completely torn), the standard x-rays will show gapping between the lunate and scaphoid (Terry Thomas Sign—Fig. 14) and increased angulation between the scaphoid and the lunate. If the patient has a longstanding tear with a **SLAC wrist**, arthritis may be seen on the x-rays.

If standard x-rays are normal, then with a **dynamic injury, stress x-rays** may be useful to show gapping or instability that is too mild to show up on standard x-rays. Stress x-rays include the following views: 1) an AP wrist with a tight fist, 2) a PA wrist with ulnar deviation, and 3) a PA in radial deviation. The physician may also order an x-ray during which the fingers are gently pulled on. These x-rays may show gapping or abnormal angulation that only occurs during activities and **not** when the wrist is at rest. X-rays of the normal wrist may be taken for comparison.

Where available, MRI and wrist arthroscopy may be very useful to clearly define the injury. (**Editor's Note**: It is understood that most of the surgeons that this publication is intended for will neither have MRI nor arthroscopy capabilities.)

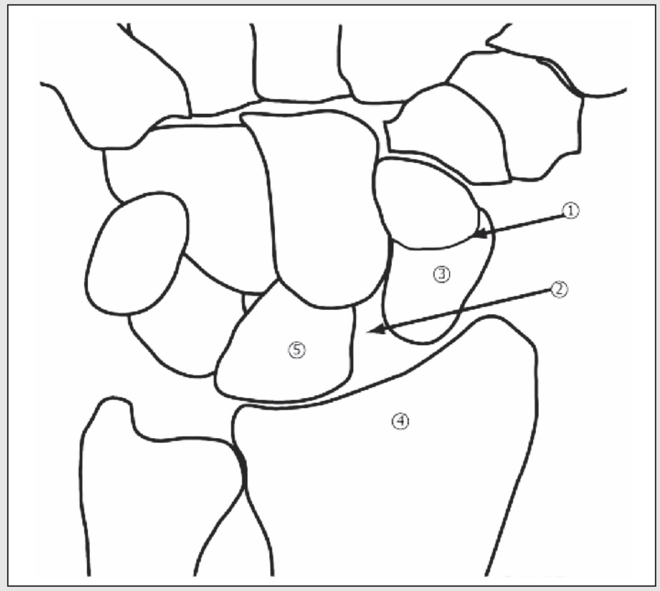


Fig. 14

1) Scaphoid waistline. 2) Scapholunate diastasis (Terry Thomas Sign). 3) Scaphoid. 4) Radius. 5) Lunate.

Fig. 15

Fig. 16

Stress views showing scapholunate instability.

Treatment

A) Intercalated Segment Instability: dissociative (Carpal instability that occurs within a row—Grade III tears).

Scapholunate Dissociation: Indications for Surgical Treatment

- If there is gapping and increased angulation between the scaphoid and lunate on x-rays (DISI and VISI, if there was a perilunate dislocation), or if treatment without surgery hasn't been successful, then surgery is warranted.

- If the x-rays don't show gapping, but treatment with a cast or brace has not been successful, surgery might be necessary. (**It will be a rare occurrence for this to be done in a district hospital without some definite findings. In this situation, unless one has considerable experience, it would be best to have the patient go to the capital city or medical school for an MRI/arthroscopy—if such is available there.**)

- If significant instability is present, pins may be placed to hold the bones in place, and/or for reconstruction of the ligaments—an open procedure and best performed in the first weeks after injury.

- **If x-rays show gapping, as in dynamic or static injuries**, then surgery is warranted. This involves repairing the ligament. The ligament will be difficult to repair after several months. The pins are usually placed to help protect the ligament repair while it is healing. After surgery, a splint is placed, which is then changed to a cast at 1-2 weeks. The cast protects the repair as well as the pins, which are protruding through the skin. The pins are removed at 10-12 weeks after surgery.

Then range of motion and strengthening exercises are begun. **(If one reaches this stage and feels confident with wrist anatomy and surgery, then one must consult major hand texts to learn the appropriate hand therapy or consult with the editor of this book.)**

- **There are several new and advanced techniques for SL ligament repair which are beyond the scope of this chapter.**

- If x-rays show **gapping and arthritis, or collapse of the carpal bones, ligament repair is not likely to work**. Treatment without surgery may be indicated because surgical options are more involved and would involve a Proximal Row Carpectomy or wrist arthrodesis. In this situation, treatment without surgery may involve bracing, anti- inflammatory medications, avoiding painful activities, and cortisone injections. In time, the patient will likely require surgery.

Methods of Treatment
- Closed reduction and casting alone are inadequate for long term treatment of these injuries.
- **Open reduction** through a dorsal incision in the center of the wrist, with ligament repair and pinning, remain the mainstay of treatment for acute scapholunate ligament tears. Cast is applied for 6 weeks.

Technique
- A typical dorsal longitudinal incision for wrist surgery is carried out between the 3rd and 4th dorsal compartments. The EPL will be freed from its compartment and reflected radially. Only in the acute case will one be able to repair these ligaments. Any DISI deformity has to be corrected, and the scaphoid and lunate pinned or screwed together. Bone anchors can also be used to repair the ligament by inserting anchors in both bones and tying the sutures together. K-wires (0.045 or 0.062) can be passed into the scaphoid and lunate under direct vision to be used as "joy sticks" so that the bones can be aligned properly for the ligament repair. After the ligament has been repaired, two similar K-wires should be passed between the scaphoid and lunate, and one or two between scaphoid and capitate for stability.

One may view the technique of dorsal capsulodesis below in a text and add it to this procedure.

- **This problem is commonly recognized late** (>3 months), and ligament repair may no longer be possible. In this case, several treatment options exist. Simple debridement may be adequate for partial tears. **The technique above can be done. The techniques below are difficult and mentioned only for completeness**.
  - Ligament reconstruction can be performed with a tendon graft. Bone-ligament-bone reconstruction is appealing, and has proved successful in other orthopedic applications, such as anterior cruciate ligament reconstruction of the knee. Potential sources of bone-ligament-bone tissue include hamate metacarpal joint and the cuneonavicular ligament from the foot.
  - Dorsal capsulodesis alone, or combined with a reconstruction, can limit flexion of the scaphoid (not recommended for most institutions).

- Once the **arthritic process** has commenced, a partial wrist fusion may be indicated. Fusion of the scaphotrapeziotrapezoid, scapholunate, scaphocapitate, and scaphocapitolunate joints has been described; however, **proximal row carpectomy (PRC)** may afford good pain relief and potentially improved motion compared with a partial wrist fusion, although this remains somewhat controversial. Proximal row carpectomy remains a viable option, even in the presence of capitate base arthrosis, as long as a strip of dorsal capsule is interposed between the capitate and radius—a fascial arthroplasty.

- **Treatment Options for Chronic Tears and arthritis**: If sophisticated surgery is not possible, then conservative management with splinting and pain relief should be the aim. If pain becomes unacceptable, then PRC or wrist arthrodesis is indicated. PRC is a wonderful and relatively easy operation. Limited arthrodesis procedures mentioned above would be difficult for a surgeon not trained in hand surgery. See wrist arthrodesis technique below.

B) Dorsal Perilunate Dislocations

This is a severe wrist dislocation that can **easily be missed**. With severe trauma, the same forces on an

Fig. 17

PA X-ray. Wrist does not look right but difficult to diagnose.

Fig. 18

Lateral view is not clear unless one notices the dislocated lunate with the "spilled tea cup" sign.

outstretched hand that led to a scapholunate ligament tear can also lead to further ligament injuries, including lunotriquetral ligament tears. If these occur together, then the final stage of this injury pattern is the dislocation of the lunate. The lunate may dislocate completely when all the restraining ligaments are torn except radioscapholunate. Residents may miss this diagnosis on routine x-rays in the Casualty Department. This is the most severe wrist dislocation, and it is sometimes associated with a transscaphoid fracture and a fracture through the neck of the capitate.

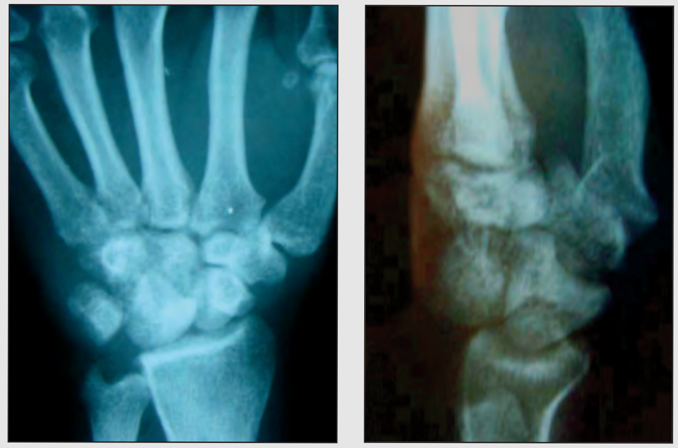


Fig. 19 **Fig. 20**

Stress views showing scapholunate instability.

Diagnosis

The patient often has severe pain, and on exam, there is significant swelling and pain on motion. Patients may have median nerve symptoms since the lunate may be displaced into the carpal canal, as in Fig. 18. It is difficult to make the diagnosis on exam alone but basic PA and Lateral x-rays should give the diagnosis.

There is a spectrum of lunate dislocation, in the so-called Lesser Arc Injury pattern, through the scapholunate and lunotriquetral ligaments. The patient above had a Stage IV perilunate dislocation with rupture of the palmar capsule—giving the lunate the appearance of a "spilled tea cup" (see blue arrow in Fig. 18).

These dislocations are difficult to reduce, and the above injury pattern could not be reduced closed as the lunate was outside the volar wrist joint capsule. This patient required operative intervention.

Treatment: Closed Reduction

An attempt should be made to reduce all ACUTE (seen within hours after the injury) injuries using Tavernier's method. You will likely never see an acute case. After 10 minutes of elevation and uninterrupted traction with finger traps, then under complete anesthesia (regional or general) and with the wrist extended, one hand maintains the traction while the thumb on the hand stabilizes the lunate on the palmar surface. The wrist is gradually flexed allowing the capitate to snap back over the lunate. If this occurs, the wrist is gradually extended while the thumb continues pressure over the lunate. X-rays are then repeated. If there is near perfect reduction with normal angles and a scapholunate gap of less than 3 mm, then dorsal and volar splints are applied, as in a sugar-tong splint. Frequent x-rays are taken to ensure reduction. The wrist is immobilized for at least 12 weeks.

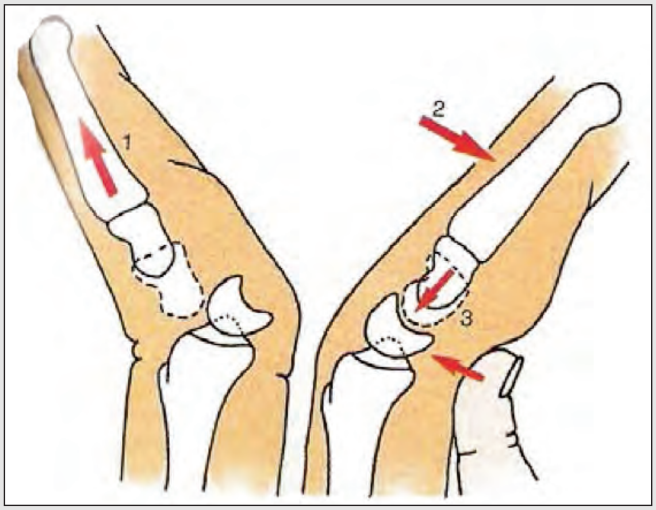


Fig. 21

Tavernier's Method of closed reduction of a dorsal perilunate dislocation.
(From *Green's Operative Hand Surgery*, Sixth Edition Page 511.Used by permission)

Treatment: Open Reduction
Closed reduction was described since many will not be capable of open reduction; open reduction, however, will be needed in most cases, especially since most will come in late. Open reduction involves using both dorsal and volar approaches in most cases. The wrist joint can be opened dorsally as described earlier in this chapter. Often with wrist extension for a few minutes, the lunate can be reduced similar to the technique above. When this is not possible, the lunate may have **herniated** through the volar capsule and caught in the carpal tunnel. This requires a volar incision with a carpal tunnel release and then reduction of the lunate. Though dislocated, in most cases the lunate is still attached to some soft tissue and often the short radioscapholunate ligament (Ligament of Testut), and it will still be viable in most cases.

When the lunate is reduced, the volar capsule is repaired. If the scapholunate and lunotriquetral ligaments can be found, then they should be repaired after K-wires are placed across the joints—scaphoid to lunate, triquetrum to lunate, and scaphoid to capitate. The K-wires are placed percutaneously. If the ligaments are not suitable for reconstruction (often the case), the lunate can be held in reduction and two K-wires can still be placed across each joint. In addition, suture anchors if available may be placed in all three bones and sutures tied down as artifical ligaments. The dorsal capsule is repaired. The skin is closed in one layer, preferably with absorbable sutures.

If there is an associated transscaphoid fracture, it should also be pinned. The patient is placed in a short arm thumb spica cast for 6 weeks. The pins are then removed and the cast reapplied for 2 more weeks. Then the patient is placed in a splint and, if the x-ray is satisfactory, gentle range of motion is begun.

On occasion, an older patient will present late with a chronic complete lunate dislocation, and the lunate cannot be reduced without tearing surrounding scar and what tissue remains. In such cases, a proximal row carpectomy is a good solution. No healing of ligaments or bone is necessary, and the patient can start motion in a few days. This would **only** be done in late cases with an avascular displaced lunate in the carpal canal. One should always examine the patient for carpal tunnel impingement and release the carpal tunnel if indicated.

C) Intercalated Segment Instability: non-dissociative (Carpal instability that occurs between rows).

When the instability is between the proximal and distal rows, both DISI and VISI deformities can occur. It is often associated with ligamentous laxity. A painful clunk may be palpated with radio-ulnar deviation of the wrist.

Treatment
Treatment is usually conservative, but mid-carpal arthrodesis may be indicated for those unresponsive to non-operative management. If the laxity is secondary to an underlying deformity, this will need to be addressed first (e.g., corrective osteotomy for a distal radius malunion).

Proximal Row Carpectomy
Proximal Row Carpectomy is a relatively easy salvage procedure for chronic unsalvageable wrist pain and indicated in:
- Disabling wrist pain, secondary to SLAC wrist.
- Kienbock's disease.
- Scaphoid Nonunion or avascular necrosis (AVN).

- Acute and subacute severe carpal fractures and dislocations.

Contraindications
- Severe degenerative changes in the head of the capitate—relative, as one may be able to place dorsal capsule between the capitate and radius. This is a fascial arthroplasty and works well in most cases.
- Rheumatoid arthritis.
- Patients >35 years old are more likely to require revision surgery (fusion).

Wrist arthrodesis is an alternative to when proximal row carpectomy is contraindicated.

Technique for Proximal Row Carpectomy
- Well-padded tourniquet placed high on the arm.
- Longitudinal incision centered on radiocarpal joint from ulnar side of radius to the base of 2nd metacarpal.
- Dissection under 2.5x/3.5x loupe magnification, if available, and identify the extensor retinaculum. Incise longitudinally, opening the 4th extensor compartment. Preserve cuff of retinaculum for later repair.
- Identify and release EPL from third dorsal compartment.
- Isolate and retract extensor tendons with Penrose drain.
- Identify the posterior interosseous nerve in floor of the 4th dorsal compartment and transect proximally.
- Perform T-capsulotomy centered over scapholunate joint—note dissociation of scapholunate ligament, degenerative changes in radioscaphoid joint, etc.
- Preserve cartilage of the capitate.
- **The bones should be removed in the following order:**
  - Place a Steinmann pin in the lunate and excise lunate.
  - Place Steinmann pin in the triquetrum and excise.
  - Divide the scaphoid at its waist with in osteotome. Remove the proximal fragment. Excise distal fragment using a threaded Steinmann pin as a “joy stick”.
  - Protect and verify the integrity of the radioscaphocapitate ligament.
  - A radial styloidectomy may be performed with dissection between the 1st and 2nd dorsal compartments. Remove distal 5 to 7 mm of radial styloid. Ensure that the radioscaphocapitate ligament is preserved.
- Irrigate.
- Repair capsule to maintain capitate in lunate fossa.
- Repair extensor retinaculum and close in layers.
- Apply a volar splint in neutral and elevate the

Fig. 22

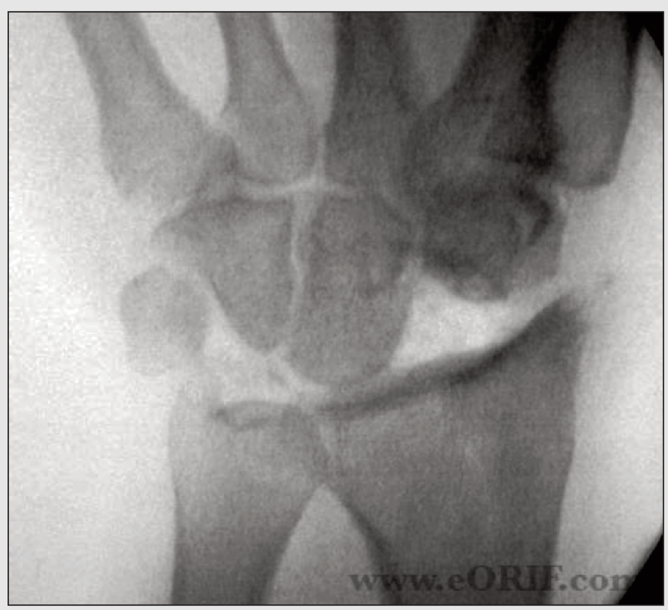


Fig. 23

22) SLAC Wrist. 23) After Proximal Row Carpectomy.
(From www.eORIF.com. used by permission)

hand.
- Some will place a pin through radius and into capitate for several weeks.

For all chronic conditions resulting in severe pain and/or significant functional limitations, proximal row carpectomy or wrist fusion works well. The techniques are described below.

Follow-up Care
- Wound check at 7-10 days.
- At 4 weeks the splint is removed and X-rays done. Start gentle strengthening exercises and functional activities. Apply a cock-up wrist splint as necessary for light duty work. No heavy manual labor.
- Full activities at 3 months: may resume manual labor if adequate strength has been achieved.

Proximal Row Carpectomy Complications
- Degenerative changes in the radiocapitate articulation.
- Stiffness, motion loss.
- Weakness.
- CRPS—Complex Regional Pain Syndrome.
- Continued pain.
- Instability.
- Degenerative changes in the radiocapitate articulation.

Technique of Wrist Fusion (This assumes the surgeon does not have special reconstructive plates and screws)
- Well-padded tourniquet placed high on the arm.
- Longitudinal incision centered on radiocarpal joint from ulnar side of radius to the base of 2nd metacarpal.
- Dissection under 2.5x/3.5x loupe magnification (if available) and identify the extensor retinaculum.
- Incise longitudinally, opening the 4th extensor compartment. Preserve cuff of retinaculum for later repair.
- Identify and release EPL from third dorsal compartment.
- Isolate and retract extensor tendons with Penrose drain.
- Identify the posterior interosseous nerve in floor of the 4th dorsal compartment and transect proximally. The nerve is beneath the tendons.
- Transverse incision through the wrist capsule and reflect the capsule distally or a reverse T incision can be used.
- Using an osteotome or a large rongeur, remove all the cartilage from the articular surface of the radius, scaphoid, lunate, triquetrum, capitate, hamate, and 3rd CMC joint.
- One may perform a Proximal Row Carpectomy first to make the arthrodesis easier. The bones may be morselized and used for bone graft.
- Steinman (3mm) pins may be placed percutaneously and laterally along the shaft of the 3rd MC, and then obliquely through the base of the MC and into the carpus. They can be left protruding for 2-3 months, or better, left under the skin with the end bent so that they do not migrate proximally. They can then be removed in 3 months or left permanently.
- If one has a way to countersink the Steinman pins, they can be inserted into the 3rd MC head down into the carpus, and then into the distal radius. An additional pin may be necessary through the 4th MC head. The pins are cut off close to the MC heads and countersunk 15 mm into the distal MC so they do not back out.
- Most will use the previous method that does not require one to countersink the pins.
- There is less chance for infection when the pins are buried.
- An attempt is made to slightly extend the wrist while inserting the pins.
- The wrist is casted for at 12 weeks or until there is evidence of healing.

(**Editor's Note**: A simplified approach to the injuries in district hospitals is simply this: Acute ligamentous tears, whether isolated to the scapholunate ligament or lunate/perilunate dislocations, can be treated with open reduction and repair with k-wires and casting. Chronic injuries that result in instability, with or without arthritis, avascular necrosis, collapse, or significant functional limitation should be treated with proximal row carpectomy or total wrist fusion.)

Chapter 36

Distal Radius and Ulna Fractures

Robert F. Greene

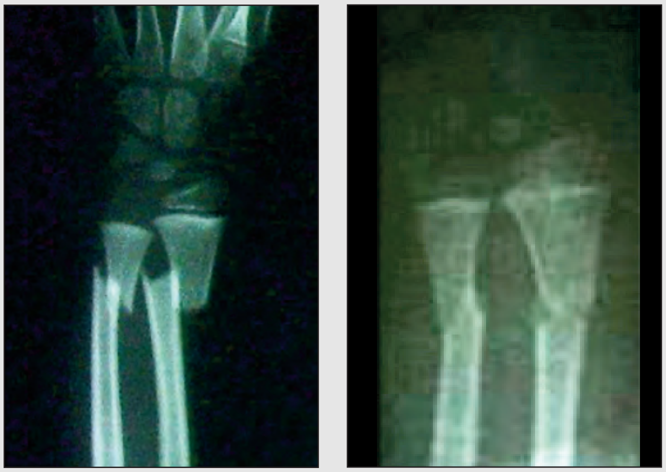


Fig. 1
(L-R) Distal Radius and Ulna Fracture and subsequent end-to-end reduction.

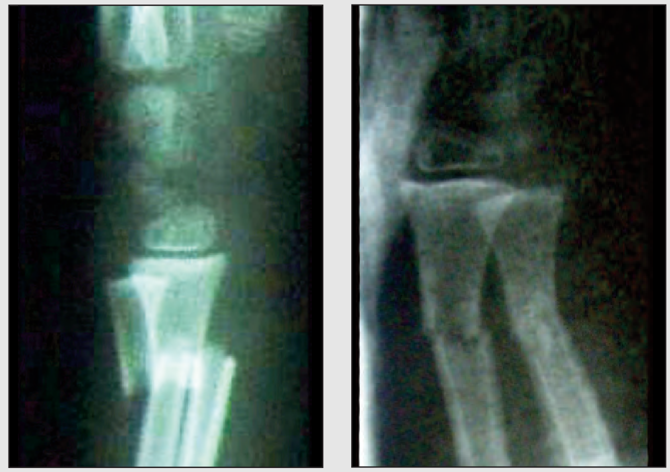


Fig. 2
Lateral view of the fracture and reduction seen in Fig. 1.

Editor's Preface

These fractures are well-covered in many major orthopaedic textbooks. Since these fractures are so common in Sub-Saharan Africa, the editors felt that a basic chapter from someone who has spent much of his life in Africa would be helpful to the surgeons in remote hospitals. Often these hospitals do not have a C-arm or the instrumentation for rigid fixation as found in the West.

Introduction

Most closed wrist fractures can are treated with closed reduction and casting/ splinting. For unstable or neglected fractures open reduction and pinning maybe needed. It is not necessary to obtain a perfect postop x-ray to have an acceptable functional result.

Reduction

For the completely displaced children's distal radio-ulnar fractures, strive for an end to end reduction. If this is not possible, in younger children (under 10) one can accept complete displacement and overlapped alignment (Figs. 1-2). It will remodel. For older children (and adults) an open or closed reduction with pinning is often used.

Under anesthesia (IV regional, axillary block or

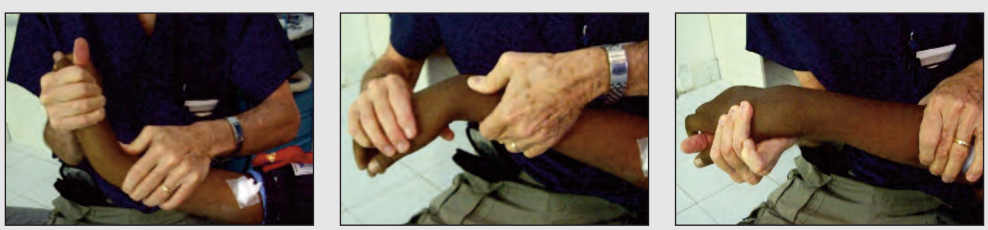


Fig. 3
Closed reduction of distal radio-ulnar fracture.

Fig. 4
Displaced wrist fracture and subsequent reduction.

general) the wrist is reduced by first reproducing the original fracture deformity (usually dorsal or hyperextension—Fig. 3a). Then shove the distal radius with your thumb until it engages the edge of the radial shaft (Fig. 3b), flex the distal fragment, and finally align the wrist bones (Fig. 3c). Put the wrist in slight flexion and ulnar deviation, and apply a well-padded short or long-arm cast, being careful to mold over the dorsal side of the distal radius. (This section assumes most distal radius and Colles' fractures are dorsally displaced.)

Fig. 4 shows an 8 year-old with a displaced wrist fracture with reduction views in a cast.

Fixation

In the case seen in Fig. 5, percutaneous pinning under regional (or general) anesthesia was used (Kapandji technique). The pins are not inserted through the distal fragment, but into the fracture a short way. Then by thrusting the pin distally, using it as a lever, the distal fragment is tipped into the corrected position and held there by drilling the tip into the opposite cortex.

Often it is simpler, however, to just enter the styloid with one pin and drill through to the ulnar cortex of the radius. If additional fixation is needed, a dorsal pin can be added in similar fashion, perhaps via Lister's tubercle. Notice the length and ulnar inclination of the distal radius has been restored on the AP view (Fig. 6). Also, on the lateral view, the normal volar tilt (11-12°) has almost been obtained (Fig. 7).

When the fracture is open or comminuted, external fixation is often used. Pinning sometimes will be helpful, however, if a large styloid fragment is present. In the external fixation x-ray pictured in Fig. 8c, a styloid pin might have been useful to restore the radial articular surface to approximate the ulnar length. The external fixator is usually removed after six weeks (Fig. 8 a-c).

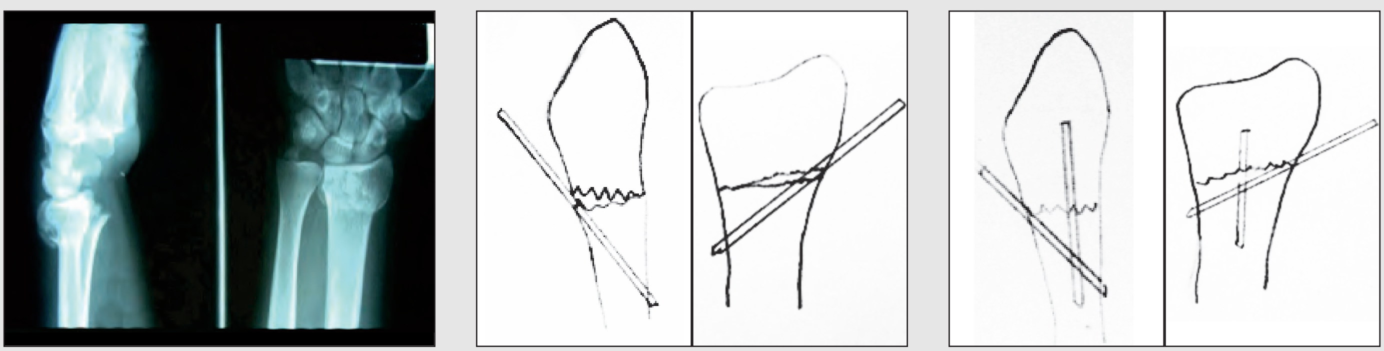


Fig. 5
"Kapandji pinning" via the fracture, levering with the pin.

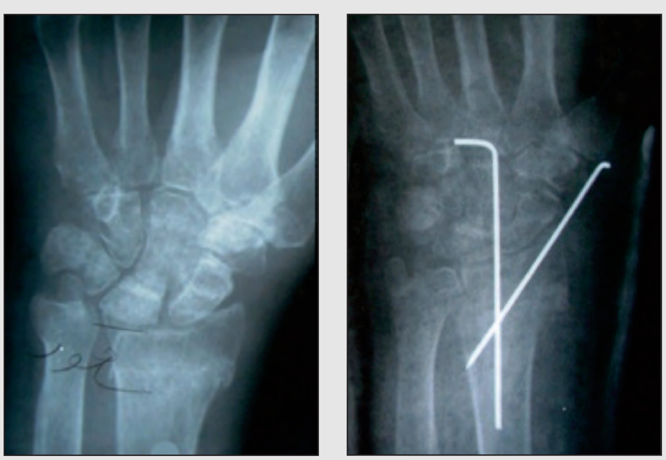


Fig. 6
(L-R) Fracture and internal fixation.

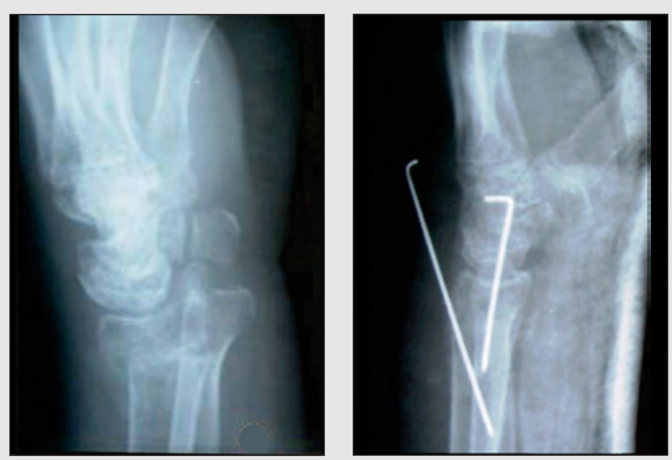


Fig. 7
Lateral view of the case seen in Fig. 6.

