Chapter 20

Flaps for Wound Coverage and Tissue Expanders

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This chapter will be an overview of flaps used in plastic surgery. Many of these flaps will 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 to always 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 closed primarily or 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 débridement, 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 a transposition, rotation, bilobed, etc. flaps. 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 3 X 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 which 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 can supply the entire abdominal wall skin. Most of the flaps discussed here will be axial flaps and 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 own 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 flap according to their blood supply.

Muscle Flap Classification:

Type I – one vascular pedicle as in the gastrocnemius muscle flap where each head is supplied by either the medial or lateral sural artery

Type II—one dominant pedicle and several minor pedicles as the gracilis muscle which has one dominant pedicle from profunda femoral artery and several minor pedicles off superficial femoral artery

Type III—two dominant pedicles which 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 allows 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, as groin flap

Type B—Septocutaneous, vessels that course between muscles to the fascia, as parascapular flap

Type C—Musculocutaneous, vessels from the muscle to fascia, 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 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 septa or fascial hilar
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 “free style” design is developed. See chapter on “Perforator Flaps.”

Expanders: Skin expansion is an additional method for wound closure, using expanded tissue, flaps, adjacent to the wound for advancement and closure of 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 carefully measure the size of the recipient area before raising the flap.

Usually antibiotics are given before surgery and in some cases they are used for 24 hours after surgery. In special cases, as in diabetics, 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 or 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 a donor defect is either stapled into place or sutured with running absorbable suture, as chromic or Monocryl suture. A wet cotton dressing is applied to the skin graft.

When adjacent skin graft is not meshed, then a drain is left beneath the flap for 24-48 hours. If there is meshed skin is adjacent to the flap, usually 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 for comfort to allow the skin graft to take and heal well.

Most flaps will not need division but pedicle flaps from a distant location as a groin or SIEA flap to the hand will need division. Normally this is carried out at 3 weeks. If the recipient site is severely scarred with questionable blood supply, then the flap can be partially divided at 3 weeks with the remaining
pedicle divided at 4 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 inserting it nicely for cosmesis may put tension on these recently formed capillaries around the edges of the flap and 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 ones you will commonly use. Descriptions of these flaps and others will be found in specific 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

- Orticochea—local scalp flaps with scoring of the galea for expansion
- Scalp rotation flaps based on one or more of the 5 major arteries on each side
- Forehead for nose, cheek, upper lip
- Cervical
- Mustarde
- Deltopectoral
- Pectoralis myocutaneous
- Supraclavicular

**Flaps for Shoulder Girdle Reconstruction:**

**Latissimus Dorsi Muscle Flap** may be used as a myocutaneous flap or just muscle alone. If muscle alone is used, it maybe 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 STSG.
- **Reconstruct the top of the shoulder and deltoid.**
- **Reconstruction of the biceps brachii**—it is the flap of choice. It 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
into the radial tuberosity. If into the tuberosity, use the technique of tendon repair described in the tendon chapter. 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, perforators from the intercostals, for coverage of the spine.

**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 which 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 3-4 X the length. This flap will easily rotate to reach the coracoid process of the scapula anteriorly 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 burned then the latissimus dorsi muscle fascia or even the lateral half of the muscle may be included in the flap. The donor site 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 the chapter on burn reconstruction of the axilla.)

![Image](image_url)

**Parascapular flap used to reconstruct an axillary contracture that would not heal due to continued use of the arm. STSG used for donor site below joint. Mobilization of skin above flap to close arm wound**

**Elbow Reconstruction:**

**Latissimus Dorsi** – for biceps reconstruction, see above

**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, but because of its location in the upper extremity, it is extremely reliable even when the length is 3X the width and reaches 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 muscle. 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 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 1st 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 radius may be taken with the flap.
Though other texts can give 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. In addition 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 “Perforator Flap” chapter for reverse radial artery perforator flap where the radial artery is not sacrificed.)

These are soft pliable flaps that easily mold in to any defect. Most often the donor sites must be grafted. With the antegrade flap, care must be taken to ensure that soft tissue and/or 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. In recent years it is not uncommon for both flaps to be taken as fascial flaps alone without skin. (See Perforator Flap and Burn Reconstruction chapters.)