Fig. 8

Distal radius fracture repaired with external and internal fixation.

Fig. 9

Comminuted Colles' fracture managed with closed reduction.

Colles' Fracture

The x-rays in Fig. 9 illustrate how you can sometimes get an excellent closed reduction even when the Colles' fracture is comminuted. This wouldn't be possible with a fracture that arrives late.

The very comminuted fracture shown in Fig. 10 cannot be easily restored. In the bush, a pinning through the radial styloid might help restore length, but casting it as is will probably give a stiff but functional result.

Fig. 11 shows a healed Colles' fracture in a 70 year-old patient. The wrist will be functional, even though flexion will be limited. The dorsal angular deformity is more than is usually accepted, and the radial length is a bit short.

Fig. 10

Severly comminuted Colle's fracture

Fig. 11

Colles' fracture in elderly patient.

Editor's Addendum

Most remote mission or government hospitals will not have a functional C-arm in surgery. These hospitals may have a portable x-ray machine that can be moved to the operating theatre if there is a need to take multiple x-rays after a fracture-dislocation is reduced.

If the hospital does not have a portable x-ray machine, then the x-ray room can be used as an operating theatre for upper extremity surgery. Sterile drapes and instruments are taken to the x-ray room. The x-ray table is used as the operating table, and an operating theatre technician is available just as in the theatre. Initial x-rays are taken. Local anesthesia or Ketamine will be used for anesthesia and the patient monitored by the nurse anesthetist with a pulse oximeter. The nurse anesthetist should have basic resuscitation equipment if this is necessary. After anesthesia is administered, the fracture is reduced and pinned based on known and palpated landmarks. After reduction, x-rays are taken once again. If the fracture is not reduced adequately, additional anesthesia may be given and reduction attempted again.

If a fluoroscopy is available, this could be used to monitor the reduction without the need for multiple x-rays. Final x-rays are taken for documentation in the patient's records.

As stated by Dr. Greene, an acceptable final result can usually be obtained without the need for opening the fracture site. The wrist may end up stiff but it is likely that any open reduction and internal fixation will also leave the wrist stiff. (See admonition at the end of Chapter 34 on Hand Fractures.)

Chapter 37
Hand Infections and Bites

Louis L. Carter, Jr.

Introduction
Many hand infections in Africa will present in an advanced stage and will require more than just oral antibiotics and simple Incision and Drainage (I and D). When the infection is advanced or occurs in an otherwise healthy person without injury, one must consider underlying systemic diseases such as diabetes mellitus or HIV/AIDS. These infections will often need differentiation from fungal infections. Some regions of the world have unique conditions seen commonly in their region. Such is the case with felons and tenosynovitis that are frequently seen in dry, arid areas where there are many thorn bushes. Other areas where HIV/AIDS is common will see a high incidence of necrotizing fasciitis requiring radical surgical treatment.

Most infections seen will be bacterial, but many surgeons will not have access to sophisticated lab procedures, including reliable culture and sensitivities. Common infections seen in the West and covered in major texts will be discussed briefly.

Paronychia
Simple paronychia is rarely seen early. When it is seen early, warm soaks, elevation, a cephalosporin antibiotic and with early I and D are usually adequate. When presentation is delayed, one may be dealing with destruction of the nail bed, osteomyelitis of the distal phalanx, and/or a felon. The treatment for a felon will be discussed below. Destroyed nail bed will need debridement and later closure, depending on viable tissues left behind. Osteomyelitis of the distal phalanx requires removal of the distal phalanx and later closure with available tissue. Often, proximal amputation will be required. With a severe paronychia, **one must always suspect underlying osteomyelitis**.

Felon
This closed space infection within the septa of the palmar pad of the distal phalanx is usually secondary to a puncture wound or bite wound in the pulp of the distal phalanx. Such puncture wounds of the hand and foot are commonly seen in desert and arid conditions where thorn bushes are common. The thorns can be several cm. long and very stiff, easily penetrating the palm of the hand or even the sole of a shoe. Often the injury occurs at night when walking or working in the dark. A swollen painful distal phalanx is seen when the infection is confined to the distal phalanx. At this time simple I and D is all that is necessary. Many incisions have been described, but the author has found one simple midline vertical incision, illustrated below, on the volar aspect of the distal phalanx is sufficient. Once within the soft tissue, the septa may be divided, and


Fig. 1

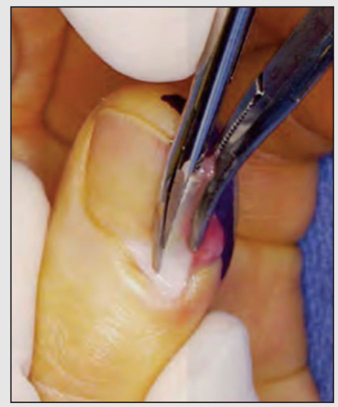


Fig. 2

Severe paronychia treated by excision of nail and underlying nail bed.

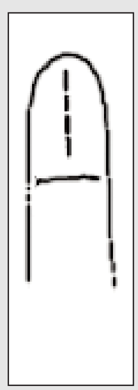


Fig. 3

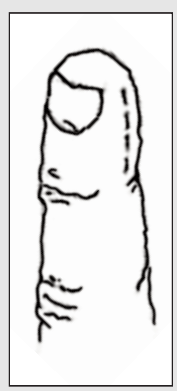


Fig. 4

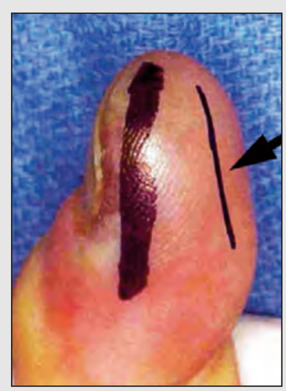


Fig. 5

These show the appropriate incisions to drain a felon. Some prefer the lateral incision, while the author prefers the midline incision in Figs. 3 and 5. (Courtesy of Anthony Smith)


Fig. 6


Fig. 7


Fig. 8


Fig. 9

Felons and osteomyelitis secondary to thorn injuries.

the fingertip drained. Because the incision is midline, the major nerves and vessels are not damaged. This wound heals well with few long-term complications. The incision on the lateral side of the distal phalanx in the drawing in Fig. 4 is advocated by some but not by the author.

With a longstanding felon, osteomyelitis of the distal phalanx is common, and the distal finger will require amputation. Also, the infection may extend deep into the flexor tendon sheath, proximal with flexor tenosynovitis, and later a deep space infection in the palm.

Flexor Tenosynovitis

This must always be the likely diagnosis when one sees a swollen finger as above. The etiology may be a felon or a direct injury, as a puncture wound, into the flexor tendon sheath. If the infection is confined to the tendon sheath, then it is a closed space infection and will have the four cardinal signs as described by **Kanavel**:

1 Swollen finger.
2 Flexed posture.
3 Tenderness directly over the tendon sheath.
4 The most important finding on exam is severe pain, when the flexed finger is extended.

Occasionally a soft tissue infection will present in a similar fashion. There will be an obvious superficial infection, as seen in cellulitis, but there will not be the exquisite pain on extension (see Fig. 14).

When tenosynovitis presents late, the flexor tendons may be destroyed, there may be extension into the deep palmar space or thenar space, and finally rupture into the superficial soft tissues (See Fig. 12). If seen early, then opening of the tendon sheath proximally and distally with irrigation may be sufficient. The distal tendon sheath is opened at the DIPJ through a zigzag incision. Proximally, a similar incision is used at the level of the distal palmar crease, just proximal to the A-1 pulley and over the MPJ. An IV cannula can be used to irrigate in both directions. Some use 24 hour irrigation through the cannula with normal saline solution. Others prefer intermittent irrigation. The author prefers distal to proximal irrigation. Once the sheath has been opened and drained, the patient is placed on high doses of IV antibiotics, and the hand is elevated. There is no advantage to using an antibiotic solution for irrigation. In the rare case, the finger may respond to these measures, and one will be able to


Fig. 10


Fig. 11

10) Flexor Tenosynovitis. Note posture and swelling. Passive extension will cause severe pain.
11) Late delayed cases are often seen on admission.

Fig. 12

Late stage tenosynovitis.

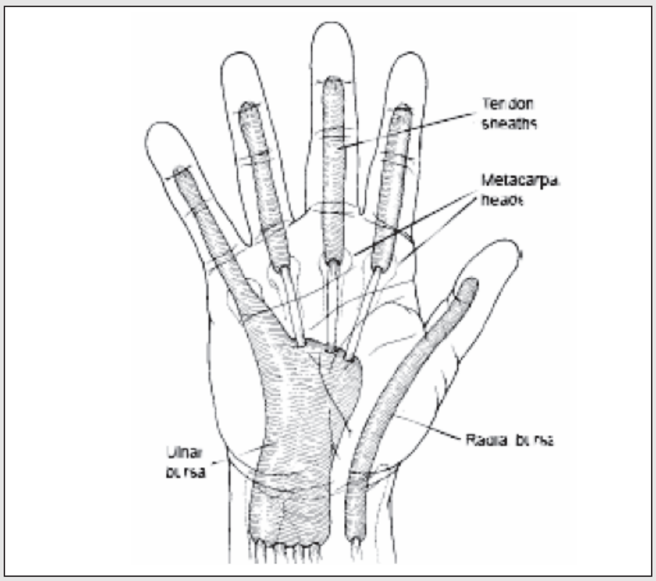


Fig. 13

Flexor tendon sheaths.

Fig. 14

Superficial abscess—must be differentiated from flexor tenosynovitis.

begin early range of motion (ROM) exercises. There will be a slow resolution of the swelling—always taking longer than expected in a finger.

When tenosynovitis destroys the tendons, it is often obvious that the function of the finger cannot be saved, even though the finger itself is salvageable. It will then be best to amputate this non-functioning finger. Even though the infection will resolve, the finger will be stiff and will not actively flex with the adjacent fingers. In fact the adjacent fingers will also lose full range of motion. Amputation of a viable, but non-functional finger is a radical approach which is often not accepted by the patient or his/her family, but in cultures where hands are so important for livelihood, the one infected finger should be removed to allow full use of the remaining hand. In females, a ray amputation is best, as it gives a more pleasing cosmetic result. In a male, an amputation at the MP joint level, if there is good soft tissue at this level to close, will preserve palmar width and grip strength. Once the non-functional finger is amputated, the other fingers will usually regain full range of motion with an excellent functional outcome. Most people never notice the amputated finger in a female if a ray amputation has been carried out.

Cellulitis and subcutaneous abscesses must be differentiated from flexor tenosynovitis. In the case seen in Fig. 14, there was minimal pain when the finger was extended

Septic Arthritis

Septic arthritis may occur in any joint of the hand. It must be differentiated from other causes of arthritis, though in Africa rheumatoid and osteoarthritis in the hand are uncommon.

The etiology of septic arthritis is usually traumatic, though it may occur with a systemic infection, such as salmonella in sickle cell patients and gonorrhea. It must be also be differentiated from fungal infections. A possible etiology in many countries will be an infected human bite wound with an infection in the metacarpal phalangeal joint. Often part of a tooth is left in the joint.

Lab work usually points to a bacterial infection. X-rays should be taken to rule out any foreign bodies and to determine the status of the articular surface.

Findings are a swollen, erythematous, warm and tender joint that must be differentiated from tenosynovitis and a superficial cellulitis. The author will initially treat these with broad spectrum antibiotics, heat, elevation, and splinting. If there is localization to a joint, then an arthrotomy is performed with irrigation and drainage. Repeat irrigation procedures are usually necessary. The exposure of the PIPJ and MPJ is through a dorsal curvilinear or zigzag incision. An incision over the point of maximum tenderness is best for the wrist joint. The typical dorsal approach to the wrist joint between the 3rd and 4th dorsal compartments may be used.

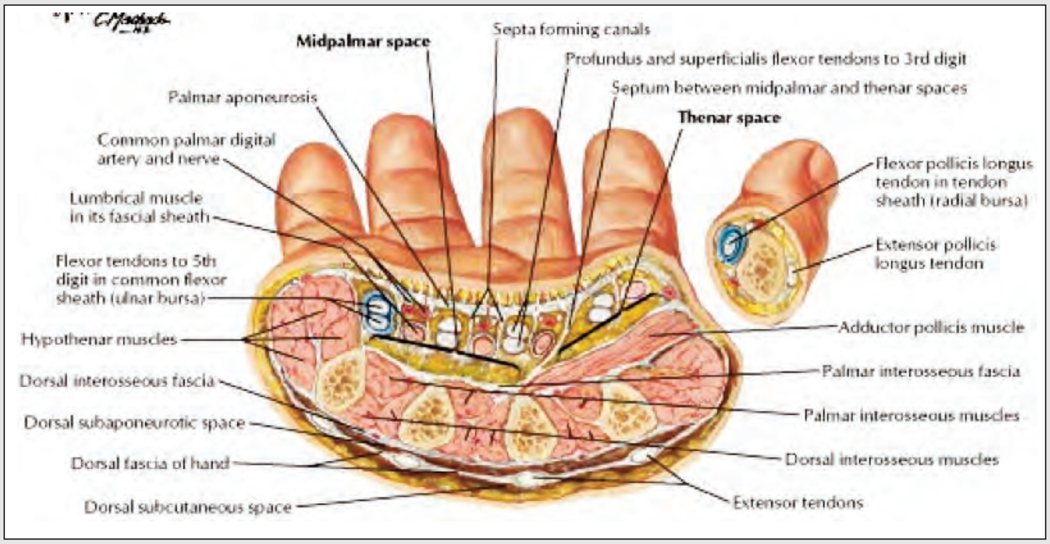


Fig. 15

This Netter drawing shows the tendon sheaths in blue and the deep spaces (thenar and midpalmar spaces) are in green with the septum from the palmar fascia to the metacarpal (Courtesy of Elsevier).

As soon as the inflammation improves, gentle exercises are begun to regain complete range of motion. Swelling in the hand dissipates very slowly, and one must begin range of motion exercises before the swelling subsides. During the recovery, the hand must remain elevated and splinted except for exercises.

Deep Space Infections

There are two deep space infections, the mid-palmar space and the thenar space. A fibrous septum from the superficial palmar fascia to the 3rd metacarpal divides the two spaces. The thumb and index fingers drain into the thenar space and the ulnar three fingers drain into the mid-palmar space. Tenosynovitis and any other finger infection may lead to a deep space infection.

Thenar space boundaries are:

- Flexor tendons and lumbricals volarly.
- Fibrous septum to the 3rd metacarpal on the ulnar side.
- Metacarpals and deep fascia dorsally or deep.
- Skin in web space radially.

Midpalmar space boundaries are:

- Flexor tendons and lumbricals volarly.

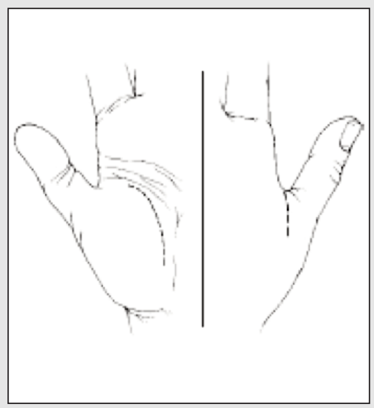


Fig. 16

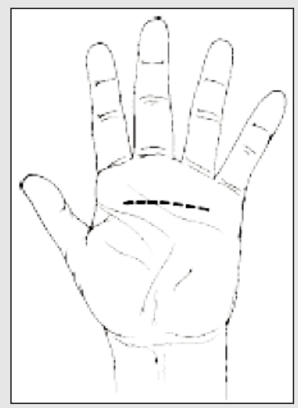


Fig. 17

16) Shows the incisions for thenar space drainage. Note that there is no incision through the web space.
17) Incision for mid-palmar space drainage.

- Fibrous septum radially.
- Deep fascia and metacarpals dorsally or deep.
- Skin on the ulnar side.

Because of the thick palmar fascia, swelling on the volar side is initially minimal. These infections usually present with dorsal swelling or swelling in the first web space. Workup includes routine lab work and x-rays, the latter to rule out a foreign body.

Both of these deep space infections are closed space infections with little way for the purulent fluid to

Fig. 18

Fig. 19

Fig. 20

Thenar Space Infection. Note Adductor Pollicis in depths of Fig. 20 (arrow). Thenar space is deep to flexor tendons and superficial (volar) to metacarpals.

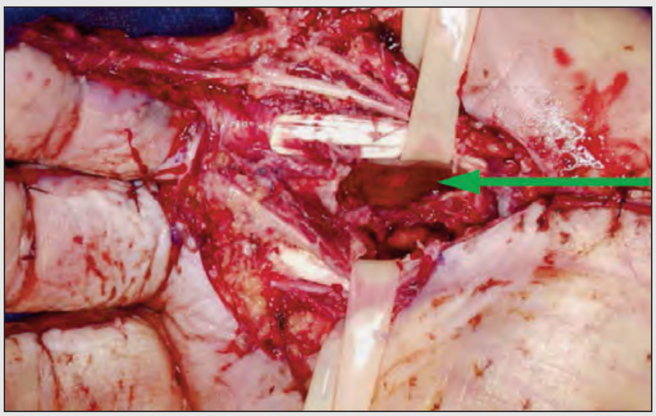


Fig. 21

Deep Palmar Space (arrow).
Dorsal (deep) to flexor tendons and volar (superficial) to metacarpals in a volar approach.

escape. Urgent exploration and drainage are necessary to protect vital structures once a diagnosis is suspected.

Surgery

- The incision for the **thenar space** decompression is on the dorsal side of the first web space. The incision is vertical, extending up to, **but not through**, the web between the thumb and index finger. This incision provides excellent exposure to the thenar space that lies just below the tendons to the index finger. After irrigation and drainage, a Penrose drain is left in the space for several days.

- The **mid-palmar space** is approached volarly through a transverse incision just proximal to the distal palmar crease. Once through the skin and superficial fascia, a vertical dissection is then used to dissect through the soft tissues and between the vessels and tendons. **Once the incision is made through the subcutaneous tissue, a hemostat can be bluntly inserted where there is bulging and between the flexor tendons and vessels**. One should attempt to identify the digital vessels and nerves, though in an edematous hand this may be difficult. After irrigation, a drain is left in place for several days. These deep space infections may require a second look procedure to ensure adequate decompression.

- Post-operatively, the hand is elevated, early gentle exercises carried out and antibiotics continued for 3-7 days. When the drainage diminishes, the drains may be removed.

In all hand infections, culture and sensitivity studies may be done if available. If not, antibiotics such as a cephalosporin are usually adequate, except in cases of immuno-compromised patients and abscesses secondary to farm injuries. In such cases, gram negative and anaerobic infections may need to be covered. These infections will commonly occur in the diabetic or AIDS patient. See below.

Parona's Space Infections

This is a rare infection. It is found on the volar aspect of the distal forearm, above or volar to the pronator quadratus and deep to the flexor tendons. Extension of infection, tenosynovitis, from the first or fifth flexor sheath can lead to infection in Parona's space (see Fig. 13). A zigzag incision ulnar to the palmaris longus will give good exposure for drainage. One must also rule out the need for decompression of the flexor tendon sheaths of the thumb and small finger, since they drain directly into this space.

Osteomyelitis

Osteomyelitis is most commonly seen after an open bony injury, though it can be from hematogenous spread. It is occasionally seen after an open reduction of a fracture. Late presentation of an open fracture is the most common presenting finding. In these cases, it is very important to irrigate and debride the wound well and delay closure until there is no sign of infection. Early closure of these open fractures that present late is a major contributing factor. Fortunately, in the upper extremity, the blood supply is excellent and open fractures do not lead to osteomyelitis as readily as in the lower extremity. Still, repeated debridements must be carried out before wound closure and fixation in an open fracture. When osteomyelitis does occur from traumatic wounds, even after adequate debridement of non-viable tissue and bony fragments, it is important to rule out a co-existing systemic illness.

Hematogenous osteomyelitis in the upper extremity is rare, though it can be seen in the long bones like the humerus. In such cases, the patient may present early with an erythematous swollen painful extremity with negative x-ray findings. It is easy to diagnose cellulitis and not realize there is underlying early osteomyelitis. If there is no purulent material in the soft tissue, then drilling of the bone must be done to rule out acute osteomyelitis. Purulent material will exude from the bone, and the bone can be opened further to allow adequate drainage. The good news is that this bone will never form a sequestrum, and will heal quickly without residual. There is approximately a 3 week window between the onset of the osteomyelitis and periosteal reaction. If there is obvious purulent material in the soft tissues and bone involvement on x-ray, then the treatment is irrigation and debridement of any loose bony fragments, drainage, systemic antibiotics and immobilization. When the x-rays show lytic changes in the medullary canal, and there is evidence of periosteal elevation and striping of the periosteum, then the bone cannot be saved. At this time the infection has spread through the cortex, and wide bony debridement should NOT be carried out as this will result in the debridement of periosteum and a sequestrum will not form without the periosteum. The infection is well drained and obvious necrotic tissue debrided. The result will be a flail limb if the periosteum is removed. This limb may drain for 6-12 months before the involucrum forms and the sequestrum can be removed. So the surgeon **must be patient** while the involucrum forms. The involucrum is new bone around the sequestrum. The involucrum gives the extremity stability. **If one removes the sequestrum before the involucrum forms, then a flail extremity will result.**

Salmonella osteomyelitis is seen across Africa, and it often heals with systemic antibiotics and without drainage procedures. Often, there are multiple sites of osteomyelitis with a diagnosis of Salmonella.

There are four very severe extremity infections that are seen in Sub-Saharan Africa and in the Developing World: Tropical pyomyositis, Gas

Fig. 22

Osteomyelitis from penetrating injury, showing lytic, cystic changes with bone destruction.

Fig. 23

Fig. 24

Tropical pyomyositis in a thigh—common and multiple sites are commonly found. Lower extremity common but may occur in arm and forearm. (Courtesy David Thompson) gangrene, necrotizing fasciitis, and tropical diabetic hand syndrome. Gas gangrene is also discussed in Chapter 40 on Compartment Syndrome.

Fig. 25

Fig. 26

Early necrotizing fasciitis in open fracture of leg—developed under a tight cast. Note blister formation with brownish "dish water" fluid oozing out. The infection extended to lateral side through the fracture. Leg required multiple daily debridements, "second looks," and the use of VAC once the wound began to clean up.

Fig. 27

Fig. 28

Gas gangrene after traditional "bone-setter" treatment. Note gas in tissue in left photo.

- **Tropical pyomyositis** is a bacterial infection of the skeletal muscles which results in pus-filled abscess cavities within the muscles. It is most commonly caused by Staphylococcus and usually affects the larger muscles in the lower extremities in children and in immuno-compromised patients. When there are multiple abscesses, the upper extremity may also be involved. Etiology is unknown, though some feel minor trauma is the initial predisposing event. One must have a high degree of suspicion when one sees any swollen extremity, and must rule out osteomyelitis first and then pyomyositis. These abscesses are often deep within the muscle, and careful exploration is necessary. There are often multiple cavities within the large muscles, and these must also be adequately drained. Persistent fever and pain should alert the surgeon that more abscess cavities are present and need to be drained. Careful exam will be needed to determine the location. Late cases may present with septic shock.

- **Necrotizing fasciitis** is rare in the upper extremity, but may occur in debilitated patients and those with untreated deep space abscesses. This is also covered in Chapter 40. This is frequently called the "flesh-eating disease." There are a number of variants of necrotizing fasciitis which are covered under other diseases in this text, including cancrum oris and Fournier's gangrene. This fasciitis involves the superficial fascia of the body—as Scarpa's fascia in the abdomen. There is a superficial fascial layer throughout the body. The blood supply to the skin lies just above this fascia as seen with the superficial inferior epigastric artery in the abdomen. The deep muscle fascia is not involved in the classic case. The infection may spread quickly in the loose areolar tissue, and for this reason "second looks" are often necessary to rule out further progression. It is a polymicrobial infection, with aerobic and anaerobic bacteria including Staphylococcus, Group A Streptococcus, Clostridia, Bacteroides, etc. Trauma is the leading etiology, and early symptoms are pain, swelling, and cellulitis. Immune deficient conditions must be ruled out. This is quickly followed by diarrhea, vomiting, blisters, necrosis of skin, and brown, foul, watery drainage from the involved area. Septic shock quickly ensues.

Surgery involves radical debridement and



Fig. 29 **Fig. 30** **Fig. 31**

TDHS: Presentation, progression and radical debridement. (Courtesy of Peter M. Nthumba)


Fig. 32 **Fig. 33**

Rapid progression of TDHS requiring multiple debridements and thumb amputation. (Courtesy of Peter Nthumba)

extension of incisions proximately and distally into normal tissue. Usually, it is **impossible** to save the overlying skin, since the blood supply to the skin has been lost. The infection can extend into deeper tissues. Since these infections often have both gram negative and anaerobic organisms, broad spectrum antibiotics must be given. Drugs such as a cephalosporin, vancomycin, and clindamycin may be used but others include chloramphenicol, high doses of Penicillin G, and metronidazole. Each hospital has different antibiotics, and the surgeon should use those that will cover suspected organisms. The patient must be watched closely for signs of septic shock, and every patient should go back to the OR several times in the first week to rule out and control any progression of the infection. Early aggressive surgery is the key for survival.

- **Gas Gangrene** is usually seen in patients who have had a tight cast applied or have gone to the native bone setter. These patients often require immediate amputation and a second and even third look. These wounds should not be closed initially but only after the wound is definitely clean.

One can see the gas in the tissue planes in Fig. 27. Broad spectrum antibiotics must be used to cover aerobes, anaerobes, Clostridia, and microaerophilic organisms.

- **Tropical diabetic hand syndrome (TDHS)** is a rare condition seen in Type II diabetic patients in the tropics. In most cases, the infection is progressive and daily debridements are often necessary. Amputation is frequently the final result. The etiology is frequently minor trauma to the hand. Hyperglycemia is not under control in most patients, and occasionally this condition is the first sign of diabetes. In cases where cultures have been performed, Staphylococcus is the most common organism. Though necrotizing fasciitis is part of the differential diagnosis, this infection often spreads into the deeper tissues with gangrene of muscles and soft tissue.

Chapter 38

Tumors of the Hand

Tertius H. J. Venter and Louis L. Carter, Jr.

Introduction

Tumors of the hand may arise from any tissue present in the hand; skin, subcutaneous tissue, tendons, nerves, blood vessels, or bone (See Table 1).

They occur at any age, and certain tumors (such as the epidermal inclusion cyst and the glomus tumor) are seen in the hand more than in any other part of the body. The vast majority of tumors are benign, and excision is the treatment of choice.

A detailed history, careful systematic physical examination, and detailed examination of the hand are important in the diagnosis of the tumor. X-rays of the hand and chest are performed if either bone involvement or malignancy is expected.

Malignant tumors are uncommon but must be in the differential diagnosis when dealing with hand tumors, as premalignant and life-threatening malignant lesions demand early diagnosis and prompt definitive management. Diagnosis is based on a clinical examination, high level of suspicion, special investigations (e.g. X- rays, CT scans when available, radio-isotope scans, and magnetic resonance imaging) and biopsy. It is understood that most will only have an x-ray.

Incidence: the most common tumor is the ganglion, with benign giant cell tumor and the lipoma following next in order of frequency.

I. Benign Soft Tissue Tumors of the Hand

Ganglion

This is the most common tumor of the hand after the wart (verruca vulgaris). The ganglion is a small cystic swelling containing clear, jellylike fluid. The pathogenesis and etiology of ganglions continue to be confusing. Specific traumatic initiating history is cited as an etiological factor in approximately 10% of patients. Mucoid degeneration of the joint capsule producing cystic degeneration is still a widely accepted theory. Ganglia commonly arise in joints and tendon sheaths, and some regard ganglia as being the result of herniation through the joint capsule or tendon sheath.

Sites: Ganglia usually occur in very specific locations. The most common site is the dorsal wrist (60-70%), followed by the volar wrist (18-20%), the flexor tendon sheath ganglion (volar retinacular ganglion) (10-12%), and the distal interphalangeal (DIP) joint—the mucous cyst. Ganglia may also occur at any other joint or tendon in the hand. They may also occur in the carpal or ulnar tunnels, where they may compress their respective nerves. Ganglia may also rarely occur within the bone as a cyst—intraosseous ganglia.

Symptoms: In the majority of ganglia, a symptomless swelling is mostly the only concern. The swelling is often hard and not compressible. Some patients may, however, complain of pain and weakness especially with increased activity. The intraosseous ganglion most often presents with persistent aching pain in the absence of a mass.

The most symptomatic ganglion is the volar retinacular ganglion, which presents as a small, hard, painful lump at the base of the fingers. This barely palpable ganglion may cause more discomfort than the larger protruding ones, especially with gripping objects.

Treatment: Most ganglia will resolve spontaneously within two years (75%). A wide variety of non-operative methods have been tried in treating ganglia. These include rupture by firm external pressure, rupture by needling under local anesthesia, and aspiration with or without injections of cortisone, hyaluronidase, cortisone or sclerosing agents.

Excision is the treatment of choice, however, if adequate surgical technique is not followed, recurrence is likely.

Surgical Principles: Not all ganglions require operative treatment. In fact, a number will resolve spontaneously, depending on their location. Over half recur after rupturing by pressure or by a needle. The cure rate with operative treatment has been reported to be between 70-90%. If the source of the ganglion is eliminated surgical cure approaches 100%.

Adequate anesthesia and a tourniquet are essential. The incision must allow for extension to follow the stalk. Damage to nearby nerves must be avoided (particular attention to the cutaneous branches of the radial nerve with dorsal wrist ganglia and digital nerves with volar retinacular ganglia). The ganglion must be carefully exposed, taking care to identify communications. It is most important to find the site of origin of the ganglion. Failure to do this will predispose to recurrence. Tracing the ganglion to its origin can be difficult in those cases where the ganglion has a long pedicle. The volar radial ganglion may pose considerable difficulties because of its close relationship to branches of the radial artery.

Because ganglia can spontaneously resolve, the surgeon should wait at least six months before planning operative intervention as the method of treatment. Ganglions present for a long time or those with significant symptoms are operated on immediately.

Dorsal Wrist Ganglion

The dorsal wrist ganglion usually presents between any of the extensor tendons and often directly over the scapholunate ligament (Fig. 1). Even in the

Table 1

Tissue	Benign	Malignant
Skin	Verruca Vulgaris	Epidermoid Cyst, Basal Cell Carcinoma, Squamous Cell Carcinoma, Malignant Melanoma
Fat	Lipoma	Liposarcoma
Fibrous Tissue	Fibroma, Juvenile Aponeurotic Fibroma, Nodular Fasciitis, Desmoid Tumor	Fibrosarcoma
Tendon Sheath and Joint Capsule	Ganglion, Mucous Cyst, Benign Giant Cell Tumor	Synovial sarcoma
Muscle	Leiomyoma	Rhabdomyosarcoma
Nerve	Neurilemmoma, Neurofibroma, Neurofibromatosis	Neurofibrosarcoma
Vascular	Glomus tumor, Hemangioma	Hemangiosarcoma
Bone	Simple Bone Cyst, Aneurysmal Bone Cyst, Chondroma, Osteochondroma, Osteoid Osteoma	Chondrosarcoma, Osteosarcoma, Subungual Exostosis Carpal Boss, Giant Cell Tumor
Macrodactyly (Lipofibromatosis, Hamartoma of Infancy or Localized Gigantism)		

Classification of hand tumors.
(Courtesy Prof. Ulrich Mennen, Editor *The Hand Book: A Practical Approach to Common Hand Problems*, Southern Book Publishers, South Africa

Fig. 1
Dorsal Wrist Ganglion

absence of a mass, the dorsal ganglion should be included in any differential diagnosis of the painful wrist.

Under tourniquet control, dorsal ganglia are approached through a transverse incision over the proximal carpal row, avoiding damage to the cutaneous branches of the radial nerve that can vary in their position. Damage can cause troublesome tender neuromas in addition to areas of anesthesia on the dorsum of the hand. Under loupe magnification, if possible, the ganglion is mobilized through the extensor retinaculum to the underlying joint capsule. The portion of the capsule through which the ganglion arises is excised including its origin from the scapholunate ligament. The origin can be cauterized leaving the ligament intact. Often small ganglia/vesicles can be seen arising from the ligament and these must be cauterized. Care must be taken to preserve this ligament. The tourniquet is released, hemostasis obtained, the wound closed, and wrist use is limited for 2 weeks. The patient should be warned that discomfort in the wrist might be experienced for 3-4 weeks. Some surgeons may leave a small drain in overnight.

Volar Wrist Ganglion

These ganglia commonly present along the volar wrist crease between the abductor pollicis longus and the flexor carpi radialis tendons. Due to the high incidence of injury to the radial artery and/or injury to the palmar cutaneous branch of the median nerve causing long-term pain, operative treatment of volar wrist ganglions is only indicated when the ganglion is causing chronic pain or prolonged functional limitations.

The surgical technique for excision of this volar ganglion is similar to that described for dorsal ganglion. Loupe magnification and tourniquet control are important as these ganglia are usually intimately associated with the radial artery. The ganglion pedicle is followed to the volar joint capsule, and the capsular origin is excised. Hemostasis is obtained and the skin closed.

Volar Retinacular Ganglion

This small ganglion presents as an almost bony, firm, tender mass near the metacarpal phalangeal (MP) or palmar digital flexion crease. It usually arises in the junction between the A 1 and A2 pulleys of the flexor tendon sheath or often in the center of the A2 pulley. Surgery can often be avoided by rupturing the ganglion with 20 gauge needle under local anesthesia; this has a 90% cure rate. If the patient experiences pain when gripping objects or if the mass recurs and patient requests surgery, it can be excised under local anesthesia with the use of a forearm tourniquet. Identification of both radial and ulnar digital neurovascular bundles is important to avoid possible injury to these nearby important structures. The ganglion is traced to its origin from the tendon sheath, and a small portion of the sheath is excised along with the ganglion. The skin is closed and early motion allowed.

Mucous Cysts

This cyst is classically found at the base of the nail (Fig. 2). It is a ganglion of the DIP joint that usually occurs between the fifth and seventh decade. It can present with longitudinal grooving of the nail caused by pressure on the nail matrix by the cyst, and it can be present with or without a palpable nodule. X-ray almost always demonstrates evidence of

Fig. 2
Mucous Cyst of the DIP Joint
(Courtesy http://dermatlas.med.jhmi.edu)

osteoarthritic changes in the DIP joint.

Exposure of the ganglion is through elliptical skin incision - the overlying skin may be difficult to dissect away from the cyst. Care is taken to protect the nail matrix directly under the cyst. The neck of the cyst is traced to the joint which is exposed by incision alongside the extensor tendon. Synovectomy and joint debridement of osteophytes must be done to limit the possibility of cyst recurrence. The skin is closed directly but might occasionally need an advancement or rotational skin flap. Many will just debride the osteophyte without dissecting out the cyst, as the osteophyte is the cause for the cyst.

Giant Cell Tumor of Tendon Sheath

Giant cell tumor of the tendon sheath is the second most common tumor of the hand. (Figs. 3-4) It is known by many names, including pigmented villonodular synovitis, benign synovioma, brown tumor, and fibrous xanthoma.

The term "giant cell tumor of tendon sheath" is however really a misnomer, for the lesion is not a tumor, may not involve a tendon sheath, and may only have a few giant cells. Some regard this lesion as a benign reactive inflammatory response.

These lesions are firm, lobular masses, ranging in size from a few millimeters to several centimeters. They have a dense fibrous covering and usually gray with brown or yellow areas, due to hemosiderin or lipid contained within the histiocytes. Microscopically, the tumors are characteristic; composed of small oval or spindle-shaped cells, multinucleated giant cells, lipid-laden macrophages, and irregularly placed connective tissue.

Clinical Features: The tumor may occur at any age, but usually during middle age. It presents as a painless nodular lump. The size may vary from a small nodule to a very large mass (Figs. 3-4) While the tumor may occur at any site, it commonly occurs near the proximal or distal digital joints. From here, the swelling gradually extends volarly or dorsally, over or under the tendons and surrounding the neurovascular structures. Pressure erosion of bone may occur in long-standing cases.

Treatment: The tumor needs to be carefully excised under tourniquet control. Care must be taken to avoid injuring the digital nerve, since it is often intimately associated with the tumor. The recurrence rate is high if even the minutest trace of discolored tissue remains in the synovium. Surgical magnification lessens the likelihood of recurrence to approximately 5%. If local recurrence occurs, further local excision is indicated, for the lesion is a benign condition.

Epidermoid Cyst

Epidermoid cysts, also known as inclusion cysts or implantation dermoids, are caused by the traumatic implantation of a fragment of skin into the subcutaneous tissue. The fragment of skin grows slowly, producing a cyst lined by squamous epithelium containing a creamy fluid with cholesterol crystals and keratin flakes. These cysts are common in persons whose hands are subjected to repeated minor trauma (e.g. manual workers). When seen on the volar or grasping surface of the hand, they may be fixed into position secondary to confinement by fascial planes. On the dorsum of the hand, they are more round and freely movable. The cysts are round or ovoid with thick walls. As a rule, epidermoid cysts are painless, but they may cause discomfort by interfering with hand function.

Fig. 3

Fig. 4

Giant cell tumors of the hand. Fig. 4 is far advanced.

Treatment is by simple excision though care must be taken to remove the entire epithelial sac because recurrence is possible.

Verruca Vulgaris

This most common benign skin tumor is caused by the human papovavirus—DNA virus. It is transmissible by direct contact and/or autoinoculation.

There are different treatment modalities. The two most common are the application of a topical irritant to elicit an amount of virospecific IgM and IgG response (e.g. Salicylic acid preparations). The second is surgical, with total and complete excision of the wart. A third method is to shave the wart to the level of the surrounding epidermis, and the remaining wart is cauterized and then curetted from the surrounding normal epidermis. Cryotherapy is a fourth method, with or without prior shaving of the wart level to the dermis.

Lipoma

Although there is a moderate amount of fatty tissue in the hand, lipomas are relatively uncommon compared to other areas of the body. Lipoma of the hand has the characteristics of lipoma elsewhere in the body. Lipomas can cause significant problems. They may occur subcutaneously or deep to the fascia. Most lipomas are painless, but they may compress nerves or cause mechanical problems due to their size, and may be cosmetically unacceptable.

Excision is the treatment. Although they can often easily be shelled out, simple surgical removal can sometimes be difficult, due to the tumor's propensity to grow along the line of least resistance. They can extend in any plane for a considerable distance. Again a bloodless field and loupe magnification are important to prevent damage to important structures in the hand and to ensure complete removal of any remaining lipoma cells.

Fibroma

Fibroma may present as a firm, nodular swelling. Treatment is excision.

Juvenile Aponeurotic Fibroma

A fibrous lesion occurs in the palms and soles. It consists of an ill-defined, highly cellular fibrous proliferation occurring in the subcutaneous tissue, deep fascia, and sometimes muscle. Although locally invasive, these lesions are benign and therefore, should be treated by local excision preserving tendon and neurovascular function.

Nerve Tumors

Nerve tumors in the hand are relatively rare. These tumors include neurilemmoma (Schwannoma), neurofibroma, or the multiple neurofibromatosis of Von Recklinghausen's Disease (See chapter 21 on neurofibromatosis).

The **Schwannoma** or **neurilemmoma** characteristically occurs in only one location in a peripheral nerve. The tumor is intra-neural but grows eccentrically. It can usually be shelled out without loss of nerve function.

The **neurofibroma**, however, grows in an interlacing fashion with the nerve fascicles. It is extremely difficult to dissect and excise without nerve damage. Even though there is a reported 15-30% chance of malignant degeneration in the neurofibromas of Von Recklinghausen's disease, excision is only warranted if a particular lesion begins to grow, presents as a large tumor affecting hand function, or otherwise changes its behavior.

Fig. 5

Neurofibroma of the hand.
Note the secondary deformity of the small finger as well as a second neurofibroma on the wrist

Glomus Tumor

This tumor arises from the glomus body, a neuro-myoarterial apparatus with its function in temperature regulation. The normal glomus is a tiny organ, less than one millimeter in diameter, usually

Fig. 6

Fig. 7

Fig. 8

A large neurofibroma of the radial digital nerve of the thumb required a 2.5 cm. nerve graft. The rest of the tumor was carefully dissected out without damage to any other nerve elements or structures.

found in the nail beds, finger pads, and elsewhere in the hands and feet.

The majority of these tumors occur under the nail. Others occur in the distal part of the finger. They are made up of hypertrophied and disorganized elements of the normal glomus body.

Patients with a glomus tumor present with a triad:

- pain.
- tenderness.
- cold sensitivity.

Pain is the first symptom to appear. It is described as sharp, stabbing, or burning and usually triggered by external pressure or cold. Careful physical exam will delineate one very tender spot. This is best done using the head of a pin or closed jeweler's forceps. A physical examination may also show ridging of the nail. This is a pressure phenomenon and radiographs may show indentation of the distal phalanx, again from pressure. The tumor is more common in adults and multiple tumors in one fingertip have been reported. Rarely, the glomus tumor can present as an intraosseous lesion.

Fig. 9

Pyogenic granuloma secondary to an injury with a piece of wire. Treatment consists of excision followed by cauterization of the base.

Treatment of this tumor is satisfying, with a cure rate of 100% if completely removed. Surgical excision is done under tourniquet control with magnification. If the lesion is subungual, the nail is removed, and the nail matrix is incised longitudinally. The lesion can then be bluntly dissected from the nail matrix that is repaired with 6-0 or 7-0 absorbable sutures.

Pyogenic Granuloma

This is usually a solitary polypoid capillary hemangioma, often associated with trauma or local irritation, representing a vasoproliferative inflammatory response, found on the skin and gingival or oral mucosa. It presents as a small erythematous papule that enlarges, may become pedunculated, and may become infected and ulcerate with accompanying purulent exudate.

Hemangiomas

Hemangiomas of the hand may range from the capillary telangiectasia to the extensive cavernous lesions (Fig. 10). Gigantism of digits may also occur. Lesions may regress spontaneously and, therefore, treatment in infancy should be delayed.

Fig. 10
Cavernous Hemangioma

Hemangiomas can be classified into three groups: (a) the cavernous hemangioma, (b) the capillary hemangioma, and (c) a mixture of cavernous and capillary hemangioma. They are thought to arise as embryonic rudiments of mesoderm tissue manifested as independently growing blood channels.

Hemangiomas are either **involuting** or **non-involuting** tumors:

- All involuting hemangiomas seen at birth or found soon thereafter grow rapidly for approximately 6 months, then begin to involute at around 1 year, and generally disappear by age 7–9 years, the so-called 'strawberry nevus'. The ratio of involuting to noninvoluting tumors is 4:1; therefore, knowledge of the onset of the appearance of the lesion is important in both diagnosis and prognosis.
- Non-involuting hemangiomas (Fig. 10) are seen in older individuals who present with complaints of pain, discomfort, or a feeling of fullness in the affected part. A mass is usually palpable. If a thrill is palpable or a bruit heard, the lesion is better classified as an arteriovenous fistula.

Treatment of hemangiomas varies with the age of onset.

- The tumors that occur early will involute and their prognosis is good. Occasionally, if the tumor is large, ulceration or bleeding may be a problem, but this can usually be treated conservatively with steroids. Oral propranolol is a new effective treatment **(See chapter 8 on Cutaneous Lesions)**.
- For non-involuting lesions, except for the capillary hemangiomas (also known as the port wine stain), surgical excision is the treatment of choice. In the well-defined lesion, surgery will almost always be successful. If, however, the lesion is infiltrative, recurrence is common, and a number of surgical procedures are often necessary for ablation. Complete surgical excision can be difficult but should be attempted if at all possible without risking damage to vital structures or functional loss.

Arteriovenous (AV) Fistulas

AV fistulas may be placed in two categories: acquired or congenital.

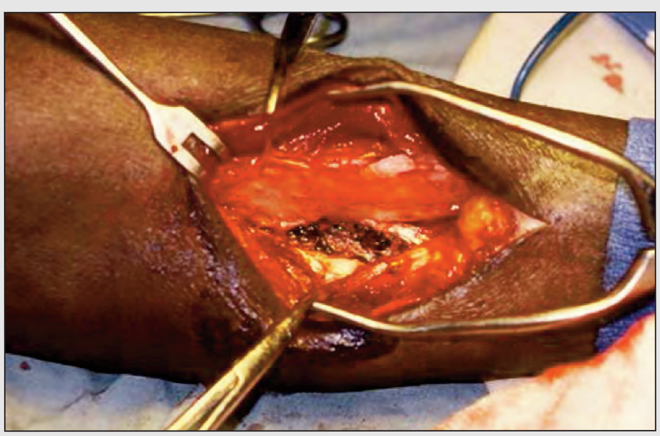


Fig. 11

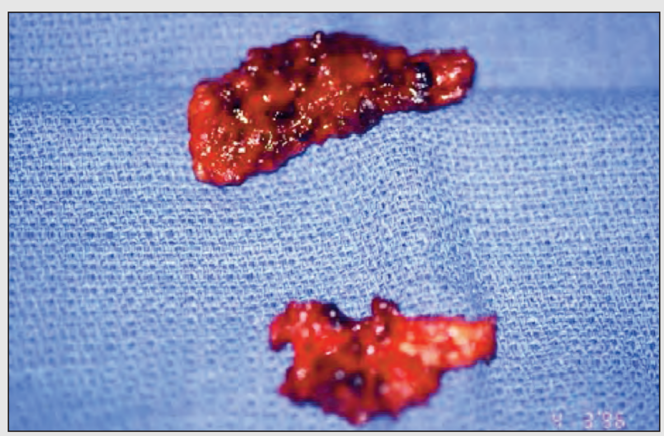


Fig. 12

The patient complained of dull aching pain in the forearm for years. At exploration, a hemangioma was found in the intraosseous membrane between radius and ulna. When a patient presents with persistent pain with negative x-rays and CT and MRI are not available, exploration should be done, as in the case above

Fig. 13

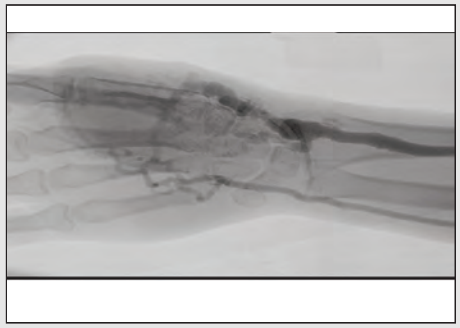


Fig. 14

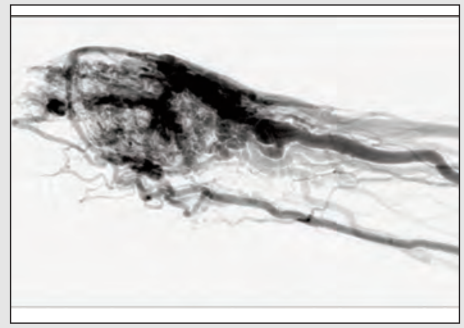


Fig. 15

AV malformations—congenital: arteriogram.
Patient still had good use of his hand and surgery was not recommended at this time (images courtesy Dr. Bill Rhodes).

Acquired AV fistulas can be either surgical or traumatic in origin and will not be discussed here.

Congenital AV fistulas share a common etiology with hemangiomas. These are classified as primarily arterial, venous, capillary, or a combination.

Treatment of congenital AV fistulas is extremely difficult and not recommended in the district hospital unless very small.

The surgical options are: (a) excision of the fistula in stages, (b) ligation of feeder arteries and communicators and (c) amputation.

Surgery on these lesions, however, often promotes the lesion into a more active phase, making them quite aggressive locally. Nonsurgical options on these lesions include x- ray therapy or intra-arterial embolization.

Leiomyoma

This is a slow-growing, usually painless lump that occurs in the subcutaneous tissue. It is well encapsulated, firm to hard in consistency. They probably arise from vascular smooth muscle and can be easily excised.

II. Malignant Soft-tissue Tumors

Basal Cell Carcinoma (BCC)

These sun-related lesions are rarely found on the hand except in Caucasians with many years of chronic sun exposure. They are extremely rare in people with darkly pigmented skins but very common and often very problematic in people with lightly pigmented skin, and particularly in Albinos. When present, it is usually located on the dorsum of the hand as an ulcer with raised pearly edges and an erythematous base. Treatment consists of excision with a margin of normal 2-3 mm of adjacent normal tissue as well as in depth. When located near the nail bed, it can be mistaken for a paronychia. Skin grafting is normally required at this location. When basal cell carcinoma involves the nail matrix, amputation at the DIP joint may be required to reach normal tissue margins.

Squamous Cell Carcinoma (SCC)

One of the most frequently encountered malignancies of the hand is SCC, but fortunately as with the BCC, almost never seen in darkly pigmented skins except in long-standing wounds with Marjolin's ulcer. It is sadly a significant problem in Albino patients. In a large percentage of cases, premalignant lesions such as solar keratosis have been present for a considerable period of time before the development of malignancy. SCC can

Fig. 16
Marjolin's ulcer—SCC in old burn wound.

metastasize, usually through the regional lymphatics. SCC involving the nail matrix and perionychial area can be a difficult diagnostic problem. Biopsy-proven SCC in any area of the hand requires **early wide excision with margins of 1-2 cm or more of normal tissue**, depending on how well circumscribed the lesion is and the location on the hand. This may require amputation of one or more digits and metacarpals. Extensive involvement of recurrent or untreated tumors of long duration could require hand amputation.

Any unusual tumor, such as the superficial Marjolin's ulcer in Fig. 16 should be biopsied.

Malignant Melanoma

Again, these are uncommon in people groups with darkly pigmented skin, except for the acral lentiginous type. Four types of malignant melanoma are distinguished.

- **The lentigo maligna or melanotic freckle of Hutchinson** is a small lesion. It may be tan, black or brown in color and flat with an irregular border. They are slow growing lesions.

- **Superficial spreading melanomas** come in a variety of colors varying from tan to black with combinations of blue or red. Occasionally, these melanomas become depigmented and will appear as white lesions.

- **Nodular melanomas** usually present as a raised darkly pigmented lesion

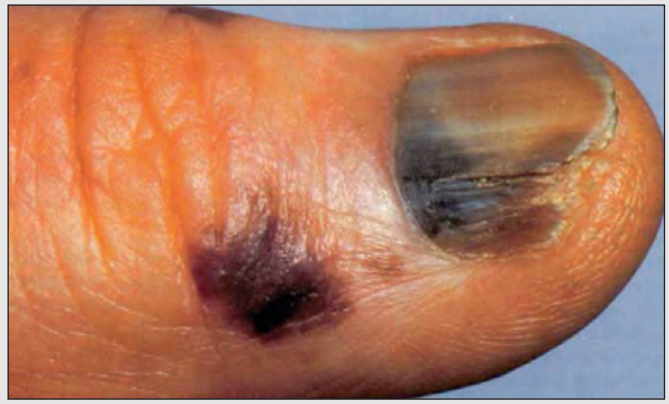


Fig. 17

Subungual Melanoma
(Courtesy www.dermpathmd.com)

- **Acral lentiginous melanoma** is a melanoma that appears on the palms of the hands, soles of the feet, subungual areas of the fingers and toes, and web spaces. The subungual melanoma (Fig. 17) usually occurs as a dark lesion under the nail, usually on the thumb. Care must be taken in making the diagnosis of subungual melanoma, and a thorough history is needed to differentiate from post-traumatic nail bed changes. The importance of the subungual melanoma is that it is often erroneously believed to be a fungal infection, and its proper treatment may be delayed because of a delay in its biopsy. This type of melanoma has the lowest 5-year survival rates of all these variants, generally found to be in the range of 10% to 20%. These tumors spread aggressively and have a high incidence of local and regional recurrences. Therefore, they are best

Fig. 18

Fig. 19

Acral Lentiginous Melanoma

treated by aggressive resection.

Treatment

For the surgeon in a district hospital, obtaining accurate pathological diagnosis may not be possible. Tumor levels may be difficult or impossible to determine. The different types of melanoma are listed below for those who occasionally see a light skin person. Mostly you will see acral lentiginous melanoma, and these need amputation or wide excision.

The evaluation of a patient with suspected melanoma should include a thorough physical examination, chest x-ray, and routine laboratory studies. Precautions must be taken if a biopsy is done; where possible, an excisional biopsy should be the choice. The operative treatment of malignant melanoma is determent by the type of melanoma, the Breslow thickness, and the stage. (Breslow thickness is the standard now and not Clark's levels.)

- **All melanomas, regardless of the histological subtype, are treated the same now**. The margins should be **one cm for Breslow thickness of .75mm or less and two cm for lesions > .75mm thickness.**
- Since most do not have the capability of getting Breslow thickness determinations, **one should resect all melanomas with 2 cm. margin**.
- Elective lymph node dissection is not indicated in any patient, since long term studies show no improvement in mortality.
- If histopathology is available and sentinel node biopsies are possible for melanomas with a Breslow thickness of > .75 and ulcerated lesions, if the biopsy is positive and there are no other distant metastasis, lymph node dissection could be carried out.
- Subungual melanomas will require an amputation with a 1 cm. margin, usually at the DIPJ level.
- Acral lentiginous melanomas should be excised using the same guidelines as above—1 cm. for Breslow thickness <.75mm and 2cm. for Breslow thickness > .75mm. **Practically a 2 cm. margin should be used in most of our hospitals**.

Fig. 20

Acral Lentiginous Melanoma

- There are times that **the author would consider wider resections** in district hospitals when no other form of treatment is possible, and when there are other findings as satellite lesions.
- Other treatment modalities as isolated perfusion of the extremity with chemotherapeutic agents and immunotherapy are not possible in most locations.

Sarcomas

All histogenic types of soft-tissue sarcomas may occur in the hand. They are, however, uncommon when compared to the more proximal part of the upper extremity and appear less aggressive in their course.

Synovial Sarcoma

Synovial sarcomas are reported to be the most common malignant neoplasm of mesodermal tissue in the hand. This sarcoma arises from synovial tissues, the joint capsules, bursa, or tendon sheaths. It presents as a small, soft, fixed lesion usually misdiagnosed as a ganglion. In contrast to other sarcomas, the lesion is usually not painful and has a slow growth rate. The synovial sarcoma has significantly higher incidence of metastasis to regional lymph nodes than other soft-tissue sarcomas. Treatment of synovial sarcoma is by wide local excision with adjuvant chemotherapy.

Epithelioid Sarcoma

The epithelioid usually presents in the superficial subcutaneous tissue as a painless raised nodule. The nodule may progress to ulceration, leading the surgeon to make the diagnosis of an infected wart,

Fig. 21 **Fig. 22**

(L-R) Malignant fibrous histiocytoma; Benign lipofibromatosis hamartoma.
The two conditions above look similar. The fibrohistiocytoma in Figure 21 is a malignant condition, and was seen in an older patient. The hamartoma in Figure 22 is a benign lipofibromatosis condition seen in a child.

chronic ulceration, or foreign body granuloma. When the tumor originates deeper in the hand, it may appear as nodular fasciitis or tenosynovitis.
The tumor spreads along tendon sheaths in the subcutaneous lymphatics or along fascial planes. When vascular invasion is found in epithelioid sarcoma, there is extremely poor prognosis and amputation is recommended as early as possible. The regional lymph nodes should be dissected. If recurrence occurs, a forearm amputation must be done.

Malignant Fibrohistiocytoma

The malignant fibrohistiocytoma presents as a painless mass of fewer than 6 months' duration. This tumor is believed to be of histiocytic origin. The treatment of malignant fibrohistiocytoma is by radical local excision. In the absence of metastasis, there is good prognosis if the tumor is controlled locally. Adjuvant therapy should be considered where the tumor involves skeletal muscle, because the metastatic rate is over 40% regardless of the surgical procedure carried out.

Desmoid Tumor

By the nature of their locally aggressive behavior, desmoids are sometimes referred to as low-grade fibrosarcomas. They are rare tumors and their treatment can be very frustrating, as they frequently recur after excision because of the difficulty in recognizing clear tumor margins. Most recurrences are at the site of excision and, frequently, amputation must be done to prevent further spread.

III. Benign Bone Tumors of the Hand

Chondroma (Enchondroma)

Chondromas are the most common bone tumor in the hand. The majority of chondromas are solitary lesions, but multiple chondromas may occur, as in Ollier's disease and Maffucci's syndrome. The proximal phalanx and metacarpal are the usual sites. Chondromas may be discovered incidentally during the investigation for some other purpose, or they may present as smooth, hard, painless lumps or as

Fig. 23

Multiple enchondromas—Ollier's disease

pathological fractures (most common presentation). The solitary lesion presents a typical radiographic appearance—a radiolucent area is present in the shaft with thinning and expansion of the cortex. Irregular calcification occurs in the central portion of the lesion. Less commonly, the chondroma may be situated eccentrically, forming a mass called enchondroma.

Treatment: Asymptomatic chondromas can be watched. Symptomatic chondromas can be curetted and bone grafted. A dorsal approach is used, the extensor tendon split or retracted to one side, a window made in the bone and the lesion thoroughly curetted out. In the fingers, cancellous bone graft from the distal radius is packed into the cavity. If there are large defects, then the iliac crest maybe used for cancellous bone grafts.

Osteochondroma
These are aberrant cartilage areas that produce a bony mass. They are relatively uncommon in the hand. If troublesome, these lesions can be excised.

Osteoid Osteoma
This uncommon tumor may occur in any bone of the hand, the terminal phalanx being a favored site. The clinical presentation is typical—intense local pain often relieved by aspirin. Local swelling with tenderness and increased sweating may be present. Radiographs reveal a typical round lucency containing a dense sclerotic central nidus, surrounded by sclerotic bone. A bone scan is often diagnostic if available. The osteoid osteoma shows up as an intense hot spot on bone scan.

Treatment: Osteoid osteoma may undergo spontaneous resolution. Indomethacin can help with pain relief if the patient wants to try to avoid surgery. Surgical excision achieves dramatic relief, provided the nidus has been removed. A dental drill is helpful in making a window in the affected bone, and care must be exercised in identifying and excising the nidus.

Aneurysmal Bone Cyst
This is very rare in the hand. The lesion may resemble a chondroma. Treatment consists of curettage and bone graft.

Giant Cell Tumor of Bone
Giant cell tumor of bone may occur in the metacarpals of the hand. The lesion arises in the epiphyseal area, causing an expansile, radiolucent area. Clinically, the patients present with pain and swelling, and sometimes a pathological fracture. Treatment is by curettage and bone graft. The clinical behavior resembles that of other giant cell tumors of long bones.

Carpometacarpal Bossing (Carpal Boss)
This is a firm bony mass on the dorsum of the bases of the second and third metacarpals. It is best seen when the wrist is volar flexed. The carpal boss may be confused with the more common wrist ganglion, especially since it may also be associated with a small ganglion. If symptoms are persistent the boss may need to be excised—ostectomy.

IV. Malignant Bone Tumors of the Hand
Primary malignant bone tumors of the hand are very rare. The diagnosis is made by incisional biopsy. When the diagnosis is confirmed, ablation of the tumor with tumor-free margins should be the goal of surgery. Reconstruction is usually performed at the time of excision, but it may be delayed. The same surgical staging of malignant bone tumors as used for musculoskeletal sarcomas can be used to decide on the proper procedure. Combined treatment of radical surgery and adjuvant chemotherapy is used if available.

Osteogenic Sarcoma
Osteogenic sarcoma of the hand is extremely rare. It presents as a progressively painful mass occurring most commonly in the first and second decades. The radiographic appearance is typical for osteogenic sarcoma, with an expansile sclerotic destructive bony lesion.

Chondrosarcoma
Chondrosarcoma presents the majority of time in patients that are over 40 years of age. In the hand it is extremely rare. If seen, however, the most common location is the proximal phalanx. On x-ray, it appears as a radiolucent area with cortical destruction in the margins.

Ewing's Sarcoma
Ewing's sarcoma occurs in the first decade of life and is a very rare malignancy in the hand. It may present as an inflammatory process with erythema, swelling, and pain. Radiographically, it is seen as a destructive lytic lesion.