Olecranon coverage: Therefore, the cubital artery flap and antegrade radial artery flaps can 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.

Wrist and Hand Reconstruction:

Reverse Radial Forearm Flap--see above

Posterior Interosseous Flap maybe used in wrist and hand reconstruction however the author feels the elevation of this flap is difficult and other flaps are better for the surgeon in the district hospital. Below is an illustration of this flap. (Courtesy of Dr. David Chang) In addition, 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 with a wide pedicle and in-setting the flap without tunneling the flap to the recipient site.

Fig 11
Posterior Interosseous Flap (Courtesy of David Chang, MD)

Fig 12

**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 long 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 frequently the distal end will need thinning. For dorsal hand coverage, this flap will often need debulking 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, in 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 is placed in), and the need to for flap defatting.

**The thoraco-epigastric flap** has the advantage of allowing the hand to be less dependent; the edema is less, as is the degree of digit stiffness.

A line is drawn between the tip of the shoulder and the umbilicus (Fig 16). The flap may be based on either medially (peri-umbilical perforators (Figure b)) or laterally (Fig 17), 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. Children may require flap pre-expansion (Fig 19). Most thoraco-epigastric flaps can be closed primarily.

**The Kangaroo flap**

When wounds require urgent cover, but are more extensive than available flaps, the ‘Kangaroo flap’, in essence a bipedicled abdominal flap, may be used.

![Fig 20](image1.png) ![Fig 21](image2.png)

Kangaroo Flap (Courtesy Dr. Peter Nthumba)

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.

![Fig 22](image3.png) ![Fig 23](image4.png)

![Fig 24](image5.png) ![Fig 25](image6.png)
This patient presented with a crushed, degloved, infected forearm, for which an above-elbow amputation had been offered. She presented at 10 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 ulna nerves were subsequently grafted – she now has sensation in all her digits. She waits tendon grafting.

**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 and 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.
Extension contractures of MPJs after previous inadequate surgery with skin graft. After complete MPJ release the MPJs were pinned in flexion, a SIEA flap was used for reconstruction. Pins are placed through metacarpal head and then brought out through finger tips with MPJs flexed.

**Radial Artery Perforator Flap**

This is a retrograde flap at the wrist that does not require the use of the radial artery. It is supplied by perforators off the radial artery at the wrist and can be taken for 6-8 cm. above the wrist. It can be turned and used to cover the volar wrist when a wrist contracture has been released. Usually skin grafts over the volar wrist joint will contract leaving the patient with a slight functional deformity, but the wrist will not re-contract with this flap. See “Perforator Flap” chapter for a more extensive use of this flap.

**Becker or Dorsal Ulnar Artery Flap**

This 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. This flap is further discussed in the chapter on “Upper Extremity Wound Reconstruction.” This is a more reliable flap than the radial artery perforator flap.
**Posterior Interosseous Flap**

This 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:

**Finger Reconstruction:**

The various flaps are listed here and well described in the chapter 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  
Reverse Cross-Finger for dorsal finger reconstruction  
Side finger flaps for reconstruction of small dorsal or volar defects

**Abdominal Wall Reconstruction:** (see chapter on abdominal wall reconstruction)

Abdominal wall reconstruction for trauma or cancer involves the use of the following flaps and techniques:  
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 as Tram flap  
VAC  
Mesh

**Pelvis and Hip Reconstruction:**

**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 may be used to cover large hand and forearm wounds. The TFL may be used as a fascia only flap and skin grafted in these cases. 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 3 X 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 along a line from the ASIS to the lateral condyle of the tibia. The flap can be raised easily and quickly once the correct plane under the TFL is found distally. (See Burn Reconstruction chapter)

The TFL flap may also be turned laterally to cover trochanteric and ischial decubitus ulcers. See Pressure Sore chapter

**Abdominal Wall Reconstruction:** (see chapter 16 on abdominal wall reconstruction)

In addition, the TFL flap may be turned superiorly and used for abdominal wall reconstruction along with the Rectus Femoris flap. It may be used as a muscle/fascial flap or a myocutaneous flap to cover lower abdominal defects. The flap may be divided above the blood supply and used as an island flap. This will allow the flap to rotate and reconstruct larger areas.