Metastatic Tumors of the Hand

Fig. 24

Fig. 25

Macrodactyly of the middle and ring fingers.

The most common tumors that metastasize to the skeleton of the hand are from the lung, breast, or kidney. The distal phalanx is the most common site. The hand is involved with metastases 0.1 % of the time. Occasionally, biopsy will identify the primary lesion. Metastatic disease in the hand is an extremely poor prognostic sign. The vast majority of patients are dead from the primary disease within 1 year of the diagnosis. As such, limited amputation is indicated for hygiene and pain management.

Macrodactyly

This is not a typical tumor. It is also discussed in chapter 38 on congenital hand deformities.

Classification of Macrodactyly or Gigantism:

Fig. 26

Macrodactyly of the index and middle fingers.

Fig. 27

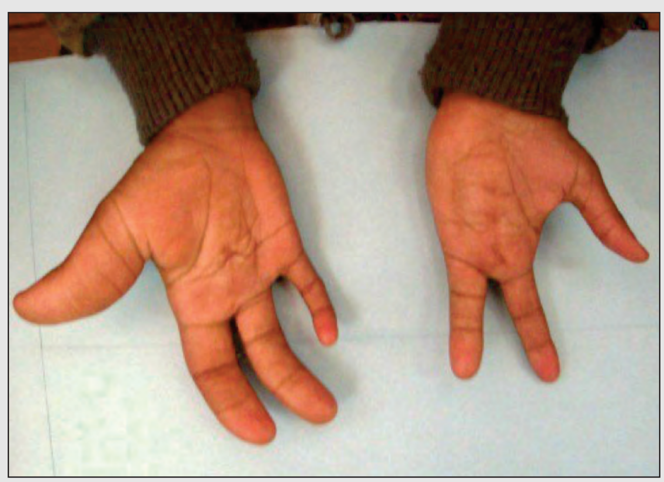


Fig. 28

Macrodactyly both hands in young girl. Treated with amputation as primary procedure.

Fig. 29

Fig. 30

Fig. 31

Macrodactyly of the first and second toe with syndactyly.

Fig. 32
Lipofibromatosis hamartoma

- Group I: Gigantism associated with lipofibromatosis.
- Group II: Neurofibromatosis with fat and fibrous tissue found in peripheral nerves.
- Group III: Hyperostosis.
- Group IV: Hemihypertrophy.

Lipofibromatosis

Macrodactyly (lipofibromatosis) is a hamartomatous enlargement of soft tissue and underlying bone. It can be static, or can grow commensurately with the hand or foot, or it can be progressive, growing faster than the rest of the limb.

Some authors believe that the digital nerves cause the disproportionate growth, the so-called "nerve territory-oriented macrodactyly" of the finger. Enlargement more commonly follows the

Fig. 33

Fig. 34

Neurofibromatosis of hand

distribution of the median nerve than that of the ulnar nerve in the affected digits.

There can be an association with Wilm's tumor, adrenal carcinoma, and hepatoblastoma.

Macrodactyly simplex congenita is seen in 10% of cases. The enlargement includes skin, subcutaneous tissue, nerve, joint, and bone (tendons and blood vessels are of normal size). Most often, phalanges are involved and metacarpals are spared.

Treatment (also see in chapter 38—**the editor suggests amputation in most cases. The debulking principles below are useful, but require knowledge of hand anatomy and hand surgery experience. Even with debulking, most cases come to amputation as a secondary procedure. It is realized that in many cultures, amputation of a finger will be poorly accepted. It will take time for the families to accept amputation of a finger or fingers. Fortunately, this is not a life-threatening condition, and the surgeon can wait until the family accepts the amputation. Ideally the surgeon attempts to save a thumb but practically, it may be best to amputate and perform a pollicization of the index or long finger if available.**)

If a debulking procedure on a thumb is planned, then the editor would advise the surgeon to look for the procedure in major hand or pediatric surgery texts.

Neurofibromatosis

Minimal hand and forearm deformities should not affect existing hand function. Extensive arm, forearm, and hand lesions can be debulked for functional reasons with predictable outcomes.

Hemihypertrophy

Patients with hemihypertrophy are difficult to treat. As long as the hand is functional, and all joints are passively mobile, no surgery is recommended.

Every case must be carefully individualized, as hands with hemihypertrophy represent a wide range of hand abnormalities. Most of these hands have surprisingly good function despite the deformities caused by the hypertrophic and contracted muscle groups that result in various flexion contractures of the forearm and hand and ulnar deviation of the digits. Surgical decisions are dictated by functional and aesthetic needs.

Chapter 39
Congenital Hand Deformities

Louis L. Carter, Jr.

Introduction

Since it is not always easy to find an up to date article on congenital hand deformities, several common deformities are discussed here with simple guidelines for treatment. There are many deformities, but the surgeon will only treat a few of these in Africa. These include syndactyly, duplication, radial dysplasia or radial club hand, macrodactyly or gigantism, and constriction bands. Below is a summary of the best approaches to these common anomalies.

All congenital upper extremity deformities occur in the first eight weeks of gestation, and usually between four and eight weeks. Etiology is often genetic, but may be sporadic and spontaneous. An increasing number of deformities are being linked to a specific gene abnormality. Children are aware of a difference by age 2 and often seek an explanation by age 4. By age 5-6, they are self-conscious of the deformity, and that is why it is important to correct these deformities by school age.

Syndactyly

According to the literature, syndactyly is uncommon in Africans, but these cases will likely show up at a large referral hospital or a trusted Christian hospital. Syndactyly is twice as common in males, and it may be inherited, spontaneous or associated with a syndrome, such as Apert's. In congenital syndactyly, one may also see syndactyly of the toes.

Syndactyly is classified according to the length of the syndactyly—partial to complete—and according to the tissue within the syndactyly:

- Simple if only skin is involved.
- Complex if bone is also involved.
- Complicated if there are extra, missing or angulated bones within the syndactyly.

Long/ring syndactyly is most common. If syndactyly involves the border digits as small/ring or thumb/index, these should be divided by six months to prevent angulation of the longer digit. One should wait to divide syndactyly of the central digits until 18 months when the finger has doubled in size and has less fat. At this age, the surgery is easier with fewer complications.

One should never release adjacent webs at the same time, as there is not enough skin for both releases, but non-adjacent fingers can be divided at the same time. **Syndactyly release always requires skin grafts, since the circumference of two fingers together is 1/3 less than two fingers separated**. Full-thickness skin grafts are more pliable and durable, and thus preferred. For multiple skin grafts, the groin is preferred, since the closure of the incision is in the inguinal crease. The axis of the donor site is from pubic tubercle to the Anterior Superior Iliac Spine (ASIS). See Chapter 3 on Skin Grafts for the technique of harvesting these grafts. The family must be informed that the skin grafts on the fingers will always be dark in a dark-skinned individual.

A tourniquet is used, and one dose of a cephalosporin is given preoperatively. Pressure, gauze soaked in dilute Adrenaline, and the electrocautery are used to control bleeding after the tourniquet is released. The tourniquet is then re-inflated when applying the skin grafts.

The key to successful surgery is **creating a good web space**. Therefore, the length of the dorsal flap must be sufficient to reach the volar margin of the web space. A few mm. of extra length may be added to overcorrect for possible "web creep," which is a slow loss of web space depth over time. When there is syndactyly of multiple adjacent fingers, it may be difficult to determine where the proximal end of the web space should be. **The web space is approximately half way between the PIP joint crease and the distal palmar crease on the volar side**. Since skin grafting will be necessary, a dorsal flap with an extra mm. or more in length will allow for a good, deep web space, and will not affect closure of each side of the adjacent fingers. The flaps between the adjacent fingers can be drawn out in a zigzag fashion. The width of each flap should be from midline to the midline of the adjacent digits with the apex in the crease or midway along each phalanx. The opposite side should be a mirror image of the other (See Fig. 1).

(If the surgeon has limited experience in syndactyly release, the surgeon should take a diagram of the

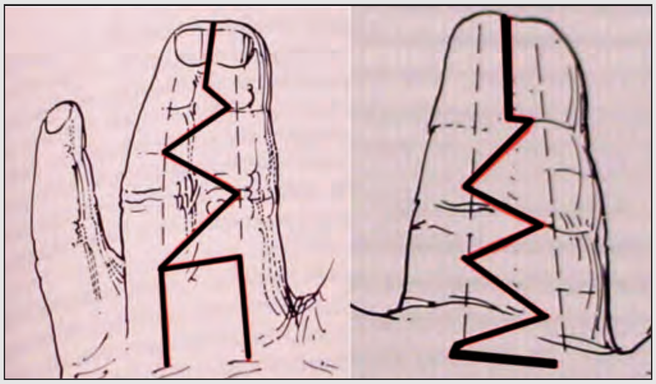


Fig. 1

Ring/Middle Syndactyly incision lines.

incisions into the operating room and post it on an IV pole.)

In some cases, the defect on each side may be nearly closed, but it is always wise to skin graft rather than closing with tension on the flaps. Some pediatric hand surgeons defat the flaps in order to close the defects on each finger, but this could risk the blood supply and is not advised.

Closure and Dressing:

- **Suture**: 4-0 to 6-0 absorbable suture, chromic or Monocryl® if available. One does not want to take sutures out in children.
- **Dressing**: multiple layers.
  - Non-adherent gauze such as Vaseline® or Xeroform®.
  - Moist cotton balls or gauze—moist cotton balls mold the skin graft into the wound edges, and a moist dressing accelerates wound healing.
  - Dry gauze is added to give a bulky dressing to cover the fingers completely.
  - Long arm splint with the elbow flexed for elevation.
  - Bandage roll as Kling®, Kerlix®, crepe or Ace® may be used, but the surgeon must be very careful not to wrap these elastic bandages too tight. A plain gauze bandage without elasticity may be best.

The author inspects the dressing for bleeding or infection at seven days, and at two weeks the entire dressing is removed. There is little gained by completely removing the dressing earlier. For better immobilization in the young child, K-wires are placed down the fingers. (#21 hypodermic needles may be used in young children if K- wires are scarce.) Even with a bulky dressing and splinting, small children may still wiggle their fingers, and the grafts may shift. In 3-6 months, adjacent web spaces are divided.

The diagram in Fig. 5 shows the small zig-zag flaps the author uses to deal with synostosis of the distal phalanx where the division of the bone may leave some bone along the edges. A small bone cutter is used to divide the distal synostosis. At times, a small amount of bone, nail and nail bed along each side of the synostosis can be removed, so these fingertip flaps shown below can cover the bone.

Complications include the rare case of infection and loss of the grafts. If grafts fail, then immediate re-grafting is required.

Fusion of the distal phalangeal tufts is called complex syndactyly. This fusion requires the division of the

Fig. 2

Fig. 3

Fig. 4

Ring/middle syndactyly repair. Note: the dorsal flap is a little longer to account for the possible future web creep to fit easily into the new web. (Courtesy of Marybeth Ezaki) synostosis as described above. In Apert's Syndrome, there is complex and even complicated syndactyly. Careful planning and innovation are required to carry out the release. In complicated syndactyly several fingers are involved, and one web space at a time is released. Because of the abnormal bones it may not be possible to leave the child with a normal number of digits (see Figs. 9 and 10). In Apert's, symphalangism with the fusion of the PIP joints and stiff fingers is also present, and the PIPJ crease, as well as the palmar digital web space crease, are often missing. The goal is to give the child as normal-appearing hand as possible, but most often it will only be a "helping hand" with no motion at the PIPJ.

Congenital syndactyly is not the same as burn syndactyly. In burn syndactyly, the fingers and web spaces are scarred, and the skin is not pliable and does not transfer easily into the web space or around

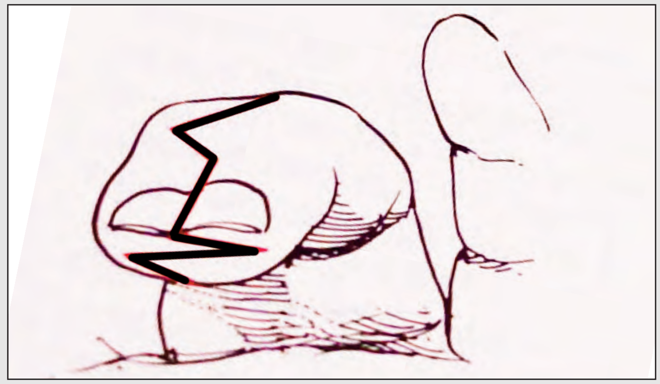


Fig. 5

Skin incisions at the tip when there is synostosis and where one covers the exposed bone with small flaps of skin. Also, a small amount of nail, 2-3 mm. and nail bed may be removed longitudinally on each side for closure.

Fig. 6

Fig. 7

Fig. 8

Complicated syndactyly on left and complex on right is present with synostosis of the tips of long and ring fingers. The tips were divided and reconstructed as in Fig. 5.

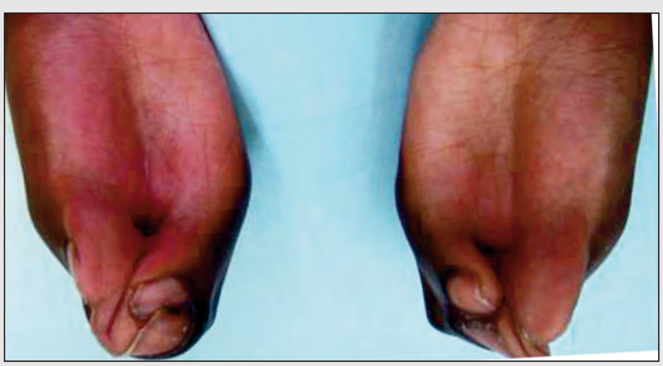


Fig. 9

Fig. 10

Complicated syndactyly in Apert's Syndrome (Acrocephalosyndactyly). It was not possible to make four fingers and a thumb. The child had both hands operated on by two teams at the same time with thumb-index web divided first. Note symphalangism—no PIPJ crease because there is no PIP joint.

the fingers as in congenital syndactyly. For burned syndactyly, one should use the hour-glass flap as described in Chapter 12 on Burn Reconstruction.

Camptodactyly

Camptodactyly means "bent finger." Camptodactyly can occur sporadically or as part of a syndrome. It usually involves the small and ring fingers at the PIPJ. When camptodactyly is part of a syndrome, all the fingers may be affected. When it occurs in childhood, the cases are equally divided between male and female. At puberty, it may occur in girls without a previous history. If diagnosed in early childhood, splinting may be attempted, but must be continuous over a long period. This condition is mentioned here only to **recommend that one not attempt operative correction**. Surgery will be difficult, and most often, there will not be a significant improvement. Incomplete correction is especially true in older children with a deformed, chisel-shaped head of the proximal phalanx (see arrow in Fig. 12). This flexion deformity is usually only a cosmetic problem, and the patient will function fairly well even with the deformity. If one has considerable experience in congenital hand surgery, techniques may be found in Green's Operative Hand Surgery or another major hand surgery text.

Fig. 11

Fig. 12

Camptodactyly. On the left is typical 90° flexion deformity of PIPJ in a young child. On the right is the chisel-shaped head deformity of the proximal phalanx. This deformity of the head is a contraindication for surgery.

With injuries presenting after 24 hours, repeated debridements may be necessary for several days before the wound can be safely closed. Sometimes the use of a VAC, if available, will be necessary. Since the soft tissues of the hand are well vascularized, minimal debridement is sufficient, along with the removal of all obviously necrotic tissue and foreign bodies. In the rare case that a wound cannot be closed directly or with a skin graft or flap, then it is important to keep the wound moist, and the extremity elevated between debridements (see again Chapter 2).

Duplication

Post axial or small finger duplication is quite common, and it often consists of just a small tag along the ulnar border of the hand and is excised or tied off soon after birth. In the black population, this is not associated with other findings. In Caucasians, small finger duplication is often associated with congenital systemic conditions

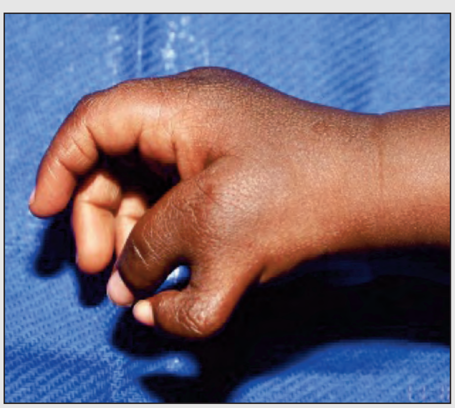


Fig. 13

Fig. 14

Wassel Type IV thumb duplication—most common.

Preaxial or **thumb duplication** is sporadic and is usually unilateral. It is classified according to the Wassel Classification from I to VII:

- I. Bifid distal phalanx.
- II. Duplicated distal phalanx.
- III. Bifid proximal phalanx.

- **IV. Duplicated proximal phalanx—most common**.
- V. Bifid metacarpal.
- VI. Duplicated metacarpal.
- VII. Triphalangism with duplication.

(Triphalangism without duplication is inherited as autosomal dominant and associated with many anomalies)

Type IV: Since this is most common, it will be discussed here in some detail. The aim of surgery is to give the child one good, normal appearing thumb with good opposition, alignment and a normal first web space without scarring. Most often, the ulnar duplication is the largest or the same size as the radial duplication and the radial duplication can be removed, sparing the first web space from incisions and resultant scarring. Surgery is performed between one and two years of age. The nail bed of the retained thumb is preserved.

Operative approach: This requires salvage of the radial MPJ collateral ligament, and also the insertion of abductor pollicis brevis into the radial base of the proximal phalanx that is removed (see Fig. 15). The periosteum on the radial side of the proximal phalanx is stripped off with the ligament and muscle insertion. The duplication may have a normal appearing ulnar thumb, or both thumbs may be angulated away from each other. In such cases, it is important to leave behind a straight thumb and this requires:

- Re-inserting the radial collateral ligament and abductor pollicis brevis into the base of the remaining proximal phalanx, and also realigning the tendons and bones.

- Occasionally the tendons to the discarded duplication are large and need to be saved and transferred into the tendons of the preserved thumb.

- The metacarpal head may require an osteotomy to remove the articular surface on the radial side (for the discarded proximal phalanx). The osteotomy trims down the large metacarpal head to allow easy insertion of the ligament and APB tendon into the base of retained proximal phalanx. This also helps to straighten the angulation (see Fig. 15—black arrow points to the site of the osteotomy).

- Additional metacarpal or phalangeal osteotomies may be needed if there is still a severe ulnar angulation of the distal IP joint.

- In some cases, **imbrication of the ulnar collateral ligament at the IPJ** is all that is needed to correct the distal angulation at the IPJ (top

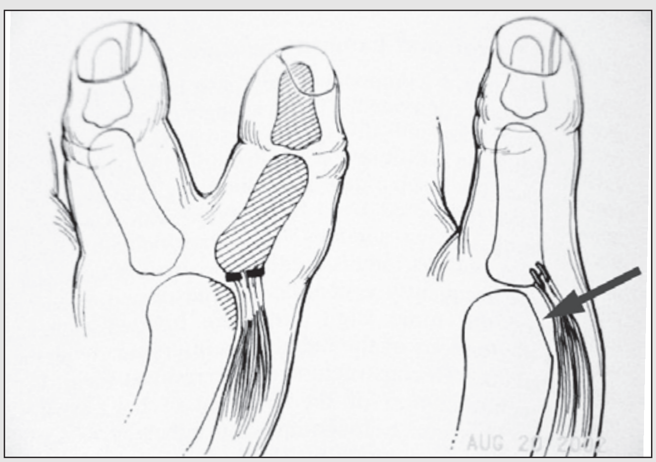


Fig. 15

Release of radial collateral ligament and insertion of AbPB from the base of radial duplication (the ablated thumb), and reattaching these to the base of proximal phalanx of ulnar thumb. (From *Green's Operative Hand Surgery,* 5th edition, courtesy of Elsevier)

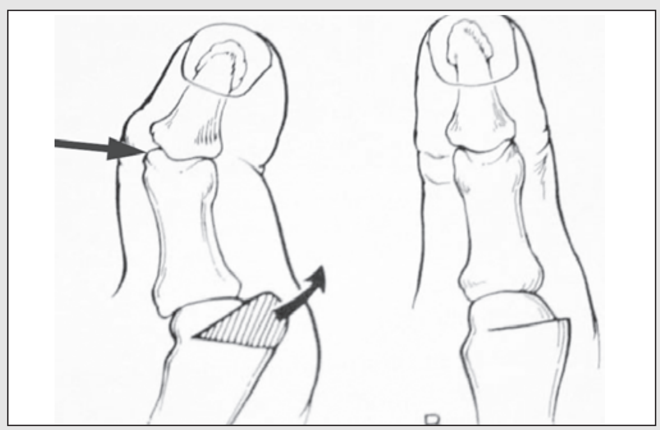


Fig. 16

An additional metacarpal osteotomy may be required to straighten the ulnar thumb. This osteotomy is at the neck of the MC but sometimes one is also needed at the neck of the proximal phalanx. These osteotomies prevent an angulated zigzag deformity. (From *Green's Operative Hand Surgery,* 5th edition, courtesy of Elsevier) arrow in Fig. 16).

- Usually, a K-wire and a thumb spica splint or cast are used to maintain alignment for four weeks.

- Range of motion exercises are then allowed.

Complications include malalignment, with a zigzag deformity secondary to bone, tendon, or ligament imbalance, instability, or stiffness.

One can refer to basic hand surgery texts for detailed description or can contact the author for further details.

Triphalangeal Thumb without duplication is relatively common. Other anomalies, including thenar muscle deficiency and cardiac anomalies are associated with it.

Radial Dysplasia or Radial Club Hand

Radial dysplasia (radial deficiency or radial club hand) is common in Africa. Cardiac, blood, and other anomalies are seen with radial dysplasia. The entire radial side (radial corridor) of the upper extremity may be deficient. This includes bones, muscles, and soft tissue. The most common finding is an absence of the entire radius, with bowing of the ulna toward the missing radius—Type IV. The thumb and radial side carpal bones may or may not be present. This condition is bilateral 50% of the time. The elbows may be extended and stiff. Valvular disease and hematologic abnormalities must be ruled out.

The goals of surgery have been to correct the radial deviation of the wrist, balance the carpus on the forearm, maintain motion, and allow for future growth. In the past, recommended treatment was centralization of the ulna on the carpus with or without an osteotomy to straighten the ulna if the bowing is > 30°. More recently, radialization of the ulna has been recommended—where the ulna is lined up with the scaphoid or trapezium (if a proximal row carpectomy is needed). The recurrence rate with subluxation/dislocation of the ulna, relapse of wrist flexion, and stiffness and poor function is high with both methods, but more so with centralization. Also, with these techniques it is difficult to preserve the ulnar epiphysis and thus future growth.

The present treatment recommended is:
- **Newborn**: early stretching and splinting.
- **At 18-24 months**: (perform at a major medical center).
- Release all tight structures on the radial side including skin, tendons, capsule, radial anlage, etc.
- Ulnar osteotomy to straighten the bowed ulna with preservation of ulnar epiphysis—do not try to centralize the carpus, since this often damages the ulnar epiphysis.
- Use ulnar-sided flap to reconstruct skin loss on radial side of wrist—see below.
- ECRL/ECRB to ECU transfer or imbrication of the ECU for tendon balance. The wrist placed in a splint for three weeks.
- **Adolescence**: a wrist fusion. Waiting until adolescence allows full growth without disturbing ulnar epiphysis.

Contraindications for surgery include:
- Life-threatening

Fig. 17

Fig. 18

Radial dysplasia with absent radius Bilateral radial dysplasia.

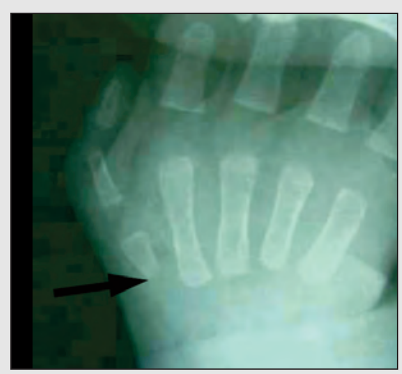


Fig. 19

X-ray showing absent CMC joint in Type IIIB hypoplastic thumb. This IIIB thumb hypoplasia requires pollicization.

systemic conditions, such as cardiac anomalies.

- Bilateral stiff elbows: straightening the hand moves it away from face and mouth. Children can flex their neck and reach an angulated hand but not a straight one.
- Older children—often adapt and learn to use their deformed hands.

Summary: Extensive surgery with centralization or radialization is NO longer recommended, and especially not recommended in the district hospital setting. The complications of aggressive surgery are explained to the parents so they will not be discouraged when it is not possible to make the hand and wrist straight in early childhood.

Thumb Hypoplasia: Thumb abnormalities are seen with radial dysplasia, but also may be isolated. Thumb hypoplasia may be minimal, as in Type I, or completely absent as in Type V. Small but functional thumbs, Type I to Type IIIA, are augmented with tendon transfers and a Z-plasty to deepen the first web space. Types IIIB to V require pollicization of the index finger—a demanding procedure. The difference between IIIA and IIIB is the presence of a CMC joint in IIIA. In IIIB, the CMC joint is absent.

Macrodactyly or Gigantism

Gigantism occurs in early childhood and is associated with lipofibromatosis. It also occurs with neurofibromatosis, vascular anomalies, and other bony conditions.

With lipofibromatosis in childhood, there is a uniform enlargement of fingers, toes and sometimes the entire extremity. All anatomic structures enlarge, including the bones that grow in width and length with advanced bone age. There is a marked increase in subcutaneous fat and digital nerves.

The author only recommends partial or complete amputations in the district hospital. When seen early, debulking can be attempted in two or more stages—debulking one side of a finger at a time. Debulking is combined with epiphyseal arrest at each joint once the finger reaches adult length. This is often the time the patient comes to the health center. The transverse axis of growth is difficult to treat. Debulking has limited success, and final results depend on the age at the first surgery. Most often, there is continued growth after the initial debulking. A second debulking may be done. Finally, the family may agree to a ray amputation to give a reasonable appearing and functional hand.

Often the parents refuse early ray amputation, even though this is the best and most definitive procedure. Ray amputation including the metacarpals of one or more abnormal fingers will often control this condition. The thumb is different, and initially requires conservative debulking with early epiphysiodesis. If the thumb continues to grow, amputation and later pollicization of a normal index or long finger gives a good final result. With large "banana fingers" that are several times the length and breadth of a normal adult finger, ray amputation is necessary at the outset if the family will agree. It is likely that no one but a parent will notice when one finger is missing.

Fig. 20

Fig. 21

Macrodactyly/Gigantism secondary to lipofibromatosis

Gigantism is may be present in the toes. With gigantism of a large toe, debulking and epiphyseal arrest is recommended in a child. When giantism involves other toes, a ray amputation of one or more toes will be necessary. This amputation is carried back to the tarsal/metatarsal joint.

Constriction Bands

The cause of constriction bands is controversial. It has long been thought to be secondary to amniotic bands. Some have linked constriction bands to a Band Syndrome or Amniotic Disruption Sequence which also includes cleft lip, other facial clefts, and clubfeet. Constriction bands can also associated with a type of syndactyly of the fingers, acrosyndactyly.

The extremity is normal proximal to the band, but with severe bands, the extremity distal to the band will have significant swelling, or there may even be distal amputations. This occurs in acrosyndactyly.

If there is severe swelling of the distal extremity, surgery is performed early. When the swelling is mild, surgery can be delayed until the child is older. Release is best done with multiple Z-plasties, 4-6, according to the size of the extremity or finger. A rim of skin and soft tissue is removed on either side of the band, down to the depths of the band and to normal tissue or bone. The adjacent tissue is undermined in a subcutaneous plane to allow tension free closure of the Z-plasties. One maybe concerned if there will be sufficient distal blood supply, but there is always ample blood supply to maintain viability. It may take some time for the distal swelling to resolve. During this time a compression bandage may be used, wrapping from distal to proximal.

Fig. 22

Fig. 23

Macrodactyly of toes—often a family will accept a toe amputation sooner than a finger amputation.

Fig. 24

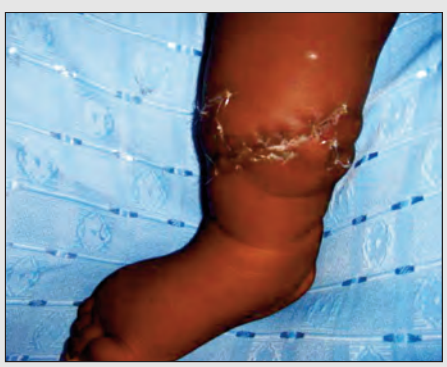


Fig. 25

Congenital constriction band treated by excision and multiple Z-plasties.

"Congenital" Trigger Thumb

This refers to a flexed IP joint of the thumb, which is usually not noticed until several months after birth. At one time, it was thought to be congenital, but some studies have shown this condition to be neither congenital nor trigger. This condition is usually not diagnosed at birth, and it does not trigger. It is a fixed flexion deformity. One rarely sees trigger thumb in a young child, and thus there is often a delay in diagnosis.

On exam, the IPJ of the thumb is in fixed flexion, and a nodule is palpated at the palmar digital crease of the thumb. This is Notta's node, a swelling on the flexor pollicis longus. It is not possible to extend the thumb.

Division of A-1 pulley is the definitive treatment. The surgery is delayed until the child gets a little older for safer anesthesia, and for the hand structures to grow. At 6-12 months, the A-1 pulley is divided under general anesthesia and with a forearm tourniquet. Great care is required to carefully identify and retract the digital nerves, especially the radial digital nerve, which crosses over the A-

Fig. 26

Fig. 27

Unilateral and bilateral congenital trigger thumb (Neither congenital nor trigger).

1 pulley. The nodule is palpated, and the FPL tendon can be identified. The A-1 pulley is identified and divided at the level of the palmar digital crease–MPJ crease. After division, the thumb is extended. Some splint the thumb in extension for a few days.

In the past, it was felt that if one waited, the condition would resolve, and one recent study has shown this may happen after several years of stretching and conservative treatment. This requires constant therapy, which may not be possible everywhere.

The differential diagnosis is a flexion of the MPJ with hypoplasia of the extensor tendon, EPB, and no extension of the MPJ. This condition usually resolves with the MPJ splinted in extension for several months. The IPJ is not flexed and Notta's node is not present at the MPJ. If the MPJ flexion is persistent, then an EIP (Extensor Indicis Proprius) tendon transfer may be done.

Addendum

Please contact the author if you have any questions: llcartermd@comcast.net.

Chapter 40

Compartment Syndrome and Volkmann's Ischemic Contracture

Louis L. Carter, Jr.

Introduction

This chapter is included for those general surgeons with an interest in upper extremity surgery and with the time and desire to help these poor, afflicted patients who have had injuries that were improperly treated. All general surgeons must recognize the conditions that lead to upper extremity compartment syndrome with the resultant chronic deformity known as Volkmann's Ischemic Contracture. When a patient presents with symptoms of compartment syndrome, urgent treatment is necessary to save the limb. In most district hospitals, the etiology will be either a supracondylar fracture with impingement on the brachial artery or a tight cast. These tight casts are often the ones applied by traditional bone setters. Immediate treatment in these cases should be the removal of the cast. Often the cast applied by the traditional bone setter will be for a minimally displaced fracture. Once the swelling has subsided, the fracture or dislocation may be reduced if necessary. In most cases, the presentation will be delayed, and a fasciotomy may be necessary even after the fracture reduction and cast removal.

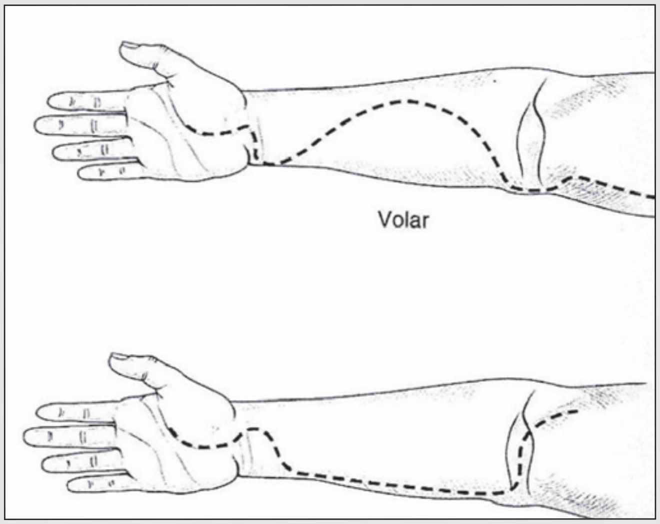
Fig. 1

Supracondylar fracture with impingement on the neurovascular bundle.

Compartment Syndrome

Compartment syndrome exists when the interstitial pressure within one of the forearm or hand compartments is elevated (this rarely occurs in the upper arm). The increased pressure leads to venous outflow obstruction within the compartment, which is followed by the decrease in arterial perfusion, decrease in oxygenation, and finally ischemia and gangrene. There are many possible etiologies for compartment syndrome in Africa, including **lack of blood flow** from proximal injuries, **elevation of internal pressure in the osteofascial compartments**, and **external pressure with constriction of blood flow**. Fractures and dislocations at or above the elbow may lead to interruption of blood flow followed by ischemia. Fractures, crush injuries, electrical burns, and snake bites lead to fluid or blood accumulation within osteofascial compartments with an increase in internal pressure. This is followed by ischemia and then gangrene. Full thickness circumferential thermal burns and tight casts may cause external pressure with ischemia and later gangrene.

Compartment syndrome must be suspected in these conditions and treatment carried out immediately to prevent Volkmann's ischemic contracture. Fractures and dislocations must be reduced and tight casts removed as an emergency procedure. Fasciotomies are often needed for snake bites and electrical burns, and escharotomies for circumferential burns when there are symptoms of compartment syndrome. The symptoms include paresthesias, pallor, loss of pulses, paralysis, and, **most important, pain when the distal fingers are extended**. Another method for determining when a fasciotomy or escharotomy in a burn patient should be done is by **measuring oxygen saturation** in the fingers or thumb. If this falls below 90%, then surgery is indicated.



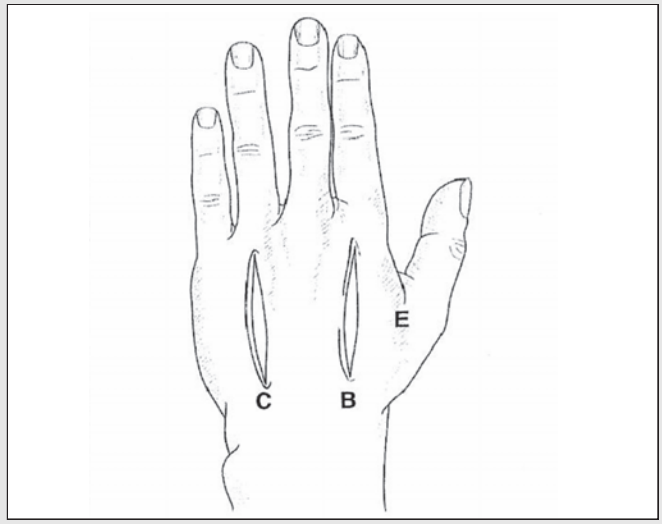


Fig. 2 **Fig. 3**

From *Green's Operative Hand Surgery*, courtesy of Elsevier.

Measuring compartment pressures is **unnecessary**, as patients will present late. If you think the compartments need to be released, then go ahead and release them based on your exam.

In all cases, except for acute full thickness burns, the incisions should be through the deep muscle fascia. In burns, the incision can be just through the skin, an escharotomy (See chapter 11 on Acute Burns).

In the acute situation, the wounds are dressed with a wet or non-adherent dressing or silver sulfadiazine, and the extremity splinted and elevated.

The basic incisions are shown in Figs. 2-3. Fig. 2 shows two volar incisions. What is most important is that the incision is on the ulnar side at the wrist, so that the palmar cutaneous branch of the median nerve is not injured (it will lie between the palmaris longus and flexor carpi radialis). The forearm incision is carried into the palm to release the carpal tunnel. The palm incision should be in line with the ring finger.

Fig. 3 shows the dorsal incisions for the interosseous compartments in the hand. All 4 of these dorsal compartments can be opened with these two incisions that are between metacarpals 2 & 3 and 4

Fig. 4 **Fig. 5**

4) Gas gangrene resulting from a tight cast.

5) The same case showing simple non-displaced fracture with gas in tissues. The patient required high arm amputation.

& 5.

It is important to reduce fractures and dislocations on admission. If there is too much swelling, then the extremity can be elevated until the edema subsides. In delayed cases, fasciotomies may need to be performed as soon as the patient is seen.

The aim of this chapter is not to cover the material that is well covered in major textbooks, but to cover the late reconstruction in Volkmann's ischemic contracture. There are different stages of ischemia—see below.

Volkmann's Ischemic Contracture

Volkmann's ischemic contracture, one of the consequences of compartment syndrome in the upper extremity, is seen all too often in Sub-Saharan Africa, not only the result of the commonly displaced supracondylar fracture of the humerus (Fig. 1) but also from the work of traditional bone setters, Fig. 4 and 5. Traditional bone setters are seen throughout Africa, especially in Nigeria and Ethiopia and in other countries where orthopaedic surgeons are not readily available. In most cases, the traditional bone setters stabilize the fracture very well (Fig. 5), and many patients attest to their skill in treating fractures. They do not have formal training, and most often they do not have x-rays available to identify the fracture. There are many complications from traditional bone setting—from compartment syndrome to necrotizing fasciitis, gas gangrene, and late ischemic contracture. The author has seen some cases where the extremity was swollen after trauma suggesting a fracture and the traditional bone setter applied his "cast" with his presumptive diagnosis of a fracture. Later, when complications developed, x-rays showed no fracture. The method is similar in each country whereby wooden/plywood strips or sticks are placed over the fracture site, and these are wrapped tightly with cloth or leather strips to stabilize the extremity. This chapter will deal with the treatment of established Volkmann's Contracture. Necrotizing fasciitis and gas gangrene are covered in chapter 36 on hand infections.

All these conditions can be prevented by early splinting, elevation of a complex fracture and/or a crush injury and then careful checking and documentation of peripheral pulses on a regular basis. Major textbooks discuss measuring compartment pressures, but this will be difficult to do in many locations, and delay in treatment may lead to loss of function. When there has been an early reduction of a fracture or dislocation with splinting and elevation, casting can be done several days later when the swelling has diminished. When preventive measures have not been followed and there are symptoms of compartment syndrome, immediate removal of casts and fasciotomies should be done.

Established Ischemic Contractures

Obviously, there are many variables in compartment syndrome and the resulting ischemic contracture. Most cases in Africa will present in the chronic stage. There are two main classification systems. **Holden** has described two levels of injury. In Level I, the injury is proximal to the contracture, as in an arterial injury in supracondylar fractures (Fig. 1). Usually, the volar compartment of the forearm is compromised first. In level II, the damage to the

Fig. 6

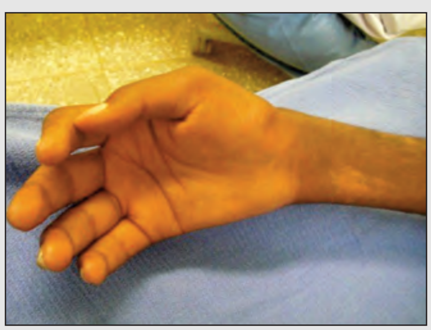


Fig. 7

Fig. 8

6-7) A mild Holden Level II contracture, secondary to direct and circumferential compression.

8) A more severe Holden II.

muscles and nerves is directly under the area of trauma, as in the "casting method" by the traditional bone setters. Since the constricting pressure is circumferential, the damage is not only to flexor but also extensor muscles. When a "cast" is applied to injuries near the wrist, the proximal forearm may be completely normal. Many factors determine the underlying injury, such as the magnitude of the fracture, swelling, amount of pressure, how long pressure was applied, age, etc.

Holden Classification

- Level I—Injury is proximal to the ischemia and later contracture, as in a brachial artery injury.
- Level II—Ischemia is directly under the injury (pressure).

Tsuge classification is basedon the three levels of severity in Volkmann's Contracture and is outlined below:

- Mild—resulting contracture of 2-3 fingers only.
- Moderate—all fingers are flexed with thumb flexed in palm, wrist in flexion and partial loss of sensation in the hand.
- Severe—all muscles that flex and extend wrist and fingers are involved.

In **Holden Level I** injuries, the volar forearm compartments are first affected. When early treatment is not carried out, the other compartments—mobile wad and extensor compartments—may be involved. Most Holden II injuries will be in the moderate to severe category in the Tsuge classification.

In the Holden Classification, surgery in Type II (as seen with traditional bone setters) is based on:

1 Severity of contracture.
2 Amount of muscle damage.
3 Condition of potential soft tissue coverage.
4 Function of nerves and remaining muscles (are all compartments involved or is the extensor and mobile wad compartments spared).
5 Available muscles for reconstruction.

Most cases of Volkmann's Contracture that this author has seen are late cases of Holden Type II, with the severe type in the Tsuge classification. The children shown in Figs. 6-10 have ischemic flexor and **extensor** muscles and significant sensory loss. The forearms are atrophic, the wrists are flexed, and the fingers are usually held in a tight intrinsic minus position—MPJ hyperextended and IPJs flexed (See Figs. 9 and 10).

Treatment

What can be done in this situation? For most general surgeons who have had limited hand and upper extremity experience—**NOTHING!**

Why then include this problem in this text? The reason is that these patients and families are discouraged with little hope, and these children will go throughout life without two good hands in a world where they need two good hands to survive. Most of the patients will be children since closed fractures of the upper extremity are more common in young children. Additionally, they are of a developmental stage that their misery is non-specific, and complaints are often easily ignored by their caregivers. Most often they cannot articulate the magnitude of their discomfort, and they are left

Fig. 9

Fig. 10

Severe ischemia in the Tsuge classification, secondary to circumferential pressure from a native bone setter's cast.

"casted" with what their caregivers consider "normal" pain. Motor function cannot be restored without sophisticated reconstructive procedures, which are beyond the scope of this chapter. Some sensory restoration can be achieved with the fairly straightforward technique of **neurolysis**, providing the patient with a "helping hand." A neurolysis of the median and ulnar nerves should be done. The nerves can be identified in the forearm, and any tight scar can be removed. This will not restore perfect sensation but, hopefully, adequate protective sensation.

Treatment of Holden Type I Ischemic Contracture.

In cases that present early, tendon Z-plasties, flexor-pronator muscle slide, and tendon transfers such as FDS to FDP can be used. Necrotic muscle should be excised. Usually, the muscles deep in the volar compartment are involved first—FPL and FDP. Neurolysis of median and ulnar nerves should be done. The reader is referred to major texts and anatomy atlases for complete descriptions of the surgical techniques. When only the volar compartment is involved, especially the FPL and FDP, then an ECRL to distal FDP (or FDS if necessary) transfer is relatively straightforward and gives a satisfactory reconstruction of finger flexion. EIP can be transferred to the distal FPL. Usually, the distal tendons are preserved and can be used to motor the fingers. In longstanding contractures, tenolysis of these distal tendons will likely be necessary.

Treatment of Holden Type II Ischemic Contracture:

(Local constricting force as seen in tight casts and with traditional bone setters)

Mild/Moderate forms—unusual (only seen if "cast" removed early).

Findings will be a flexed wrist and hyperextended MPJ of fingers with flexed IPJs—an Intrinsic Minus position, as the intrinsic tendons are paralyzed or atrophic. There will be limited necrosis and scar formation at the site of injury. The release should be done though incisions for a typical fasciotomy or directly over the site of greatest injury. Incisions should be placed where tendon and nerves will not be left uncovered after release. The release and excision of these ischemic, atrophic, and scarred muscles should be done. These muscles are pale and do not contract. They may bleed, but this is not a sign of viability. If the cast is on the distal forearm, the proximal muscles may be normal as in the case above, and tenolysis and Z- plasties of the distal tendons may be sufficient—as long as they are intact and can be released. If the proximal muscles appear viable with good color and contractility, then the FDS tendons can be excised and Z-plasties done on the FDP and FPL tendons. In contrast to the ischemic contracture seen in Holden I the superficial, not deep, muscles are most likely damaged in Holden II. Proximal muscle slides are not adequate as might be the case with Holden I type injuries. A complete release of the nerves in the area of compression should be done. If a skin graft is not sufficient closure, then a pedicle flap will be necessary, such as a groin or superficial epigastric flap.

Severe form—most commonly seen: The goal of surgery is to give the patient a helping hand.

Findings will be fixed contractures and atrophy, including atrophy distal to the site of original compression. The fingers will have a severe Intrinsic Minus posture.

The involved muscles will likely be necrotic and should be excised. Z-plasties will not be sufficient. If only the volar compartments are necrotic, then the ECRL may be transferred to motor the FDP, and the EIP can be transferred to the FPL at the level of the wrist. All proximal necrotic muscles in the volar compartment are excised, and a tenolysis of the distal FDP and FPL tendons may be necessary at the time of the transfers. Unfortunately, in these severe Holden II injuries, both the volar and extensor compartments are often involved, and there are no tendons available for transfer. Neurolysis of the median and ulnar nerves should be done in an attempt to restore protective sensation.

A **severe, fixed flexion contracture of the wrist** can be treated with flexor tendon release/excision, proximal row carpectomy, and, if necessary, a wrist fusion in neutral or slight extension when growth is nearly complete. MPJ flexion contractures will require MPJ capsulotomies (See chapter 12 on Burn Reconstruction). PIPJ flexion contractures may be passively corrected in many cases, but sometimes they will also need volar capsulotomies. The MPJs and PIPJs need to be pinned for several (3-5) weeks with pins from the metacarpal heads to the fingertips—

position of protection or "safe" position: MPJ flexion and IPJ extension. Even if the fingers do not move, placing the hand in position of protection with some sensation gives the patient a helping hand. These procedures may also be performed for the thumb. The adduction contracture of the thumb may be released with a Z-plasty or with a dorsal flap reconstruction of the web space. The AddP tendon will need to be released at its insertion into the base of the proximal phalanx. The thumb MC should be pinned to the index MC to hold it in a palmar abducted position for 3-4 weeks. (This is the position the thumb is in when it picks up a large textbook.)

Hand Therapy

It is hoped that these patients will have some residual functioning muscle and that therapy will help. These are difficult cases, and each case will have to be individualized based on what muscles are functioning and to what degree, and the therapist's capabilities at your hospital.

There are other sophisticated procedures for intrinsic contractures and restoration of finger flexion with free microvascular flaps. Gracilis and other microvascular transfers may be used in Holden Type I and Tsuge mild to moderate cases where the extensor tendons are intact. As stated above, these Holden Type I are ischemic contractures that are due to proximal lesions and not direct pressure where both flexors and extensors are destroyed from circumferential injury.

Summary

This is a very severe condition that is best prevented. **In the district hospital, when injuries prone to this complication are first seen and where close observation may not be possible, a fasciotomy or escharotomy should be carried out immediately as a preventive measure**. The initial exam should check for pain with extension of the fingers. If there is any suggestion of a tight compartment, a release should be carried out as soon as possible. Fasciotomy wounds heal well. Aggressive emergency surgery is indicated in hopes that a few of the muscles may be protected from ischemia and necrosis.

Most of the time these cases will present to a referral hospital late, but reconstruction and rehabilitation may still be possible. In mild to moderate Holden Type I injuries, neurolysis and tendon transfers may give the patient a functional hand. In most cases, surgery will only provide a hand with protective sensation and adequate position, "a helping hand," but this is a huge advantage over a totally non-functional and poorly positioned hand, especially in the context of the developing world.

Chapter 41
Lymphedema

David W. Chang and Peter M. Nthumba

Editor's Preface
This is an outstanding chapter on a very difficult condition. It is authored by experts from the West, David Chang, and from Africa, co-editor Peter Nthumba. This comprehensive chapter deals with the etiologies and medical and surgical treatments around the world.

Introduction
Lymphedema involves the accumulation of lymphatic fluid leading to progressive fibrosis, fat hypertrophy, and destruction of the lymphatic vessels. The course of lymphedema is chronic, progressive, and debilitating. Although there is no cure, the gold standard for the treatment of lymphedema is manual decongestive lymphatic therapy (MDLT) or complete decongestive therapy (CDT), which is best administered by a certified lymphedema therapist. The use of these therapies, however, is labor intensive and requires strict, lifelong patient compliance. Surgical treatment of lymphedema follows the failure of such conservative measures. The indications for surgery are to reduce the weight of the affected region, reduce the frequency of infectious/inflammatory episodes, to prevent progression of lymphedema, and to improve cosmesis and function.

Unfortunately, the large majority of lymphedema patients in Sub-Saharan Africa present later, at a stage when conservative measures are not treatment options. Surgical treatment is therefore currently the mainstay of management in this region.

This chapter offers an overview of lymphedema management.

Lymphedema results from the accumulation of protein-rich interstitial fluid within the skin and subcutaneous tissues as a result of lymphatic dysfunction.

The protein-rich edema fluid provokes an intense fibrous reaction, further reducing the lymphatic transport. This intense fibrous reaction leads to progressive swelling of a limb, induration, fibrosis, and repeated attacks of cellulitis.

Anatomy
Primary lymphatics arise in the interstitial tissue as capillaries consisting of a one-cell thick endothelial layer. These valveless vessels enlarge to form large secondary lymphatics that have valves.

Tertiary lymphatics have a diameter of about 0.5mm, do not enlarge as they ascend, communicate with each other, and have multiple valves. Their walls consisting of 3 layers (endothelium, muscular layer, and an outer adventitia).

Unidirectional lymph flow is the result of:
- Intrinsic lymphatic muscle contractions.
- Muscle pump action.
- Presence of valves.
- Negative intrathoracic pressure.

The body has superficial and deep lymphatic systems, which are contiguous with but separate from the adjacent venous system. Direct communication between the lymphatic and venous systems **normally** occurs only in the major neck veins. It is here that the thoracic and cervical lymphatic channels drain into the major veins.

Lymphatic vessels in the superficial and intermediate dermis, which lack valves, drain into the deep dermal and subdermal plexuses that have values.

The deep sub-fascial system is composed of much larger paired channels separate from the superficial system, connecting only at the supratrochlear, inguinal, and popliteal lymph nodes.

The barriers between these separate and distinct systems may be broken down with the onset of lymphatic obstruction, resulting in communications between the superficial and deep lymphatics and between the lymph and venous channels.

Pathophysiology
- The chronic lymphedematous state is characterized by a decrease in lymphatic support, as opposed to lymphatic hypertension or overproduction of lymph, as might be suggested by models of venous hypertension.

- In the pathologic lymphedematous state, lymphatic load exceeds capacity, intralymphatic pressure builds, flow stagnates, and valvular incompetence occurs. Dermal backflow (the reversal of flow into the dermal plexus) occurs as the intralymphatic pressure rises.

As the capability of impaired lymphatic transport is overwhelmed, protein-rich fluid accumulates in the extracellular space. Macromolecular protein and hyaluronan deposition lead to increased tissue colloid osmotic pressure, resulting in the influx of water and increased interstitial hydraulic pressure. Fibroblasts, monocytes, adipocytes, and keratinocytes increase in the tissues, and brawny, nonpitting edema occurs from fibrovascular proliferation.

The elastic fibers degenerate and thicken, the basement membrane of the lymphatic channels thicken and eventually obliterate as the ground substance, and inflammatory cells and fibroblasts proliferate. Collagen deposition outstrips the rate of phagocytosis, leading to further fibrosis and tissue overgrowth.

Primary Lymphedema: Unknown etiology or congenital lymphatic dysfunction.
- Women: Men; 3:1.
- Women often develop edema around the time of menarche.
- The left leg is more frequently involved than the right leg.
- Upper extremity involvement is rare.

Secondary Lymphedema: known precipitating cause. Far more common; may result from surgical, infectious-inflammatory, neoplastic, or traumatic compromise of the lymphatic pathways. Causes include:
- Filariasis (e.g.Wuchereria bancrofti).
- Erysipelas.
- Therapy for breast cancer (90% of upper limb lymphedema).
- Surgery.
- Radiation.
- Combination of radiation/surgery.

The overall incidence following breast cancer surgery is about 8%. The greatest prevalence is among those who undergo extensive axillary surgery followed by axillary radiation. The swelling is usually delayed for approximately a year as a result of the ongoing fibrotic process.

Primary Lymphedema
Primary lymphatic obstruction may be caused by a number of anatomic abnormalities, including lymphatic aplasia, hypoplasia, functional insufficiency, and absence of lymphatic valves.

It is subdivided by:
- Age of onset.
- Lymphangiographic findings.
- Congenital lymphedema includes all forms of lymphedema present at birth; this may be genetically determined, and accounts for more than 90% of patients with primary lymphedema.

It can present at:
- Birth (Milroy's disease)—familial sex-linked form of lymphatic aplasia/lymphedema congenita.
- Adolescence—lymphedema praecox.
- Adulthood—lymphedema tarda (presents in middle age or after age 35)

Lymphedema congenita
- Occurs in the first two years of life, but often apparent at birth.
- May involve multiple limbs, as well as the genitalia and face. Lymphedema congenita has a lower limb to upper limb ratio of 3:1.
- Bilateral lower limb involvement more likely in this form than in others.
- Girls: Boys; 2:1.
- The majority of patients do not require any specific treatment.
- Edema may improve over time.

Lymphedema praecox
Usually diagnosed during puberty, but may appear as late as the third decade of life. Edema is usually unilateral and limited to the foot and calf. This type has a strong female predominance (4:1 up to 10:1), suggesting an estrogenic effect.

Lymphedema tarda
Usually presents after the age of 35 years. It is relatively rare, accounting for less than 10% of patients with primary lymphedema.

Lymphangiographic Classification
Aplastic lymphedema (15% of patients)—mostly in congenital lymphedema. These demonstrate a normal dermal plexus with total absence of the subcutaneous lymphatics.

Further Pathophysiology
- At the arterial end of circulation, hydrostatic

pressure is greater than osmotic pressure—this drives protein-rich fluid into the interstitial tissue. Most of this fluid returns into circulation at the venous end (where osmotic pressure is greater than hydrostatic pressure).

- The remaining high-molecular-weight proteins and associated water are removed from the interstitial tissue by lymphatics; some are broken down by monocyte-derived macrophages and absorbed into veins.

Edema develops when the number of lymphatics is reduced below a critical level. It may also result from increased lymphatic load. A decrease in the number of functioning lymphatics leads to a high-protein edema, increasing the tissue osmotic pressure, hence additional shift of fluid into the interstitial tissue. The high protein edema provokes an intense inflammatory reaction, leading to a perilymphatic scarring and obliteration of lymphatic trunks, effectively reducing lymphatic transport even more. Both deep and superficial lymphatics are obstructed, although the deep lymphatics are the first to show evidence of obstruction. Lymphedema is confined to the subcutaneous compartment; the deep muscle compartments remain uninvolved.

Effects of lymphedema are seen mainly in the more expansile superficial tissue:

- Increased skin thickness (mainly dermal elements).
- There is scarring of subcutaneous tissue. Extensive scarring in subcutaneous tissue may very rarely lead to venous obstruction.
- In time, low oxygen tension, decreased macrophage function, and the presence of increasing amounts of protein-rich fluid give rise to a chronic inflammatory state and consequent fibrosis. The excess protein serves as a medium for bacteria, and the resultant infection leads to additional lymphatic dysfunction. Repeated cellulitis/lymphangitis gives rise to progressively increasing lymphedema.

Diagnosis

- **History and Physical Exam:** Edema most often begins distally and progresses proximally over months to years. The edema is initially soft and pits easily—it gradually becomes non-pitting as fibrosis develops and the tissue becomes indurated.

  Skin changes may occur, but ulceration is infrequent. Once ulcerated, these wounds become chronic (because of lymphorrhea) and very difficult to treat.

- Patients may complain of fatigue or pressure in the extremity. Pain is an infrequent complaint (unless the edema develops rapidly), and a search for an alternative cause is necessary. A family history is unusual.

Differential diagnoses include:

- Edema as a result of cardiac, renal, or hepatic insufficiency. These are differentiated from lymphedema on the basis of history and physical examination.
- Venous stasis disease—has characteristic skin changes and pigmentation that accompany the edema.
- Lipedema causes symmetric enlargement of the lower extremities and is often associated with obesity.
- This lipodystrophy characteristically affects females, and a family history of the condition is not uncommon.
- Combined forms of lymphedema and lipedema have been described.
- Kaposi's sarcoma—an important differential, especially in HIV epidemic environments (see Figs. 1-2).
- Laboratory studies should be obtained to distinguish other sources of edema.

Fig. 1

Fig. 2

This could very easily pass for lymphedema with fungal infection and advanced skin changes. A closer look reveals small Kaposi's sarcoma nodules that clinch the diagnosis.

- Venous studies are helpful if venous insufficiency is suspected.

Imaging
Should be used to confirm the diagnosis, as well as in the assessment of the results of therapy. Computed tomography and magnetic resonance imaging (MRI) are useful to rule out malignancy.

Lymphoscintigraphy

- Uses radiocolloids (99mTc rhenium sulphide colloid or 99mTc pertechnetate stannous sulphur).
- Helps delineate the anatomy of lymph vessels, lymph nodes and in evaluating the dynamics of lymph flow.
- Does not enable direct visualization of anastomosis.
- Rate of clearance of the radiotracer is good indirect evidence of lymphatic function.
- This technique is useful in planning physiologic forms of surgery.
- Serial linear limb measurements allow for evaluation of results of treatment.

Lymphangiography has been largely replaced by the above techniques.

- The most common lymphangiographic finding is hypoplasia of the lymphatic vessels. The lymphatics are narrowed and reduced in number.
- In the hyperplastic pattern (fewer than 10%), the lymphatics are dilated and increased in number owing to obstruction or incompetent valves.

Management
Lymphedema is not a curable condition, but can be controlled. The stage of lymphedema (Table 1) at presentation is an important determinant of the mode of treatment given to the patient (Table 2).

Aims of treatment

- Permanent decrease in size of the affected limb without continued use of conservative measures.
- Improvement of skin texture, softness and consistency.
- Elimination of episodes of cellulitis.

Physical therapy intervention methods

- Skin care.
- External pressure (bandaging, intermittent compression pumps, or compression

Table 1

Stage	Description	Clinical Presentation	Pictorial Representation	Management
0	Subclinical, or pre-stage	At risk of developing lymphedema, but has not yet developed any symptoms.		Observation
1	Soft, pitting edema	Pitting edema, soft to touch, protein-rich fluid.		Can be improved with early treatment.
2	Moderate Lymphedema	Swelling and fibrosis both present. Tissue not soft to touch.		Requires intensive treatment to improve.
3	Severe Lymphedema	Skin hard due to swelling and tissue fibrosis. Loss of normal elasticity.		Limited tissue mobility, disfiguring.

Staging of Lymphedema

garments) (Fig. 6).
- Isotonic exercise.
- Massage.

Basic skin care is essential in the prevention of infection, and may assist in preventing associated skin changes, including dermatitis, hyperkeratosis, and warty verrucous. Also helps prevent the breakdown of the epidermis and lymphorrhea.

Meticulous foot care and daily use of a low-pH, water-based lotion will help to prevent fungal infections of the web spaces. Topical antifungal therapy is recommended for localized fungal infections, but invasive infection may require systemic antifungal therapy.

Conservative management is indicated for mild lymphedema and as pre- and post-operative adjunctive measures.

The non-operative measures aim for:
- Reduction of hydrostatic pressure.
- Minimization of valvular incompetence.
- Decreased infection.
- Vigorous treatment of lymphangitis when it occurs.

Non-operative (conservative) measures include:
- Bed rest with limb elevation—reduces arterial hydrostatic pressure, hence fluid extravasation.
- Repeated elastic bandaging alternating with sequential compression pumping as necessary—increases tissue hydrostatic pressure and the return of edema fluid through lymphatics.
- Weight reduction.
- Massage by a Physiotherapist.