**Rectus Femoris Flap** is a usually a muscle flap that is also used for groin or abdominal wall reconstruction. It originates from the ASIS and rim of acetabulum. It is supplied by the lateral femoral circumflex artery approximately 10 cm. below the inguinal ligament.

**Anterior Lateral Thigh perforator flap** requires some experience to elevate but a great flap for lower abdomen. (See chapter on Perforator Flaps.)

**Back Reconstruction:**

Upper Back—Trapezius muscle or myocutaneous flaps
Pelvic and Genitalia Reconstruction:

**Rectus Abdominis Flap** is a versatile flap that may be turned down as a muscle only flap to cover the groin and 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 into the pelvis. It can used to fill large defects from injuries or massive perineal/pelvic resections for malignancy.

**Prepuce flaps** have been used to reconstruct urethral strictures which are common in Africa. Often the urethra can be dissected above and below the stricture and a primary repair carried out. When the defect is too long for 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 below or horizontally proximal to the corona and circumferential giving 13 cm. length. A 26 mm. wide strip can be tubed to reconstruct the urethral circumference.

**Vulvoperineal flaps/Singapore flap** have been used for vaginal reconstruction for vaginal atresia and also reconstruction of vesico-vaginal 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 reconstruct VVF defects. It is passed beneath the labia and into the vagina.

**Gracilis muscle or myocutaneous flaps** have been used for many reconstructions in Africa. It can be used for vaginal reconstruction and for **reconstruction of 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 Fournier’s Gangrene Chapter)*

**Decubitus Ulcers:**

See chapter on Pressure Sores where other flaps for reconstruction are described.

One 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.
Lady developed a large sacral decubitus secondary to radiation. Reconstruction performed with two large transverse back flaps and biceps femoris flap (See Chapter on Pressure Ulcers)

**Knee Reconstruction and Lower Extremity Reconstruction:** (in addition, see chapter Lower Extremity Reconstruction)

**Saphenous Flap and Cross Leg Flap** is a thin fasciocutaneous flap supplied by the small saphenous artery which runs alongside the saphenous vein on the medial side of the leg. This flap is an excellent flap 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 for 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 the donor site is closed with a meshed skin graft.

This flap is also the most commonly used cross leg flap. The donor site must be grafted and a stent dressing applied (Vaseline gauze, wet cotton balls, wet and dry gauze with stent sutures tied over this dressing to hold it in place) before the flap is inset into the recipient area 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 so that the flap is fixed into position and will not move. Any movement of the flap may disrupt the capillaries bridging the suture line. In addition, it is important to put the extremities and 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 when additional coverage is required. The muscle may be used to cover one area and the fasciocutaneous portion for another area.

![Fig 48](image1.png) ![Fig 49](image2.png) ![Fig 50](image3.png)

**Fig 48** Saphenous flap: the muscle fascia of the medial gastrocnemius muscle is not included

![Fig 51](image4.png) ![Fig 52](image5.png) ![Fig 53](image6.png)

**Fig 51** Open ankle wound requiring cross leg, saphenous, flap. Note: skin graft applied before flap is inset. Final result after the flap was divided 4 weeks later.

**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 into the popliteal fossa. Though it can be 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 can be lengthened by dissecting up to its origin and even carefully dividing the origin.
from just above the medial femoral condyle. In order to cover the entire anterior knee and distally 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 assure that there is no constricting pressure on the muscle and pedicle. Occasionally 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 fascia in order to gain 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 securely inset into the surrounding tissue. In all reconstructions the muscle may be grafted with a meshed skin. 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 after the initial debridement if the wounds are clean. (See Fig 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 midline.
Soleus Flap may be used to cover middle third tibial defects. This 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, 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 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 has been raised as a distally based flap on the distal perforators 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 Chronic Wound chapter where a soleus muscle was used acutely to cover the distal tibia in a severe lower leg injury.)
Distal Third Tibial Defects:

These are difficult to cover without microvascular capability. The cross leg flap can be used to cover these defects but this requires 3-4 weeks of immobilization. The sural artery flap is a very reliable flap when it is taken with the parameters described below. The use of the VAC (Vacuum Assisted Closure (Negative Pressure Therapy)) is an excellent addition to the armamentarium of the orthopaedic surgeon. 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 in the Chronic Wound chapter. Perforator flaps off the posterior tibial artery are very useful in covering these defects. Surgeons should become familiar with these flaps as will soon become the flap of choice when there minimal zone of injury. Newer Keystone Island Perforator flaps will become an additional method of covering the lower third of the leg. See “Perforator Flap” chapter.