Noninvasive Complex Lymphedema Therapy (CLT), consists of:
- Manual lymph drainage.
- Compressive bandaging.
- Physical therapy exercises.

CLT facilitates lymph drainage by recruiting collateral vessels so that the lymphedematous area can be drained into normally functioning lymphatic systems.

- Pneumatic compressive machines are effective if used early in the course of the disease, before the development of fibrosclerotic tissue changes.
- Cardiac failure, active infection, and deep venous thrombosis are contraindications to pump therapy.
- Limb girth should be assessed at the initial visit, and at regular intervals afterward, to provide an accurate assessment of the effect of therapy.

Custom-fitted elastic compressive garments (sleeves or stockings) should be worn 24 hours a

Table 2

Medical	Surgical (Physiologic)	Surgical (Excisional)
Skin Care	Lymphangioplasty	Total Skin and Subcutaneous Excision (Charles Procedure)
Elevation	Omental Transposition	Buried Dermal Flap (Thompson Procedure)
Compressive Garments	Enteromesenteric Bridge	Subcutaneous Excision Beneath Flaps (Modified Homan's Procedure)
Pneumatic Compression Pumps	Lymphovenous Anastomoses	
Non-invasive Complex Lymphedema Therapy	Lympholymphatic Anastomoses	
Benzopyrones for Treatment of Infection		

Summary of Modes of Management of Lymphedema day (only taken off when taking a shower or bathing). These maintain limb volume and are especially useful after surgery.

Drug treatment

- Benzopyrones (coumarin and 7-hydroxy-coumarin) have been used. These increase proteinase activity so that large proteins are broken down into smaller groups. The resultant peptides and amino acids have a more favorable osmotic balance and readily diffuse into adjacent veins.

- Diuretics have been used in the treatment of lymphedema, but their effects are short-lived.

- Parasitic infections involving Wuchereria bancrofti and Brugia malayi should be initially treated with diethylcarbamazine. However, by the time most patients present with severe lymphedema, the parasites are long dead, and all that is warranted is the treatment of the lymphedema.

- Antihistamine and/or anti-inflammatory agents are used to control the allergic reactions to the dying parasite.

- Aggressive and prompt treatment of lymphangitis or cellulitis is recommended to prevent the development of sepsis. Lymphangitis/ cellulitis should be treated with a systemic antistaphylococcal and antistreptococcal agent for 5 to 7 days, combined with bed rest and elevation of the affected limb.

- Recurrent lymphangitis or cellulitis occurs in 15% to 25% of patients with lymphedema, and some patients require long-term prophylactic antibiotic therapy, using penicillin, cephalexin, or erythromycin.

Surgical therapy

Surgical intervention should be considered if:

- Medical therapy is ineffective in controlling lymphedema or preventing complications.
- Early in mild-to-moderate obstruction, in combination with conservative therapy

There are numerous surgical procedures for the treatment of lymphedema; unfortunately, none is completely curative.

All patients will receive benefit from a one-to-three-week intensive conservative therapy pre-operatively, to decompress the leg as much as possible. Current operations for lymphedema aim to remove excess lymphedematous tissue with resultant improvement in appearance, function, and prevention of infection.

Physiologic operations attempt to re-establish lymphatic drainage, whereas excisional procedures debulk the limb by removing the skin and subcutaneous tissue. Some procedures may have both physiologic and excisional components.

Reduction/Excisional Procedures

These are indicated when lymphatic trunks are sclerosed and unsuitable for microlymphatic anastomosis, or when conservative measures have been unsuccessful or are inapplicable.

Although some have advocated for the abandonment of such procedures, most patients presenting in Sub-Saharan Africa will have advanced lymphedema that is difficult to treat with any other modality. With the correct indication and a compliant patient, severe refractory lymphedema can be successfully treated with any of the excisional methods. (See Figs. 3-6.)

Alternatively, staged elliptical excision of skin and subcutaneous tissue can also be performed to minimize morbidity or to address specific pockets of tissue. For some patients suffering with severe impairment of their ADLs (Activities of Daily Living), recurrent infections, skin ulcerations, chronic pain, and poor quality of life, radical excision may be their only, and possibly best, option for returning to function.

I. Charles Procedure (Fig. 3)

While commonly credited to Charles, his original 1912 chapter on the treatment of scrotal lymphedema did not include any lower extremity cases. It wasn't until Macey and Poth that actual reports on the treatment of the lower extremity with skin graft harvested from the specimen were described.

The Charles procedure involves total subcutaneous excision, with removal virtually all skin, subcutaneous tissue (except in the foot and region overlying the calcaneal tendon), and deep fascia. The muscle is then covered with split- or full-thickness skin.

Editor's note: This procedure should not be used routinely, but may be an option for patients with severe edema and skin changes. It has limited application in severe edema, and should not be used in upper limb edema. It may, however, be the only way to mobilize a patient who is otherwise bedridden from massive lower extremity lymphedema. A modification of technique is crucial to avoiding complications.

Following Charles' procedure, patients suffer poor cosmesis, contour irregularities (Fig. 3d), severe secondary skin changes, including ulceration, hyperkeratosis, keloid formation, hyperpigmentation, weeping dermatitis, and an unstable scar, especially where split-thickness skin grafts are used. The possible loss of skin grafts resulting in more surgery is always a risk. Using a full-thickness skin graft will decrease the incidence of most of these complications; however, full-thickness skin is in limited supply, unless harvested from the same leg during the debulking procedure.

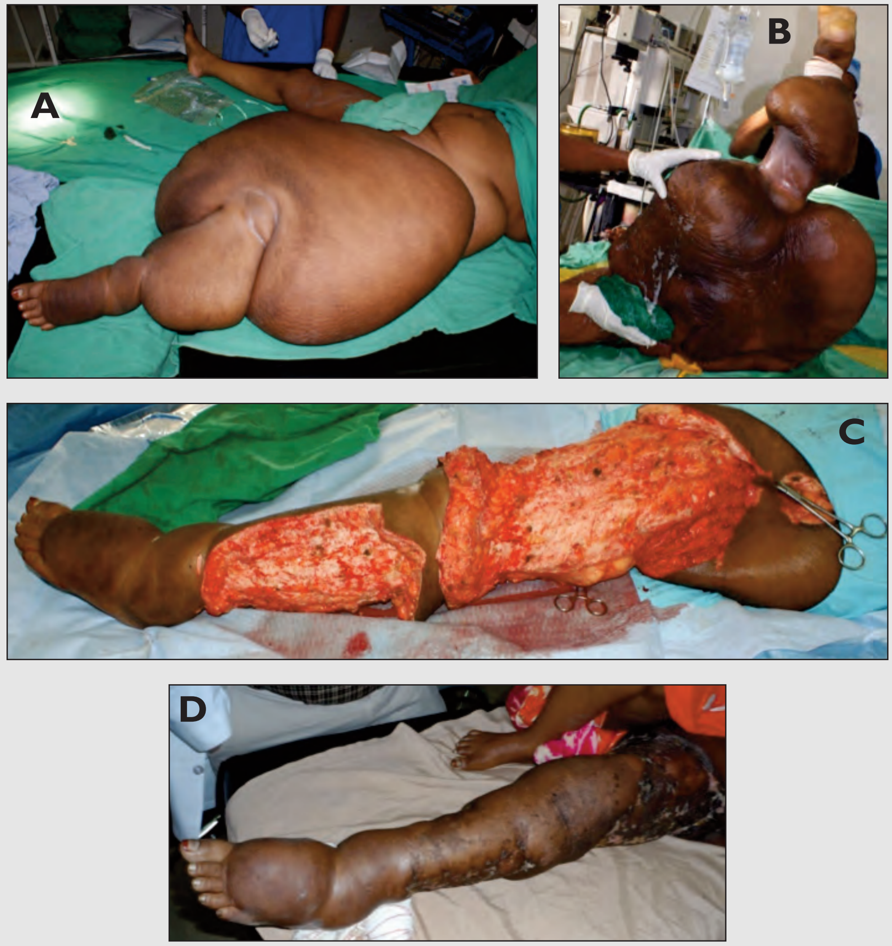


Fig. 3

Massive lymphedema that did not reduce at all, even after 3 weeks of in-hospital elevation (A and B). A modified Charles' procedure was performed; leaving what appeared to be near-normal skin on the limb, as well as circumferential skin around the knee (C). The resulting defects were grafted using the skin harvested from the excised tissue. The patient was then issued a graduated compression stocking and allowed to ambulate. For the first time in many years, she was able to lift her leg and walk. D shows the extremity at 4 months following surgery.

II. Thompson Procedure

This is an excisional procedure that may have a physiologic component. A de-epithelialized dermal flap is buried in the muscle with the expectation of achieving a permanent lymphatic communication between the edematous subcutaneous tissue and the uninvolved muscle compartment.

III. Homan's Procedure (Fig. 4)

This involves a staged subcutaneous excision beneath skin flaps, first described by Sistrunk in 1918 and later popularized by Homan.

- **First stage** (Figs. 4a to c)—subcutaneous tissue and excessive skin are excised from the posteromedial aspect of limb. A 1.5 to 2 cm rim of subcutaneous tissue and skin is left on the flaps. The remaining subcutaneous tissue down to fascia is excised, covering half the circumference of the limb. The excess skin flaps are the trimmed, and the wound closed over drains.

- **Second stage**—done 2 to 3 months later, the procedure is repeated on the contralateral side of limb (Fig. 4d).

Improvement is directly related to the amount of skin and subcutaneous tissue removed, as well as the personal care and attitude of each patient.

The modified Homan's procedure is the procedure of choice for most of our patients, and works very well in the compliant patient. The major disadvantages are the staged nature of the procedure, requiring a second surgery, and the fact that the patient must wear compression stockings for the rest of their life—this is especially difficult for the teenagers.

IV. Liposuction

The accumulation of lymphatic fluid in the limb results in increased deposition and hypertrophy of the adipose tissue. Liposuction, in which a fenestrated metallic cannula connected to vacuum suction is used to aspirate subcutaneous fat, was originally developed for body contouring, but since then has been used for the treatment of lymphedema. Brorson and Svensson compared the combined use of liposuction and compression therapy to therapy alone in stage II patients and demonstrated a 115% reduction in volume compared to 54%. This was maintained at 4 years with an average reduction of 106%.

One of the theoretical risks of liposuction is further damage to existing lymphatic vessels. In additional to volumetric reduction, functional improvement was also reported by Qi, et al., when liposuction was combined with physiological treatments. In general, treatment of lymphedema with circumferential liposuction is considered safe, with quick recovery within 48 hours. Complications are few and usually limited to minor wound healing problems and paresthesias. The use of tumescent during liposuction and tourniquets can greatly decrease the blood loss and need for transfusions.

While liposuction can aggressively debulk

Fig. 4

Homan's Procedure. D shows second-stage modified Homan's procedure. Note previous medial incision scar.

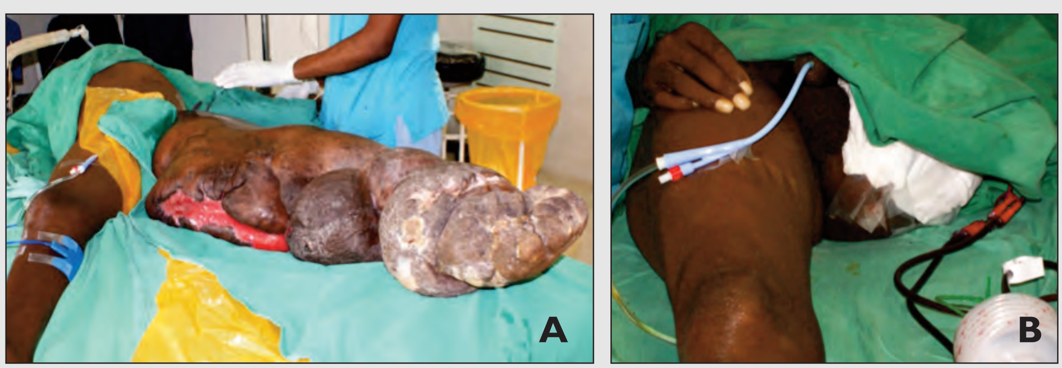


Fig. 5

A) Lymphedema with chronic ulcer that has been cleaned, and is beginning to epithelialize from the edges. The lymphedema extends to involve the pelvic region and lower abdominal wall. B) A hip disarticulation was performed.

hypertrophied adipose tissue in lymphedematous limb, the primary disadvantage of liposuction is the need for continuous use of compression garments post-operatively to maintain the new equilibrium. In the Brorson series, patients that discontinued use of compression garments rapidly re-accumulated fluid.

Liposuction is useful where lymphaticovenous anastomoses are not possible, or following failure after surgery. It may also be used after inadequate resection.

Liposuction is also used as an adjunct to a drainage procedure.

V. Amputation (Fig. 5)

Amputation of a limb for lymphedema is rarely discussed, but may be life-changing, as it may allow the successful return to activities of daily life in an individual who was previously crippled by the weight, infection and foul-smelling discharge of wounds in the lymphedematous limb.

Pre- and Post-Operative Management

Reduction Procedures

- Admit patient into hospital for 7 to 10 days with elevated leg (3 to 4 weeks for Charles Procedure).
- Apply compressive elastic dressing every day (Fig. 6).
- Charles Procedure—patient only walks after graft has taken well and stabilized.
- Well-fitting elastic garment before mobilization.

The authors use graduated compression stockings, as custom-made ones are difficult to come by. These come in standard sizes, small, medium and large. All patients get either small or medium sized stockings. They are taught to wear these 24 hours every day, except when taking a bath or shower, and to buy a new pair of stockings every 3 months.

Lymphovenous Anastomosis

- The patient is admitted for 3 to 5 days.
- Sequential compression pump alternating with massage.
- Antibiotics are administered for the first week following surgery
- Daily massage, sequential elastic stocking worn, bandaging continued for 3 months post-operatively.

Options for surgical treatment of lymphedema can be divided into two categories: excisional and physiologic treatment. Excisional treatment usually involves reductive procedures such as liposuction and excisional debulking with skin grafting (Charles Procedure). Physiological treatment is aimed at restoring or reconstructing the physiologic drainage of the lymph fluid. Several different strategies to achieve this have been proposed, such as buried flaps, direct repair of lymphatics, bypass grafting of lymphatics, lymphaticovenular anastomosis, and vascularized lymph node transfers. The outcomes of such procedures vary. The aim of this chapter is to present the overview of therapies that have been described and tested.

Physiologic Procedures

I. Flap Interposition

The basis behind flap interposition is to place functioning lymphatic vessels contained within a segment of vascularized tissue into an affected area to siphon or bypass excess lymph fluid. In 1935, Gilles and Fraser were the first to treat lower extremity lymphedema by attaching a flap of skin and subcutaneous tissue from the arm to the leg and keeping the arm by the patient's side. In the second stage, the flap was divided, and the flap was transferred to the trunk. The theory was to use the flap from the arm to reestablish lymphatic flow and then to eventually bypass the groin region and restore

Fig. 6

Compression therapy for a second stage modified Homan's procedure. The right leg is at risk, while the left has gigantism besides the lymphedema. Note the second toe is much larger than the first.

lymphatic flow to the trunk.

II. Omental Transposition

Goldsmith, et al., reported the use of greater omentum flaps to treat upper and lower extremity lymphedema. The greater omentum was pedicled off the ipsilateral gastroepiploic vessel and transferred to the extremity via a subcutaneous tunnel. The excess lymph fluid in the extremity was expected to drain into the abdominal lymphatic system through the rich network of lymph vessels in the greater omentum. In the series of 22 patients, 38% of the lower extremity and 56% of upper extremity experienced good results. Despite this moderate improvement, the operation did not gain popularity due to the high incidence of complications, including bowel obstruction, pulmonary embolus, and hernia.

III. Enteromesenteric Flap

Here, a segment of the ileum is denuded of its mucosa and apposed to bisected or deroofed normal lymph nodes. The mesenteric pedicle is of limited length; therefore patients must have a very proximal and segmental obstruction.

Lymphatic Bridging or Bypass Procedures

I. Lymphatic-Lymphatic Bypass

Some investigators have attempted to bypass fibrosed lymphatics by using lymphatic or vein grafts to link distal lymphatics to more proximal lymphatic channels. Baumeister and Suida attempted to bridge areas of stenosed lymphatic vessels with autologous lymphatic grafts in the upper and lower extremities. For the upper extremity, healthy lymphatic vessels from the medial thigh are harvested as a composite graft and buried in a subcutaneous tunnel between the supraclavicular shoulder region and the upper arm. The lymphatic vessels at either end are microscopically identified and anastomosed to the recipient lymphatics. To treat unilateral lower extremity lymphedema, the lymphatics of the graft spans across the affected thigh and the contralateral groin region. Ho and colleagues performed similar procedures, and noted that the microlymphatic bypass must be carried out before the lymphatics were permanently damaged by back pressure and recurrent infection. In addition to the drawback of long incisions at donor and recipient sites, the harvest of lymphatics from a functional extremity may predispose that extremity to lymphedema.

Alternatively, vein grafts have been used to perform distal-to-proximal lymphatic bypass. In this procedure, multiple distal lymphatic channels are sutured into the cut distal end of an autologous vein graft, which provides a conduit to more proximal lymph vessels inserted into the other end of the vein graft.

II. Lymphovenous Bypass (LVB)

The final destination of lymphatic fluid in the lymph vessels returns to the venous system by way of the thoracic ducts. Lymphovenous bypass (LVB) attempts to return the lymphatic fluid to the venous system earlier along the pathway. The use of "supermicrosurgery" to anastomose vessels <0.8mm in diameter has recently gained popularity around the world (35-38).

Results of LVB have been favorable, but outcomes have been difficult to standardize. In 1990 O'Brien, et al., reported long-term follow-up on 90 patients, some of whom received LVB-only and others who had LVB with adjunctive reductive procedures. Subjective measures of improvement have ranged from 95% to 50% of patients. Variable volumetric improvements have ranged from 75% decrease in 73% of patients to no change in 50% of patients, with the average reduction in volume of 55%. In the few studies that included incidence of cellulitis, most demonstrated a significant decrease after LVB.

Recent technological advancements with fluorescence lymphangiography have provided surgeons with the much better ability to perform real-time identification and evaluation of existing lymphatics. Injection of indocyanine green (ICG) dye into the dermis, and evaluation with near-infrared laser angiography, immediately displays the severity of the process and location of vessels, if present. Patients with early stage lymphedema have easily identifiable discrete lymphatic channels compared to patients with late stage lymphedema, which appears as a blush of dermal backflow. This improves operative efficiency, and allows for limited dissection and morbidity to the patient, as well as quicker recovery. The surgery is then performed using short horizontal incisions at the marked locations along the length of the extremity. Dissection is performed at the superficial subcutaneous plane to locate a venule and lymphatic channel, confirmed with isosulfan blue or ICG lymphangiography, and the LVB is performed.

Most reported series of lymphatic bypass surgery have reported low complication rates, primarily consisting of minor wound healing problems, cellulitis, and lymphatic fistulas. Most cases of wound healing problems healed spontaneously, and cases of cellulitis were treated with a short course of antibiotics. In general, LVB may be best indicated in patients with mild upper extremity lymphedema who still have moderate amount of functioning lymphatic vessels and minimal irreversible tissue fibrosis.

III. Vascularized Lymph Node Transfers (VLNT)

Free tissue transfer of lymph nodes has been the most recent development in the treatment of lymphedema. It is unclear whether the orthotopically placed lymph nodes act as a sponge to adsorb lymphatic fluid and direct it into the vascular network, or if the transferred nodes induce lymphangiogenesis. Although some researchers have experimented in animal models with grafting avascular whole nodes or cut up lymph node, their viability is highly variable. In general, it has been shown that preserving the vascular supply during transfer results in greater improvements, both in the degree of edema and lymphatic function.

The harvest of vascularized lymph nodes has been described using groin, thoracic, submental, and supraclavicular nodes, with the groin being the most popular. The lymph nodes in the groin have been described as being spread over five regions—central (saphenofemoral junction), superomedial, superolateral, and inferomedial, and inferolateral. Since nodes that drain the lower limb are located medially and centrally, it is more advisable to harvest the laterally based nodes that drain the suprailiac region. In attempts to avoid causing lymphatic impairment during nodal harvest, Cheng, et al., described the use of submental lymph nodes, based off the submental branch of the facial artery, taking care to avoid injury to the marginal mandibular branch. In contrast, Chang, et al., advocate for the use of supraclavicular nodes located at the midpoint between the acromial-clavicular joint and the sternal notch. At this point, several palpable lymph nodes can be harvested based off the transverse cervical artery, with the external jugular (EJ) providing the primary venous drainage. Although the vessels may be small and elevation is freestyle, the anatomy is fairly consistent. Finally, reverse lymphatic mapping of the thoracic region has been used to avoid important axillary nodes and identify the more inferior lymph nodes supplied by the lateral thoracic artery. Each set of vascularized lymph nodes has their advantages and disadvantages involving donor site morbidity, cosmesis, and pedicle size/length.

Just like the donor sites, the recipient sites also have great variability. In treating upper extremity lymphedema, recipient sites have included the wrist, elbow, and axillary regions. As most upper extremity lymphedema results from prior surgery with or without radiation to the axilla, it is important to perform wide excision of scar that may be enveloping nerves, muscles, and recipient vessels (e.g. thoracodorsal), both to ensure a healthy bed for lymphangiogensis and to remove scar that would prevent bridging of lymphatics in the recipient bed. Becker, et al., reported treating upper extremity lymphedema by transferring inguinal lymph nodes to the axillary region. The anterior recurrent ulnar artery and basilica vein, or the radial artery and its vena comitantes, have been used by Cheng and Gharb as recipient vessels at elbow. In contrast, the radial artery at the level of the wrist has been used by Lin, et al., as recipient vessels for groin nodes based off the superficial circumflex iliac vessels.

For the lower extremity, the ankle and groin are the most common recipient sites. Similar to the axilla, the groin may often require extensive lysis or excision of scar from previous surgery and radiotherapy. The superficial circumflex iliac vessels are identified superior to the inguinal ligament and used for anastomosis. The use of the ankle for the recipient site in the lower extremity follows the logic that the gravitational forces keeping the lymphatic fluid from rising up to the groin are difficult to overcome. Instead, placement of the vascularized lymph nodes at the level of the ankle would take advantage of these forces to facilitate drainage into the flap at the level of the ankle. The anterior tibialis or dorsalis pedis are used for recipient vessels, with careful attention to prevent excessive tension during flap inset, sometimes requiring skin grafting.

Aside from VLNT, women who are seeking simultaneous breast reconstruction and treatment of lymphedema may be excellent candidates for breast reconstruction using lower abdominal flaps harvested with inguinal lymph nodes. The thoracodorsal vessels are usually selected as recipient vessels, allowing the positioning of the lymphatic tissue into the axillary space.

While the literature for vascularized lymph nodes is still in its early stages, results have been favorable, with average volume reduction of 47%. The indications for VLNT are still unclear, but some have advocated criteria based on total occlusion on lymphoscintigraphy (international society of lymphedema) stage 2 with repeated episodes of cellulitis, no acute cellulitis, and more than 12-months of follow-up. While VLNT has been demonstrated to be safe, the complications include loss of flap, donor site lymphedema, seroma, lymphocele, infection, and wound healing complications. Vascularized lymph node transfer offers an exciting new horizon for physiological treatment of more advanced stage lymphedema. Furthermore, in many cases, combining both VLNT and LVA may optimize the chances for the improvement of lymphedema, as these two approaches work via different mechanisms.

Podoconiosis—Endemic Non-Filarial Elephantiasis or Mossy Foot

Podoconiosis is a geochemical disease in individuals exposed to red-clay soil derived from alkalic volcanic rock; it is a chronic, debilitating disorder that has been reported in tropical Africa, Central America, and north India.

It has been best characterized in Ethiopia, where the prevalence is 5% in the highlands. Podoconiosis occurs in Highlands, with high rainfall, where predominantly poor subsistence farmers live; most walk around and work barefooted. In Kenya, podoconiosis is referred to as the 'Nyeri leg', a reference to a high-altitude agricultural region where podoconiosis was described. The number of cases has dropped significantly with improved education and income.

Most patients develop signs and symptoms between ages 10 and 30 years.

Silica particles are thought to be absorbed through the foot. They induce an inflammatory reaction in lymphatic vessels, leading to fibrosis and obstruction that clinically presents as leg edema and ultimately lymphedema that cannot be differentiated from filarial lymphedema (see Fig. 7).

One can read more about the prevention and treatment of Mossy foot at **www.mossyfoot.com**. The good news is that this condition is preventable and treatable. Prevention includes early education of children and parents in disease-prone areas. This includes wearing socks and shoes before the disease develops and once there are any early signs of disease.

Fig. 7

Podoconiosis

Further treatment is quite simple and inexpensive and includes:

- Foot hygiene: regular washing the legs and feet with soap, water, and antiseptics.
- Regularly moisturizing the skin with a simple skin cream, and treating between the toes with anti-fungal ointment.
- Using elastic bandages (for more swollen legs).
- Elevating feet at night.
- Wearing socks and shoes during the day.

When treated early, the feet will return to a normal size. The aim of the Mossy Foot Project is to control the disease so the patients can wear shoes, work and be accepted in their society.

Genital Lymphedema

Lymphedema of the penoscrotum produces an ugly deformity and considerable physical disability, resulting from progressive swelling of the penis and/or scrotum due to impaired lymphatic drainage. It causes problems during walking, voiding, and sexual intercourse, and may thus result in severe mental anguish and social problems (Figs. 8-10).

Whereas there is no reliable or consistent treatment for lower extremity lymphedema, there are satisfactory surgical solutions for genital lymphedema. The primary treatment of genital lymphedema is surgical excision, with no place for pressure therapy or other conservative measures.

Surgical Technique

- Excision all the involved tissue (skin and subcutaneous tissue—this must be done to

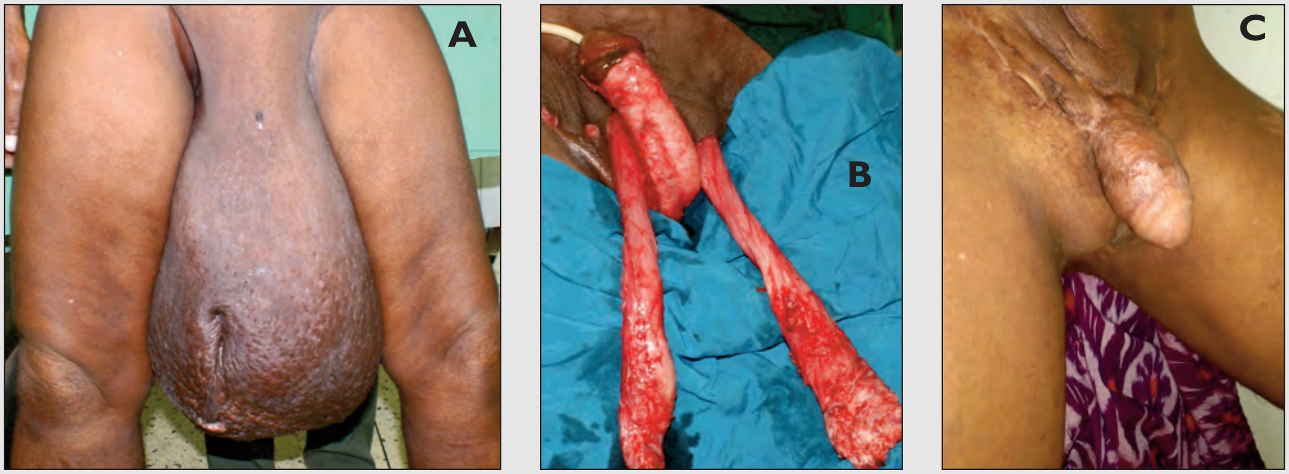


Fig. 8

A) Giant penoscrotal lymphedema in a 60 year-old gentleman. B) Excision of skin and subcutaneous tissue of all the involved areas, leaving the penile shaft, and testis exposed. Bilateral medial thigh fasciocutaneous flaps were raised and used to reconstruct a neoscrotum. C) Results at six months post-op. The patient was happy with the results and function, and did not want any further surgery.

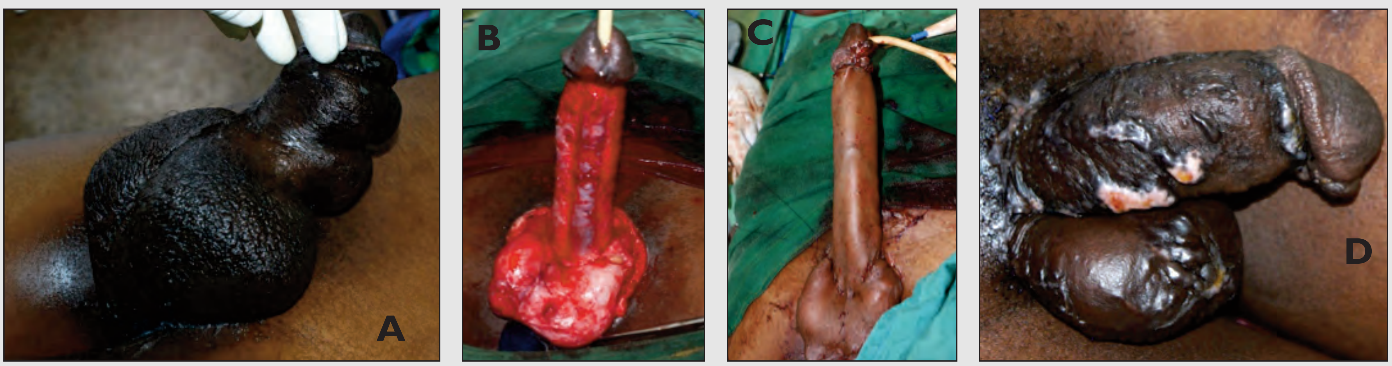


Fig. 9

A) Penoscrotal lymphedema in a young man. B) Excision of all involved tissue, leaving testicles and spermatic cord exposed. C) Split thickness sheet grafts to penis and scrotum. D) One year post-operatively—the patient was satisfied with the outcome.

prevent recurrence), with preservation of the penis, cord structures and testes (Figs. 8b and 9b). Labial tissue must be excised in the same way.

- Often the testicles are involved with massive lymphedema, and there will not be enough scrotal skin left behind to cover both of the large testicles. In such cases, one testicle should be saved.

- Reconstruction of the resulting defect is done with scrotal flaps, fasciocutaneous thigh flaps (Figs. 8c and 10c), or skin grafts (Fig. 9c). In labial reconstruction, some labial skin flaps must be left behind, as resulting cosmesis would be extremely poor with skin grafts. Labial reconstruction with regional flaps gives a poorer cosmetic appearance, but has the same risk of recurrence as native affected labial flaps.

Use of unaffected posterior scrotal flaps when available for scrotal reconstruction is preferred so as to preserve the testicular temperature controlling function of the cremaster muscle and continued spermatogenesis. Lymphedematous tissue should not be retained, as recurrence will occur.

Skin grafts and fasciocutaneous flaps lack this function, although they can provide excellent cosmetic results (Figs. 8, 9 and 10). The skin grafts

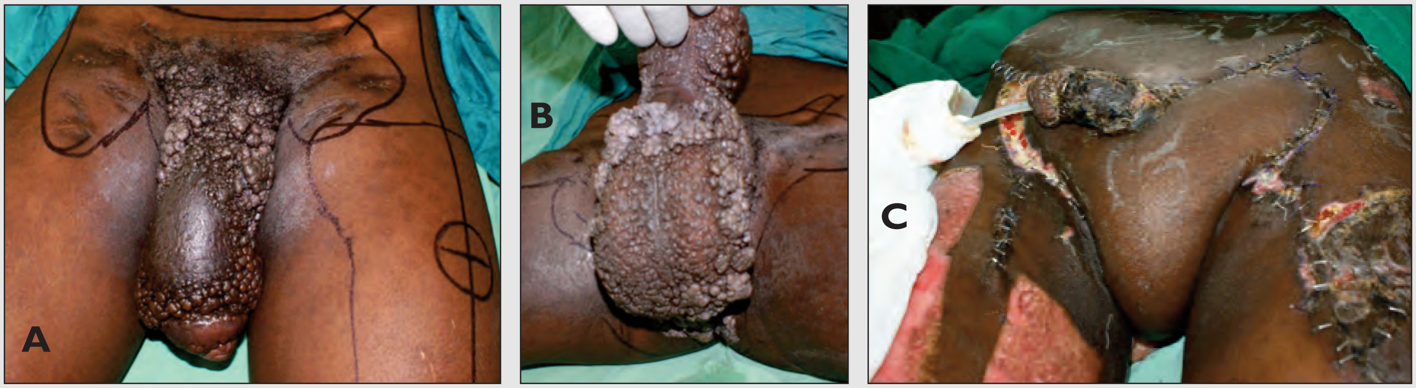


Fig. 10

Multicystic penoscrotal lymphedema—note that it extends into the perineum to involve the perianal region. An anterolateral thigh flap was used to cover the defect while sheet skin grafts were used to cover the penile shaft.

should ideally be sheet grafts, those that are not meshed, as this gives the best cosmetic appearance (Fig. 9c). Penile erections prevent contractures, and normal function should be achieved. Scrotal skin grafts may be sheet or meshed grafts (Figs. 8c and d). The traction by the weight of the testes prevents the development of scrotal contracture.

Summary

The surgical treatment of lymphedema has been attempted since the early 20th century. This has obviously been a difficult problem to solve for surgeons, and an even more difficult problem for the patients who are afflicted. Recent technological advances have enabled surgeons to refine previous techniques and develop new ones. Despite variability in protocols and reported outcomes, LVB and vascularized lymph node transfers offer promising solutions for the future. In general, early intervention, before the development of lymphatic fibrosis and adipose deposition, results in improved final outcomes. The consensus in grading systems, reporting of outcomes, and standardized protocol will help to facilitate the next phase of evolution in the treatment of lymphedema.

Important Notes

- Patients with repeated cellulitis or lymphangitis must be treated and followed up with monthly Benzathine penicillin injections. This protects from infections and a worsening of the lymphedema.

- Patient compliance with conservative measures is important prior to initiating surgical therapy—all surgical excision procedures require meticulous care of the limbs after surgery. If the patient is unable to comply with instructions before surgery, they will not comply after surgery. The pre-operative admission (for limb elevation and compression) serves as an excellent opportunity to assess this compliance.

- Genital lymphedema treatment is surgical, and should be offered; if properly executed, may be curative.

Further Reading

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Chapter 42

Principles of Hand Therapy

Jennifer Durham

The following are general hand therapy guidelines for tendon and fracture rehabilitation.

Post-Op for Flexor Tendons, Zones I-III

In the OR, the patient is placed in a dorsal slab cast that allows 45 degrees wrist extension with MPJs flexed to 30 degrees, IPJs at 0.

Day 3-4:

- Passive Range of Motion (PROM) is begun to the fingers at day 3-4 post-op.

- **Ideally, PROM** is done hourly by the patient during waking hours while in the splint. **Practically, one should attempt to do these passive exercises twice daily with ten repetitions for each finger** or whatever is required to achieve a mobile finger prior to active motion. The plaster cast is changed at five days if necessary for dressing changes.

- Active Range of Motion (AROM) in the DIPJs is allowed in the cast (gentle wiggles).

Day 4:

- Once the patient has full PROM, AROM exercises can be initiated in the cast. Under the supervision of the surgeon or therapist, the patient is shown how to actively initiate active flexion of the fingers by flexing the DIPJs. The uninvolved hand is placed across the mid-palm so that the injured fingers can just touch the other hand (see Figs. 3-6). The patient is encouraged to slide or **scratch** the fingertips down to the index finger and then down to the interspace between the index and long fingers, using the DIP and PIP

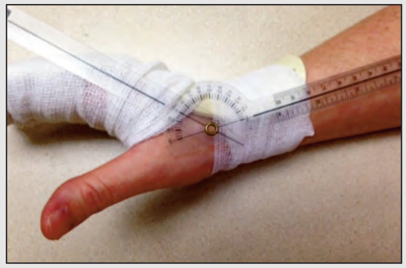

Fig. 1

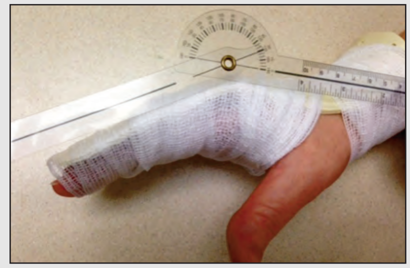

Fig. 2

Position of wrist joint and MCP joints in the post-op splint after flexor tendon repair in Zones I and II.

Fig. 3

Fig. 4

3) Starting at 4-5 days postop (when there is full PROM): actively flex finger(s) 10 reps, twice daily down to index finger and then slide (flex) down to interspace (crease) between fingers. 4) One week later, flex down to long finger and then slide (flex) down to crease between long and ring fingers.

Fig. 5

Fig. 6

5) At the third week, flex down to ring finger and then slide (flex) down to the crease. 6) At the fourth-week flex down to small finger and then slide (flex) down to one's palm.

joints for flexion rather than just the PIP and MCP joints. The initial goal is NOT to make a complete fist, but to learn to initiate movement in the fingers beginning at the tips (DIPs).

- Each week the patient is directed to go down or scratch down one more finger until by week four (week five post-op) the patient is flexing the fingers into nearly full flexion down to the small finger and palm.

Note:
1 Ideally four exercise sessions each day with ten repetitions and PROM must be done before AROM.
2 Early full active range of motion (flexion) is not necessary or safe.
3 The patient must understand that they cannot resume normal activities with the hand during the first 6 weeks to prevent rupture.
4 A night volar extension splint may be added to the splint/cast to obtain full finger extension at the IP joints.

If the surgeon and therapist are satisfied with the patient's progress, and if the patient lives far away, the patient can be seen back at four-five weeks post-op. Otherwise, if there are any concerns about the patient's understanding of the required therapy or concerns about the wound, the patient should be seen at least weekly on an out-patient basis.

2 Weeks Post-Op:
Sutures are removed. Scar massage may begin 2-3 days after suture removal. Do the scar massage 1-2 times per day. Continue with the above outlined exercises.

4 Weeks Post-Op:
At four weeks, the patient can come out of the dorsal block splint/cast **under the guidance of the therapist** and begin coordinated wrist/hand movements. Begin flexing the wrist while actively extending the fingers. Allow the fingers to bend as the wrist extends. Continue to wear the splint/cast between exercise sessions. These exercises are to be done only under the supervision of the therapist or MD. Functional exercises might include picking up cotton balls using wrist extension/flexion to help encourage finger movement. There is to be **no resistance** at this point (see Fig. 7).

6 Weeks Post-Op:

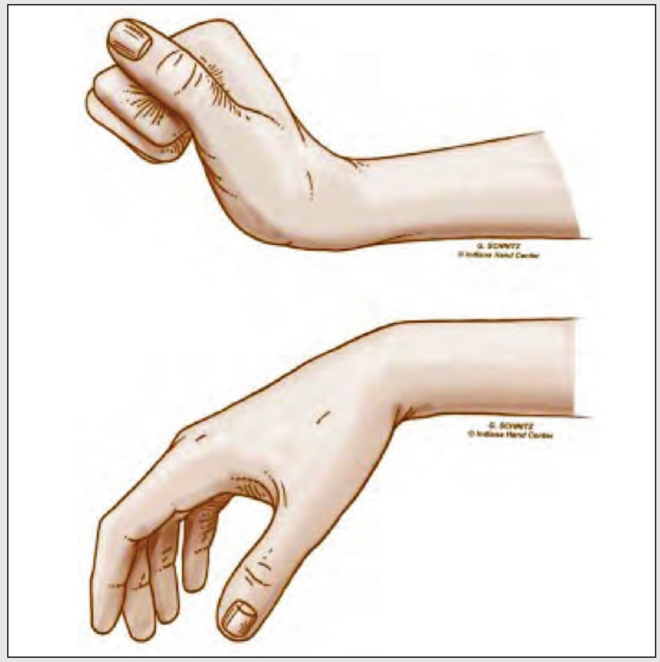

Fig. 7

From *Rehabilitation of the Hand and Upper Extremity*, 6th edition. (Used by permission from Elsevier)

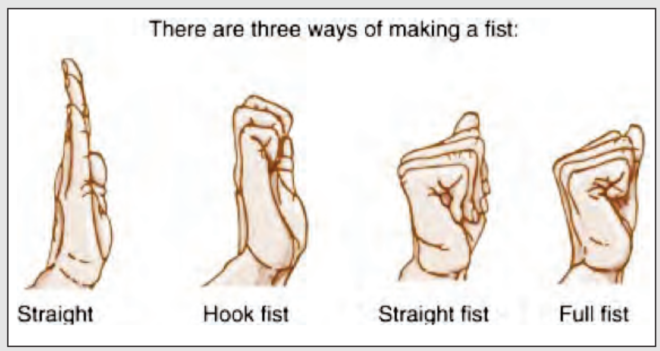

Fig. 8

- Discontinue the dorsal blocking splint.
- Begin light activities of daily living (ADLs), while continuing the exercises above. Encourage movements that include combined wrist/finger movements. Especially encourage intrinsic plus positioning (MPJs 90 degrees, IPJs 0 degrees) and hook grasp (MPJs neutral, IPJs flexed; see Fig. 8). Having the patient carry around for much of the day a 1-pound shopping bag using a hook grasp is good to help reinforce how to use the fingertips with active motion.
- Resistance is still kept at a minimum. **Remember**, tendons do not hurt when they rupture; the finger(s) just stop working.

If IPJ contractures are present, static gutter splints can be molded over the volar surface of the finger(s) at the limit of the active digital extension. These can be made straighter as the contracture lessens to continue to hold the finger at maximum finger extension.

8-12 Weeks Post-Op:

- Light resistive exercises can be included, and activities of daily living increased to include some light resisted lifting. More resistance can be added to the program at 10 weeks. Regular duties can be resumed at 12 weeks.

- Splinting and therapy may be individualized according to age, intelligence, compliance, location of patient's home, and opportunity for follow-up. When the patient will not be seen for weeks, a realistic approach is necessary.

- Children should be splinted or casted for four weeks without active or passive range of motion. Children will usually recover full range of motion.

- With flexor tendon injuries in the hand and fingers, care must be taken to clearly identify nerves and vessels and repair each one. Whether or not an individual artery is repaired is determined by an Allen test and the presence of a patent contralateral artery. Most general surgeons will not have loupes or the experience to repair digital vessels. Without loupes, it is difficult to see small vessels and nerves for repair.

(**Editor's note**: This is a radical approach for tendon therapy, and ideally should only be done under the supervision of a therapist trained in hand therapy or the surgeon. Unfortunately, most flexor tendon injuries in Zone 2 will lead to adhesions, contractures, and little active motion. This is the reason the author suggested repairing only one flexor tendon if both are injured. Ruptures may occur if the patient is not supervised.)

Fig. 9

Static Gutter Splint
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Flexor Tendon Repairs, Zones IV-V

Post-Op:
The hand is placed in a Dorsal Blocking Splint (DBS) with the wrist flexed 30 degrees, MPJs flexed 30 degrees, IPJs 0. In the restraints of the splint, passive composite flexion/extension is done to the digits. 25 repetitions are done 3-4 times each day.

2 Weeks Post-Op:
48 hours after suture removal, begin with scar massage. Continue with composite Passive ROM exercises within the DBS.

3 Weeks Post-Op:
Active ROM exercises are started within the restraints of the splint (no resistive exercises). Exercises might include grasping/releasing different shaped objects without lifting them.

4 Weeks Post-Op:
Gentle blocking exercises may be started to the PIP and DIP joints to encourage more movement at these joints. (Blocking exercises: block PIPJ over the proximal phalanx and encourage flexion of middle phalanx; block DIPJ over middle phalanx and encourage flexion of distal phalanx.)

4-5 Weeks Post-Op:
The dorsal block splint may be removed for exercises only. Unrestricted AROM exercises are performed to the wrist and digits. Pay particular attention to motion at the PIP and DIP joints, blocking to maximize motion.

6 Weeks Post-Op:
Discontinue the DBS. If it is a thermoplastic material, the splint can be remolded to make a full extension resting splint to get full composite extension of the wrist and digits if the hand shows shortening in the long finger flexors or wrist.

Unrestricted active and PROM exercises are done. Begin passive extension of the wrist and digits. Emphasize tendon gliding (See Fig. 8). Begin strengthening but avoid any heavy lifting or tight gripping.

10-12 Weeks Post-Op:
The patient may return to unrestricted use of the hand in all activities.

Extensor Tendon Therapy

As with flexor tendons, edema must be managed in order to prevent too much resistance on the tendons. Elevation, movement of the uninvolved joints, and compressive wrap will help to control this. The digits can be wrapped individually as long as any extra volume of fluids is present. Edema could be present for as much as 8-12 weeks post-operatively. Patient education is critical so that they can be compliant with the splint schedule and therapy program. Give complete explanations of anatomy, wound healing, and precautions.

The strength of the repair is dependent on the number of sutures, size of the tendon, type of repair, and suture material used. It is very helpful to know all of this before beginning any type of therapy.

Here is a quick overview of what to do for extensor tendons by level:

Zone I (Mallet Deformity)
Conservative Management
- Splint the DIPJ at -/+15 degrees for 6 weeks continuously.
- Begin AROM at 6 weeks, 4 times a day for 5 minutes each session.
- If an extension lag develops, decrease number of exercise sessions. At 8 weeks wear the splint only at night.
- At 9 weeks discontinue splint completely.

Zones II, III, IV (Central Slip, Lateral Bands, Triangular Ligament)
- Post-operatively, put the finger in a gutter splint to hold the PIP and DIP joints at 0 degrees extension. Wear the splint at all times.
- At 4 weeks, begin AROM to the finger 6-8 times per day Wear the gutter splint at all times, except when exercising.
- At 6 weeks, begin PROM if the extension lag is less than 10 degrees. Gradually begin to decrease wearing time for the splint.
- At 8 weeks, begin gentle strengthening (gripping, pinching).
- At 9 weeks, discontinue wearing the splint.
- If the injury is limited to the central slip, splinting can be done to only the PIPJ, leaving the DIPJ free to move.

Fig. 10

Mallet Splint
From *Rehabilitation of the Hand and Upper Extremity*, 6th edition.
(Used by permission from Elsevier)

Zones V & VI
- Immobilize the wrist in 20 degrees extension, and the MPJs at 0 degrees extension. The PIP and DIP joints are left free but splinted in extension at night (See Figs. 11 and 12).
- At 4 weeks post-op begin active exercises to the wrist and fingers.
- Continue wearing the splint between exercise sessions.
- At 6 weeks, begin PROM to the wrist and digits.
- At 7 weeks, begin weaning out of the splint. Begin strengthening.

Fig. 11

Fig. 12

11) Daytime. 12) Night.
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Zones VII & VIII

- Immobilize the wrist in 30 degrees extension and the MPJs at 0 degrees.
- At 4 weeks, post op begin AROM to the wrist and digits for brief sessions several times a day.
- At 6 weeks, begin PROM to the wrist and digits.
- At 7 weeks, begin weaning out of the splint.
- Begin progressive strengthening.

Guidelines for Fracture Therapy

Working with patients who live a great distance away, and who have limited understanding of therapy, is a challenge. Therapy goals must be aimed at setting realistic goals that are meaningful for the patient in their daily life. If the patient can be made to understand the big picture of what is reasonable to accomplish in therapy and the steps necessary to get there, outcomes will be much more favorable.

Working with fractures, the sooner the injured area can be moved, the better the movement will ultimately be. However, until the fracture is stable, therapy will be forced to be limited to areas proximal and/or distal to the injury. The fracture itself needs to be immobilized for 3-4 weeks until enough healing has occurred to allow it to withstand the stressors of movement. Ideally, therapy should begin within a few days of the injury or surgery. Motion is limited or controlled and protected, with functional reactivation as the goal. The degree of protection is progressively decreased, and the types of physiologic loads and functional outcomes are increased over the next few weeks until full functional recovery has occurred—usually about 3 months after injury/surgery. Each fracture is unique. The rehabilitation plan must be designed for each patient's needs, priorities, and daily functional demands.

The more tissues that are involved surrounding the fracture, the more complex the rehabilitation will be, and the greater the need to start therapy early to try to prevent secondary complications associated with immobilization. Even with simple closed hand fractures, it is important to remember that all hand fractures are multi-tissue traumatic injuries, and include soft tissue trauma, even if not obvious from examination of the extremity.

Further Pathophysiology

Phase 1: Fragile fractures—3-5 days after injury/ surgery. Rest, Ice, Compression, and Elevation (RICE). Instruct the patient to elevate and rest the hand. Apply a compressive dressing to minimize edema.

Phase 2: Limited Stability—3 days to 3 weeks after injury/ surgery. Introduce light functional use while wearing a protective support (this type of support will usually mean immobilizing the joint proximal and distal to the fracture). Light functional tasks should be pain-free, such as assisting with dressing, grasping/releasing different-sized light weight objects, etc.

Phase 3: Clinical Stability—3-4 weeks after injury/ surgery. Introduce unrestricted, full AROM. No passive motion and no resistive exercises. The brace can be modified to include only circumferential support of the fracture during functional activities. Activities must be pain-free with the fracture brace. It may be necessary to gradually reduce the fracture brace rather than cut it down all at once.

Phase 4: 6 weeks after injury/surgery. Begin light strengthening exercises and moderate functional activities outside the functional brace. Activities may include active and passive range of motion. The fracture brace should be used for heavier strengthening or functional activities.

Phase 5: 9 weeks after injury/surgery. The fracture should be strong enough to withstand moderate levels of occupational and recreational activities. Heavier therapeutic exercises without any protective support are allowed. A support is indicated, however, for any higher-risk, high-impact activities until at least 3 months after the fracture.

Phase 6: 12 weeks after injury/surgery. Unless there are complicating factors, normal activities are resumed with no need for a functional support.

Within each of these phases, progression must be done pain-free. Range of motion starts with a limited arc of motion and increases as the patient tolerates. Passive ROM and isolated joint motion is added only as the patient is able tolerate it.

How and when to progress motion following a hand fracture depends on the stability of the fracture and how well the patient is able to progress with their motion. There are no specific timelines or rules for progression, other than achieving pain-free motion without compromising the fracture. Your decision to progress the patient functionally will need to be determined based on each case. These guidelines will help you make your decision, with the help of the surgeon, as to how fast to progress the patient.

For Extra-Articular Hand Fractures, typically the joint proximal and distal to the fracture should be included in the splint/cast.

Abbreviations

P1: Proximal phalanx
P2: Middle phalanx
P3: Distal phalanx
MPJ: Metacarpal phalangeal joint
PIPJ: Proximal interphalangeal joint
DIPJ: Distal interphalangeal joint

For intra-articular fractures, the chart in Table 1 is a good guideline to follow.

(**Editor's note**: The most important part of this chapter is the Flexor Tendon Protocol. Stiff hands are often the final result of flexor tendon injuries in Africa and around the world. If flexor tendon surgery is carried out as described in Chapter 33 and the protocol above is closely followed, then one should get good results. It is recognized that patients who do not understand the protocol and those that are non-compliant may rupture their repair. It is important that these patients are identified before allowing early active flexion. The editor realizes this could be a majority of patients in some parts of the world, and your final results will be less than ideal.)

Table 1

Joint Involved	Position (Splint)	Immobilization Period	Pictorial Representation
MP Joint	Hand-based with MP's flexed approximately 70°, IPJs free unless the fracture involves the P1. Then include P1 & P2	4 Weeks	
PIPJs (non-displaced stable)	Finger-based dorsal splint blocking last 30 degrees of PIPJ extension. Allow active flexion by removing straps.	0 - 4 Weeks	
PIPJs (Unstable with ORIF)	Hand-based with MPJs 70°, IPJs extended 0-3/4 weeks.	0 - 3/4 Weeks	
Dorsal lip fracture of P2 involving the attachment of the central slip	Finger gutter with the PIPJ in extension full time. Watch for extension lag when weaning.	4-6 Weeks	
Combined fracture/dislocation	Finger or hand-based protector.	4 Weeks	
DIP (Mallet)	DIP in full extension. PIPJ free.	6-8 weeks	

Splinting for Intra-Articular Hand Fractures

Chapter 43

Positioning and Range of Motion for Prevention of Contractures

Gay Lynn McCrady

Introduction

Prevention of burn contractures is one of the most challenging aspects of burn management, as burn contractures are the main source of disability in burn patients. Proper positioning of the patient, range of motion exercises, and splinting are vital in bringing about the best functional outcomes in the rehabilitation of the patient. Proper positioning and range of motion exercises should be initiated from the beginning of recovery. Initial edema may make movement difficult, but the patient should be encouraged to do daily exercises.

Normally burn contractures only occur in patients with full-thickness burns (third degree burns) but they can occur in superficial burns that get infected, convert to full-thickness and take longer to heal.

Table 1

Area Affected	Position to Prevent Contracture
Anterior Neck	10-15 degrees extension
Anterior Axilla	90 degrees shoulder abduction
Posterior Axilla	Shoulder flexion
Elbow/Forearm	Extension/forearm neutral
Wrists	15-20 degrees extension
MCPJs	70-90 degrees flexion
IPJs	Full extension
Thumb	Palmar abducted and opposed
Palm	All joints full extension/thumb radially abducted
Hips	Extension, 10 degrees abduction, neutral rotation
Knees	Extension
Ankles	90 degrees dorsiflexion

Proper positioning of affected joints for burn patients.

Positioning

Positioning is very important in the prevention of contractures and deformities. For burn patients, the “position of comfort” is the position that most often leads to contractures. Scar contractures tend to occur more in areas where skin is loose or more pliable. Because scars continue to mature over a long period, it is critical to continue the positioning long enough to prevent the contractures. Scars in adults do not reach maturation for 6-24 months and in children, the time period is 12-24 months.

Minimal contractures in children will become more severe as the patient grows. The scars do not grow as the child grows. Therefore, in children, it is important to splint burns over the joints until the burns are well healed and until there is no evidence of a contracture.

In the African context, it is the family members who are available and provide most of the daily care of the patient. It is most beneficial to explain to the family the proper positioning for the patient and then encourage them to help follow through during the day. There are basic items available to help position the patient that the family can use. They can use a rolled up towel to place behind the neck to keep the neck in extension if the burn is over the anterior portion of the neck. They can put pillows at the end of the bed between the patient’s feet and the footboard to help keep the ankles at 90 degrees. They can use pillows or a rolled up blanket to put in between the arm and the body to help keep the shoulder in abduction.

Splinting

Splinting is very important in the prevention of contractures and ensuring the best possible functional gains for the burn patient. **Contractures are much easier to prevent than to fix**. In the African context, where surgical treatment is limited, range of motion and splinting can make a big difference to the patient's outcome. Splinting is usually initiated when the development of skin tightness is noted over a joint, causing limitation of movement. In full-thickness burns of the upper extremities, it is recommended that the splinting and elevation is begun immediately after the burn and before skin grafting. With early edema and inadequate burn therapy, contractures begin early. If skin grafting of a hand is delayed three weeks or more, there will be early contractures. Several illustrations in this chapter show contractures secondary to deep burns and lack of splinting.

Certain joints are much more susceptible to contractures and would benefit from splinting, along with range of motion exercises.

Axilla

The axilla (armpit) is the most susceptible joint for a contracture and is also the most challenging for splinting. "Airplane splints", which can be made out of various materials, are the most beneficial. The airplane splint keeps the shoulder abducted at 90 degrees and the forearm positioned in neutral. The easiest and most readily available material to make the splint in Africa is foam rubber (e.g. mattress foam). It is cut in a triangle shape with the point of the triangle in the armpit and one side extending the length of the arm down to the wrist and the other side extending down the side of the body. The arm is strapped to the piece of foam. The "airplane" splint can be made from plaster or casting material that is available in Africa but the fabrication of the splint is a bit challenging, and the casting material is heavy. The splint is constructed by making a plaster slab that starts at the middle of the trunk, goes up and curves under the armpit and runs down to the wrist. After the plaster slab has dried, it can be attached to the body and arm with an ace wrap or crepe bandage. It is good to periodically reposition the arm in the

Fig. 1

"Airplane" splint for axilla.

Fig. 1

Fig. 2

These contractures may have been pre vented by aggressive therapy, splinting, and exercises. Most come into the medical centers with fixed contractures.

Fig. 4

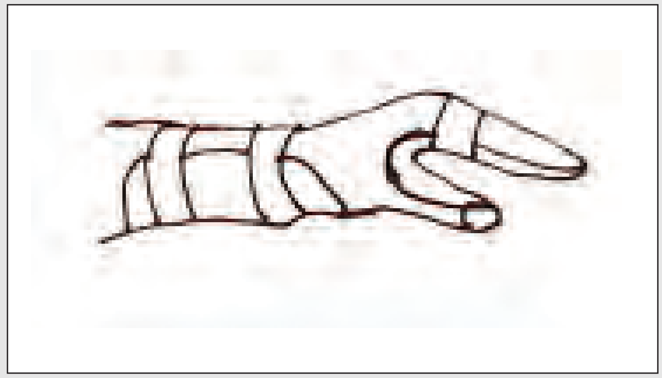

Fig. 5

Wrist and hand positioning.

Fig. 6

Fig. 7

These patients would have done well with an elbow splint as described.

splint to avoid compression of the brachial plexus that could lead to neuropathy. The foam splint is excellent, lightweight, and useful for when the patient is in bed (as seen in Fig. 1).

Wrist and Hand

The wrist, MCP and PIP joints of the hand are also very susceptible to contractures. The wrist tends to get fixed in flexion, the MCP joints fixed in hyperextension, and PIP joints fixed in flexion. Splinting of the wrist and hand in a static positioning splint is very effective in preventing these contractures, as seen in Fig. 4. The static positioning splint can be made from plaster or casting material that fits on the volar aspect of the hand as in Fig. 5. It should position the wrist in 15 degrees extension, the MCP joints in 70-90 degrees flexion and the thumb palmar abducted and opposed. This splint can be placed over the dressing and secured with a crepe bandage. The splint should be removed two times a day to do range of motion exercises.

Elbow

Many patients develop elbow flexion contractures, as the position of comfort when lying down and walking is with the elbow flexed. A simple plaster

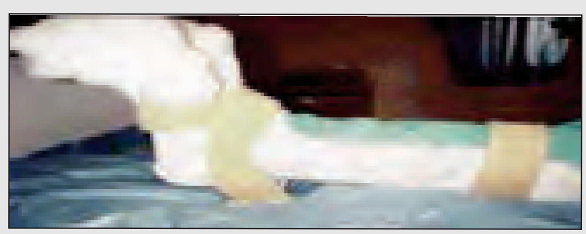

Fig. 8

Plaster and crepe ankle splint.

Fig. 9

Range of motion exercises.

Fig. 10 **Fig. 11**

These contractures could have been prevented by measures listed above: splinting the wrist in slight extension, MPJ in flexion and IPJ in extension.

slab placed over the elbow joint and secured with a crepe bandage is helpful in preventing a contracture. Sometimes even a flat piece of wood that is padded can be placed over the elbow joint and then wrapped on with a crepe bandage.

Ankle
The ankle can have contractures limiting movement in both directions. Burns and contractures on the dorsum are more common. The best position to splint the ankle is 90 degrees, to prevent shortening of the Achilles' tendon. The splint should be removed, and dorsiflexion and plantar flexion exercises should be done to make sure a contracture at the ankle does not form. A static positioning splint can be made from plaster casting material and wrapped on the foot and leg with a crepe bandage (See Fig. 8).

Knee
Skin tightening can also happen on the back of the knees and the hips that causes the knees and hips to remain more in a flexed position. If needed, a plaster back slab can be made to fit over the back of the knees attached with a crepe bandage. This helps keep the knees in extension. Lying in a prone position for short periods throughout the day can help stretch the hips in extension and prevent a hip flexor contracture.