Sural Artery or Reversed Leg Flap is a reversed fasciocutaneous axial flap that may be used for coverage of the distal tibia, malleoli and heel. The classic flap 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 proximally more than 20 cm. 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. Some surgeons may prefer to stage the flap elevation and inset because of the reversed blood supply. 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 but care is taken to preserve the paratenon over the Achilles tendon. In situations where the lateral side of the ankle is injured when one is unsure about the zone of injury, one can take a wider flap based
on perforators from both the peroneal and posterior tibial arteries and delay the flap (see below). It is important to elevate the leg postoperatively and prevent the patient from lying on the pedicle. See below where foot is elevated with external fixator and by traction on Steinman pin placed through calcaneus.

Fig 65
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 débridement of two week old wound

Fig 67
Chronic distal third wound—12 days old: wound débridged three times while a longer, delayed 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 70
Reverse sural artery flap to cover lateral malleolus
Elevation is always used in these flaps to prevent pressure on pedicle and to enhance venous drainage.
Foot:
**Dorsalis Pedis and Medial Plantar Flaps**
These 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 73](image1) ![Fig 74](image2) ![Fig 75](image3) ![Fig 76](image4)
Wound over medial malleolus: débrided, dorsalis pedis flap raised and inset. STSG

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 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. 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 3 weeks.

![Fig 77](image5) ![Fig 78](image6) ![Fig 79](image7) ![Fig 80](image8)
Wound of the plantar weight bearing surface. Radially débrided and innervated medial plantar flap raised and rotated to cover defect with a skin graft for donor site. Flap outlined in Fig 78.
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. 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 on Burn Reconstruction.)

Tissue expanders come in various sizes and shapes. The best 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 cc. up to 2000 cc.

Ideally expanders are not placed in infected wounds. 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 in red below. One may not 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 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 incisions should be placed: The author formerly placed the incision for placement of the expander along the edge of the wound (blue arrow) but this may limit the amount of the expansion.

![Expander Diagram](image)

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 as the expander may extrude as expansion is carried out (black arrow).

It is important to place the port, injection dome, over a prominent 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 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/fullness.

Expanders can usually be filled twice as much as the stated volume size. Usually this is not necessary if the surgeon has picked out the right size initially. 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 expander to determine if there is sufficient expansion to cover this 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 below 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 below.

Determine mount of expanded skin by measuring convex surface after expansion.

![Diagram showing measurement of expanded skin.

How to estimate when one has expanded sufficiently: Length of convex surface of black semicircle (the expander) equals the red line when spread out, must equal addition of 1+2 to cover donor area plus defect.

Example of scalp expansion: Crescent shaped expander used. Fig 82 shows the burned hairless scalp. Fig 83 shows full expansion. Fig 84 shows the expander after removal—some fluid had been removed. Fig 85 shows the reconstructed scalp.
Summary:

Flaps provide an excellent reconstruction of some difficult areas. There are many more flaps than listed here. These are the most commonly used extremity flaps. Other flaps are described in upper and lower extremity reconstruction and burn reconstruction. Knowledge of vascular anatomy is most important for successful elevation of a flap. Temporary immobilization and elevation of the extremity is important after any flap. In addition, 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 a flap delay and allow for collateral circulation to develop. This chapter is written to give the surgeon an idea of what flap is best to use for various conditions in Africa. Full description of the elevation of these flaps especially the last ones mentioned for foot reconstruction may be found on-line or by contacting the author below who would be pleased to send you more details.

In flap surgery, remember to “measure twice since you can only cut once.”

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