Early weight bearing on the lower limbs is most beneficial in preventing contractures of the hips, knees, and ankles. Have the patient do standing activities while holding onto the back of a chair or being supported by a person on each side. This helps to stretch the hips and knees into extension and the ankles to 90 degrees. If the patient is bed-ridden, splinting and daily range of motion exercises are the best for prevention of contractures.

Fig. 12

Prevented by proper splinting for palmar burns as described in Table 1.

Range of Motion Exercises
Range of motion exercises are imperative and should be part of the patient's care from the beginning. Range of motion is needed to prevent joint stiffness and contractures over the affected joints. Active motion, along with elevation can also help with edema in the early phase of recovery. **The exercises can be very painful for the patient at the beginning. Therefore, the patient must be continually encouraged by the staff and the family member who is assisting the patient**. Also, mild analgesics are

Fig. 13

Fig. 14

These neck contractures could have been prevented by early splinting with neck collars, lying with towel or pillow under neck to extend it, and early skin grafting. Post-op care also requires long-term splinting when grafts are used.

Fig. 15

Fig. 16

Axillary contractures are difficult to splint well, as discussed. If the guidelines discussed in this chapter are followed, these contractures can be minimized. Early hospitalization and grafting are important in prevention. Often these patients present late.

Fig. 17

Fig. 18

These knee contractures could have been prevented by a posterior splint, early range of motion exercising, and grafting. These burns were deep full-thickness burns and the patients presented late to the hospital. There are many causes for these contractures, including lack of appreciation of the depth, long distance to hospital, inadequate care in local health center, lack of finances, etc.

helpful initially to help the patient move and ambulate. As the patient continues to exercise and the skin stretches, the pain will slowly reduce, but without movement, pain and limited mobility will persist and lead to a contracture.

In the beginning, movement is very painful, and range of motion is limited due to bulky dressings. During this stage, the optimal time to do range of motion is during dressing changes when the patient is medicated and the bulky dressings are removed. It just takes a few minutes to move all the joints of the affected limbs through their full range before applying the new dressing. This is also a good time to detect which movements are becoming difficult and determine if splinting is needed to maintain a more prolonged stretch and prevent a contracture. It is important to splint the patient at the first thought of doing so, but **the hands must be splinted in position of protection from the onset of the burn**.

These are some basic range of motion exercises that should be performed two to three times a day on the affected limbs (See Fig. 9). The goal is to achieve full active and passive motion of the involved joints as much as possible. In the hand, isolated tendon gliding exercises for the fingers should also be included.

The dressing changes by the medical and nursing staff must be synchronized with therapy sessions.

Exercise

Exercise is an important part of the overall recovery of the burn patient. Often, in Sub-Saharan Africa, the mindset is that the patient is sick and needs to rest in bed until they are better. However, for the burn patient, lying in bed only hinders their recovery. Sitting up and moving around in the bed helps prevent infection, optimize lung capacity, and helps with endurance and muscle strengthening. As soon as the patient is stable, a regular daily program of sitting up in the bed should begin. The patient should then progress to sitting on the edge of the bed followed by standing. Once the patient can tolerate standing, they should be encouraged to ambulate short distances throughout the day. The family should be instructed to encourage compliance with this. The ability to get out of bed and move around also helps the patient psychologically.

When tolerated, resistive exercise and activities that challenge finger dexterity should be added. Focus on functional activities so that the patient can regain independence in self-care.

In Sub-Saharan Africa, there is a high death rate for children with burns, especially if the percentage of the body burned is 30% or more. Range of motion exercises should be started from the beginning, but the child should be monitored and an exercise program started only when the child is medically stable and physically able to handle an exercise routine.

Compression

As soon as the burns have healed and the skin grafts have healed, compression garments can be made and worn as long as necessary to prevent hypertrophic or keloid scarring (See Chapter 1). If these cannot be made, then pressure on extremities can be carried out with Crepe or Ace bandages.

Other joint contractures that must be prevented by splinting and range of motion exercises.

Summary

Minimal contractures in children will become more severe as the patient grows. The scars do not grow as the child grows. Therefore, it is important to splint burns over the joints until the burns are well healed and until there is no evidence of a contracture.

Chapter 44
Rehabilitation of the Burn Patient

Gay Lynn McCrady and Louis L. Carter, Jr.

Editors' Preface
The purpose of this chapter is to introduce pressure garments for hypertrophic and keloidal scars for the rehabilitation of the healed but scarred burn wound. Certainly in the overall rehabilitation of the burn patient, many other treatment modalities are also important.

Introduction
Health care workers throughout Sub-Saharan Africa are daily faced with hypertrophic scarring and keloids. These are difficult to treat successfully and many are left untreated (see Chapter 1). Pressure garments have been found to be an excellent method of preventing these scars as well as treating when first seen.

There is very little use of pressure garments in Sub-Saharan Africa, especially in remote hospitals. This chapter will suggest what is possible if one has an interest.

Burns occur in devastating numbers in Nigeria and across Sub-Saharan Africa. Many people are left with thick, ugly scars, and spend the rest of their lives trying to hide their skin from staring eyes. Many doctors and nurses often consider that the treatment of the burn patient is finished when the wound heals, but **a healed wound is only the first stage of the overall healing of the burn patient**. Healing also involves the return to full function and social acceptance when one can return to school and work. Resulting scars and contractures also limit spiritual acceptance and development, with associated blame, shame, and the possibility of God's judgment. Patients with burn scars, hypertrophic and keloidal, are often ostracized from schooling and society. Therefore, the prevention of contractures and scarring should begin early in the treatment.

The importance of early closure of wounds is discussed in Chapter 2. Wounds that are not closed promptly will heal by secondary intention, with resultant scarring and contractures. In burns, wound closure is often by debridement and simple skin grafting. These wounds and burns will often become infected, further delaying healing. Many factors influence wound healing and scarring, including location, blood supply, and associated illnesses (such as diabetes mellitus and other immunodeficient conditions). Pigmentation is an important genetic factor in Africa and Asia.

Hypertrophic scars and keloids are also more common in wounds across tension lines, such as across the chest and shoulder, and simple infected wounds like those after placement of earrings.

These scars can often be prevented with early treatment, and ideally prevention with direct closure or skin grafts. This begins with adequate care in the hospital or health center. Wounds that are allowed to granulate and heal by secondary intention will result in infected wounds, hypertrophic scarring and keloid formation. Unfortunately, in many hospitals, these burn wounds are often ignored and left untreated since the surgeons are busy. Unless there is a "Burn or Wound Ward", they will often be treated by "skillful neglect" leading to unhealed wounds and scars. Patients often lack funds for prolonged treatment (see Chapter 2) and they live long distances away from centers where adequate wound care is available. In addition, many doctors and nurses lack experience in the treatment of these wounds that often lead to these unacceptable scars. Most medical centers lack reconstructive surgeons who can treat the burn wounds and later the abnormal scarring successfully. (Chapters 1, 2, 11 and especially 12 discuss the surgical care and treatment of these wounds.)

Therefore, the complete rehabilitation of the burned patient is very complex and demands the long-term participation of many specialists, including social workers, occupational therapists, and pastors/chaplains.

This chapter deals with the treatment of the healed but scarred wound. Often, if reconstructive surgeons are available, they can participate in this rehab, but they are usually busy with other surgical demands. They will find the time to help manage the severe contractures covered in Chapter 12.

Seeing these patients scarred and disfigured was an inspiration for the author (McCrady) to pioneer ways to help prevent the development of these thick hypertrophic and keloid scars. She opened a pressure garment clinic called, "Healing Touch" in Jos, Nigeria. This clinic helps treat burn patients whose skin has just healed with no scar development, as well as patients who are six months to one year post-burn, with various levels of scarring. It took her a lot of time and effort to start her program 20+ years ago,

Fig. 1

Fig. 2

Young burn patients.

Fig. 3
Foot Sock

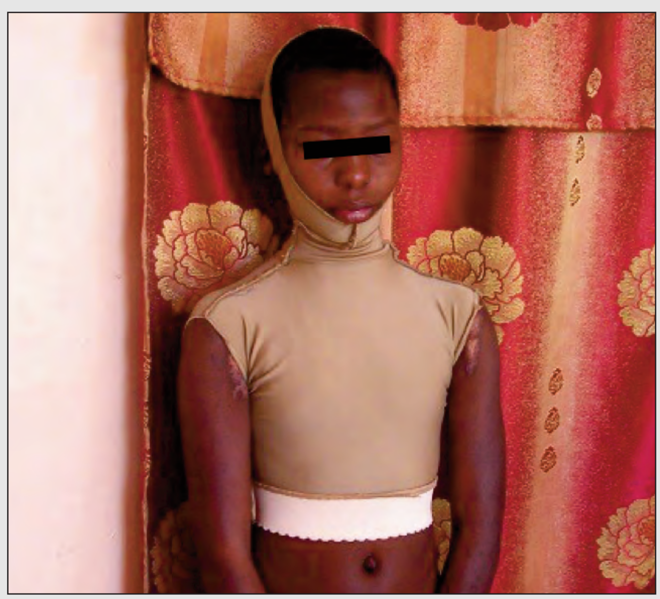

Fig. 4
Chin and Neck Strap

since no one had initiated a program to prevent or reduce hypertrophic scarring in Nigeria or across Sub-Saharan Africa. This program required education to give people an awareness of what is possible. The author started in the local hospitals and then extended the education into the schools and churches in the community. Her goal was to help people understand what pressure garments are and the benefits they can have for burn patients. (Fig. 1, 2)

What Are Pressure Garments?

Pressure garments are tight-fitting garments made from elastic-type material that are measured, sewn, and fitted for each person after their burn has healed. The pressure garment acts as an outer layer of skin, putting pressure on the healing skin, helping it to flatten out and, therefore, preventing it from developing into thick scars and even reducing scars that have already formed. In a severe burn, the top layer of skin is gone, so it is not able to put pressure on the skin below as it would in healthy skin. Without pressure on the skin, very thick and stiff scarring called hypertrophic scarring can form. This type of scarring can limit movement and be very unsightly.

The pressure garment acts as an outer layer of skin, applying pressure on the skin, and prevents the thick scarring from developing. If scars have already formed, the pressure garment will apply pressure on the scar and help it to become soft and flatten out.

The garments are to be worn 23 hours a day. They are removed to bathe and apply lotion on the skin. Then the garment is reapplied. The patient will wear the garment up to a year or more until the scar has flattened and is no longer maturing.

Setting up a Pressure Garment Clinic

When the clinic was first begun in Jos, Nigeria, contact was made with Burn Care International in the USA. They had started pressure garment clinics in three countries. At the start, everything needed to make the garments was listed and the local markets were explored to see what items were available in Nigeria.

See examples in Figs. 3-7.

Fig. 5

Face Mask

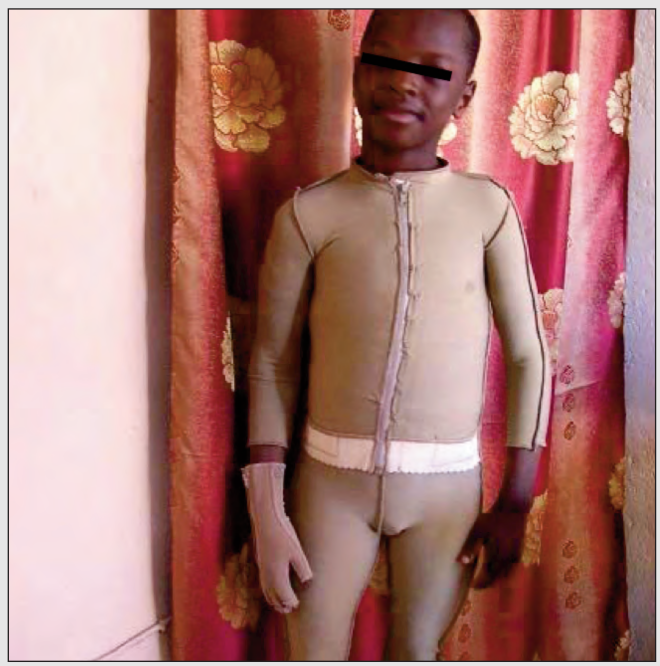

Fig. 6

Shirt and Trousers

Making Pressure Garments

To make the garments, the following items are needed:

- Elastic or spandex-type material.
- Wooly nylon thread.
- Zippers.
- 2” and 1” elastic.
- 2” and 1” hooks and loop Velcro.
- Foam (to apply extra pressure on needed areas).
- Serger—an over-locking sewing machine.

Fig. 7

Arm Sleeves and Gloves

- Sewing machine (one that does various stitches such as zig zag and button holes).

The zippers, elastic, and foam are available in the Nigeria, but the fabric and wooly nylon thread are bought in the USA and brought as excess baggage or shipped. The wooly nylon thread can be found on the Internet at www.threadart.com. It is sold in 1000 meters (1100 yard) spools (as of the date of this publication). The material is obtained through Burn Care International, usually coming in 50 yard rolls. For more about the work of Burn Care International, visit www.burncareinternational.blogspot.com or contact them at envoyseminar@aol.com.

The main step in starting the clinic is finding a good local seamstress. One may locate one through a local sewing program and then educate the seamstress on what pressure garments are and what the treatment is working to achieve for the patient through wearing the pressure garments. (Figs. 8-9). Pressure garments are more difficult to make than regular clothing. Thus training classes are necessary to teach how to measure the patients, cut out the garments, use of the serger (Fig. 10), and getting the right compression over the affected areas.

A serger is an over-locking sewing machine. A serger trims the seam and encloses the seam allowance (or edge of the fabric) inside a thread casing, all in one step (Available in Nigeria).

Fig. 8

Fig. 9

Fig. 10

Serger

A seamstress will improve with each garment made. **Figs. 11-13 (on pp. 8-10) show the measurement sheets used to measure the patients.**

Case Studies

When the patients are fitted for the pressure garments and are compliant in wearing them, there have been good results in the reduction of their scars. When patients have come in right after their burn has healed, the pressure garments have prevented scars from forming.

Example 1:
Patient was burned from someone striking a match behind him and accidentally catching his shirt on fire. (Fig. 14) He was burned on the back of his left shoulder all the way down his arm and on the left side of the face. He was fitted with a shirt and face mask as soon as the wounds had healed. He wore the shirt faithfully for up to one year, but he did not like wearing the face mask, so it was not worn regularly. At the end of one year, he had not developed any scars on his arm and shoulder, but he had a small scar develop on his left cheek. It was exciting for the therapists. to follow the patient from beginning to end and see how the pressure garments had prevented any scars from forming.

Example 2:
A four-year-old boy came, having suffered burns from pulling a pot of hot tea down on himself. He was burned on his right chest and right arm. When he came, he was three months post discharge from the hospital and had already developed scarring and a contracture of the right elbow (Fig. 15). He was fitted with a shirt with the right arm sleeve extending down to his wrist (Fig. 16). He wore the garment faithfully for fifteen months, and the scars healed flat and smooth (Fig. 17). He had surgery for a contracture release of his right elbow and he now has full movement of his elbow (Fig.18). His mother was very happy to see that the scar had healed flat and smooth. She said she wished she had known sooner that these garments were available.

Example 3:
A twelve-year-old boy came to the clinic, and he had severe scarring on his back and right buttocks (Fig. 19). He and his friends had been playing outside with matches. The back of his shirt caught on fire, and he did not know until one of his friends told him. Instead of dropping and rolling, he ran, and that caused the fire to spread down to his trousers before

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

4-year-old burned by hot tea and fitted with pressure garments. 17) Fifteen months later. 18) After a contracture release of the right elbow.

his friends could help put it out. When he came to the clinic, he was about four months post healing from the burn. The scars were still soft, so the garment would be of benefit to him. He came back for adjustment of his garments at three months, and the scars were noticeably reduced, but he still has a long way to go (Figs. 20-21). There were some cavities or sunken in places on his back, so foam was added to fit into those places and provide the needed compression. He has worn the garments for about six months now and will continue to wear them for as long as the scars are reducing. He says that the garments help reduce the itching and he is more comfortable when he is wearing the garments.

Fig. 19

Fig. 20

Fig. 21

A 12-year-old whose shirt caught on fire. 20) Fitted with shirt and trousers. 21) Three months later.

The garments are also beneficial for patients with varicose veins and lymphedema. With varicose veins, the compression garments help to push the blood through the veins, reducing pressure on the veins, therefore reducing the pain in the legs. Patients with lymphedema have chronic swelling in the arms or legs. The garment applies more compression around the end of the extremity and less pressure towards the trunk, to encourage lymph flow out of the extremity and towards the body. The amount of compression in the garments sewn for varicose veins and lymphedema patients is less than the ones for scar prevention/reduction for burn patients. One varicose vein patient came, and after wearing the garment for a month, he reported that the garment had helped reduce the pain in his leg (Fig. 22-23).

Fig. 22

Fig. 23

22) Varicose Veins.
23) Fitted with pressure garment.

Costs

The price of the garments was decided on the basis of cost for sustaining the business while keeping the garments at a reasonable price so the patients are able to afford them. This will vary in every country, according to the cost of the supplies and salary for the seamstresses.

Burn patients often experience itching, especially under pressure garments. Cocoa butter has been found effective in reducing itching.

Challenges

There are many challenges in starting a wound pressure garment clinic:

- Pressure garments are a relatively new product and not readily available.
- Many patients are referred late for treatment, or come many months after healing and have already developed thick scars. Education of doctors and distribution of brochures and posters in hospitals, clinics and churches are necessary.
- Many patients are fitted for the garments and then never come back for check-ups, adjustments, or for therapists to see the progress in healing
- Many of the supplies can be bought here in the country, but they are not a good quality, so repairs are needed quite frequently.

Fig. 24

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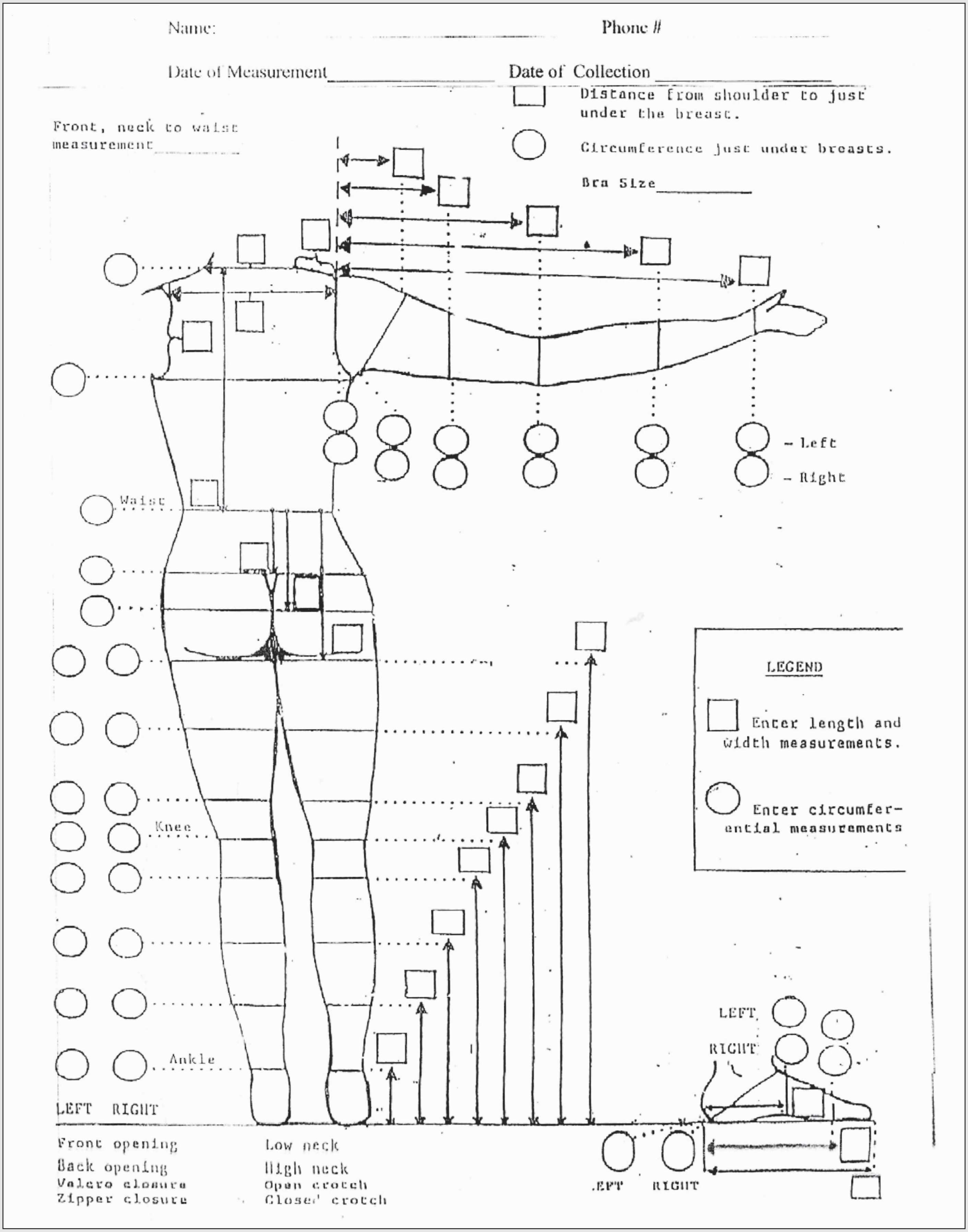

Name:
Phone #
Date of Measurement
Date of Collection
Distance from shoulder to just under the breast.
Front, neck to waist measurement
Circumference just under breasts.
Bra Size
– Left
– Right
Waist
LEGEND
Enter length and width measurements.
Enter circumferential measurements
Knee
LEFT
RIGHT
Ankle
LEFT RIGHT
Front opening
Back opening
Velcro closure
Zipper closure
Low neck
High neck
Open crotch
Closed crotch
LEFT RIGHT

Fig. 11

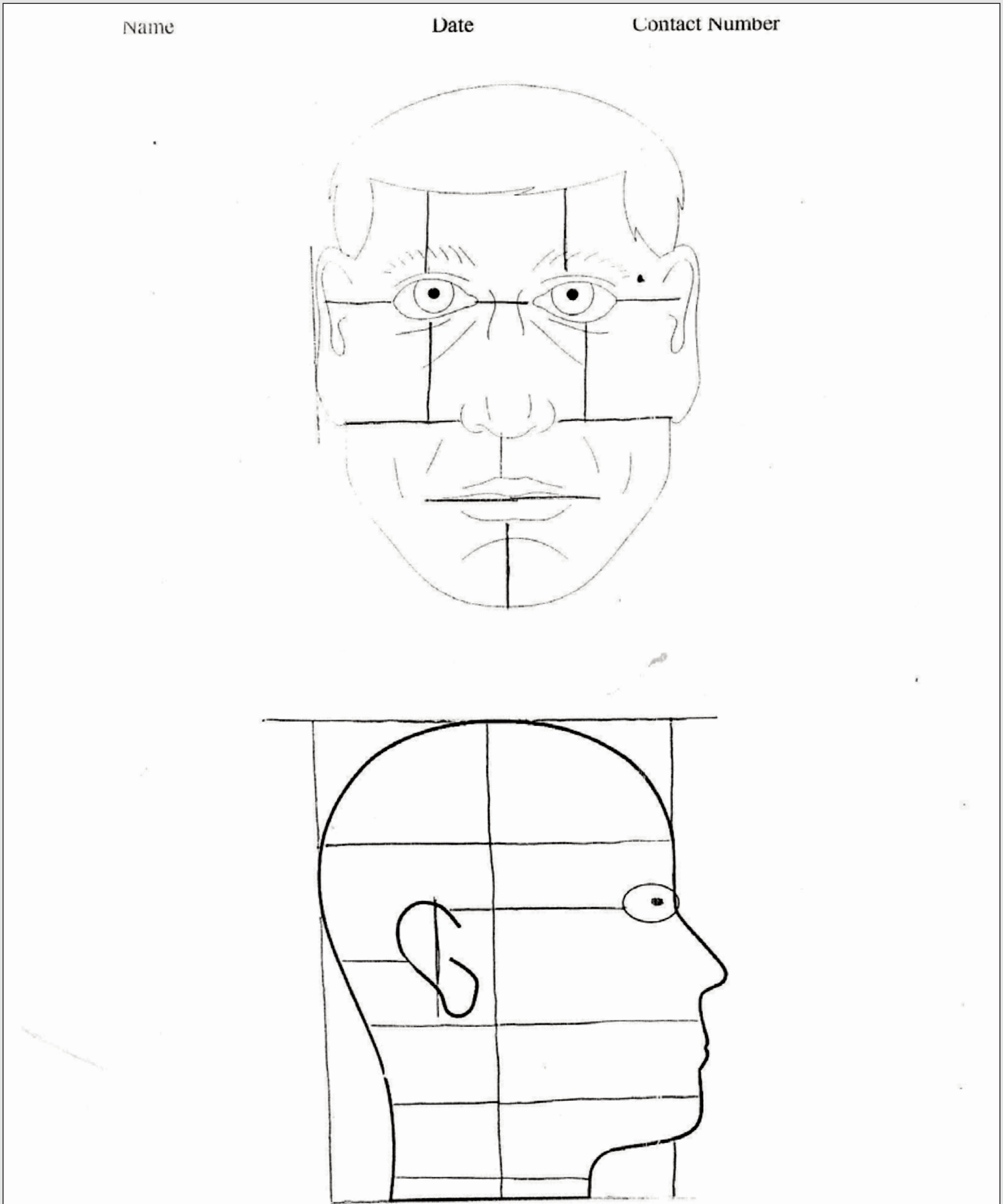
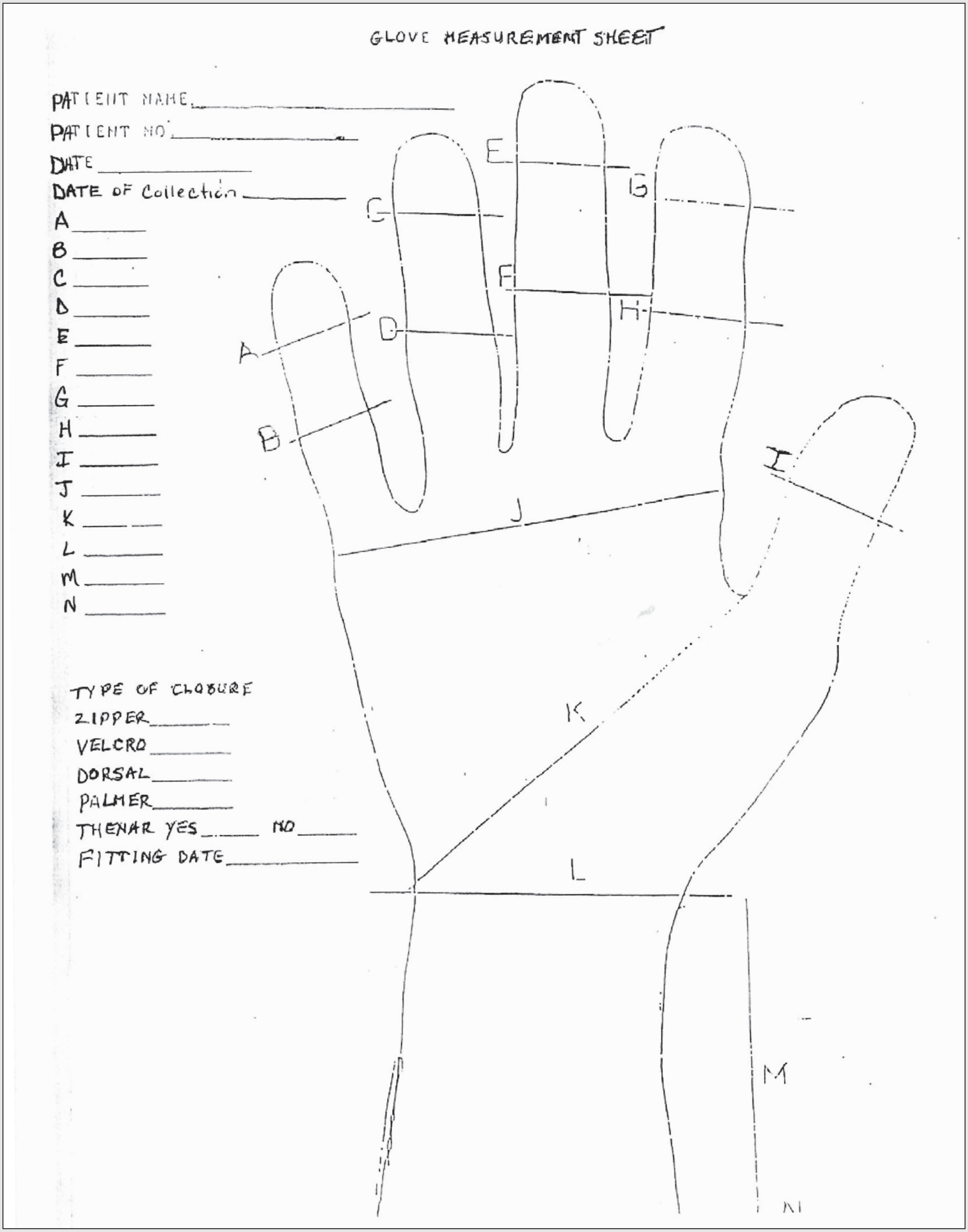


Fig. 12


GLOVE MEASUREMENT SHEET

PATIENT NAME ______
PATIENT NO ______
DATE ______
DATE OF Collection ______
A ______
B ______
C ______
D ______
E ______
F ______
G ______
H ______
I ______
J ______
K ______
L ______
M ______
N ______

TYPE OF CLOSURE
ZIPPER ______
VELCRO ______
DORSAL ______
PALMER ______
THENAR YES ______ NO ______
FITTING DATE ______

Fig. 13

Index

For ease of finding the subjects covered in this text, subjects are indexed here by page numbers within chapters. For example, a subject addressed on page 10 of Chapter 18 will be indexed to page 18: 10.