Chapter 21

Lower Extremity Reconstruction

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Overview:

This subject is also partially covered in the chapters “Flaps for Wound Coverage” and “Perforator Flaps.” This chapter will deal with reconstruction from the knee to the foot.

Primary closure or delayed primary closure 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 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 débrided and cleansed well, the 8 hour limit remains for lower extremity injuries. 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 in order for granulation tissue to develop.

Contaminated wounds that cannot be closed acutely because of contamination should be closed within the first 7 days by delayed direct primary closure, skin grafts or flaps. After 7 days, the wound will then need radical débridement 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 on Chronic Wounds).

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 débrided and loosely closed if clean.

Type II open fractures, > 1 cm. long, débrided and if possible the wound is closed very loosely over any exposed bone and a second look with repeat débridement should be done within 48-72 hours. If the wound is clean after the second look, then it should be definitely closed by skin grafts, local fasciocutaneous or muscle flaps.

Type III, >10 cm. long, débrided, with a second look 24-48 hours for further débridement. Further débridements will likely be necessary but every
attempt should be made to close the wound as early as possible and definitely by 7 days. In Type III, if closure is delayed past 7 days, then a VAC may likely 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 débridement is done and the wound is clean, the wound can be closed and sooner you can do this the better.

The many variables preclude definite statements regarding treatment of Type III open fractures. These variables include where the fracture occurred—as in the farm or on the highway, contamination, length of time before débridement, adequacy and frequency of irrigations and débridements, tissue loss, stabilization, how well the tissues are kept moist, vascular damage, availability of VACs, etc. Method of débridement is found in the chapter on open fractures in the PAACS Orthopaedic Curriculum, pg. 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 débridement.

A cephalosporin antibiotic should always be used and if microbiology is available, cultures should be 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 should be covered as soon as there fixation of the fracture. If the wound is clean, SIGN nailing is an excellent method of fixation of 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 débridements of the wound and allow for the use of a VAC and later flap coverage. When external fixation is used, care must be taken to apply it in such a way that VAC and flaps can be used. 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 definitively closed as soon as possible, preferably before 7 days post injury. Ideally a muscle flap is best but if not available then a fasciocutaneous flap. Muscle brings in a greater blood supply for débridement of wound and healing of fractures.
Flaps for Knee and Upper third of Tibia:

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. Though it can be used as a myocutaneous flap it is a bulky flap when skin and subcutaneous tissue are added to the muscle and will leave 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. 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, 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. The author will occasionally divide one or more of these tendons if necessary for complete coverage of a wound over the knee. These may be sacrificed without significant functional loss. The gastrocnemius muscle fascia may also be scored longitudinally with multiple parallel 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 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 muscles and tendons in the pes anserinus—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 taken to preserve the sural nerve and lesser saphenous vein which lie in the midline between the heads of the gastrocnemius muscle. After the muscles have been inset skin grafting should be done immediately.
Open fracture of tibial plateau. Wound débrided and medial gastrocnemius muscle flap with skin graft was used to cover the wound at the time of the original surgery and fixation.

Poilital contracture with scarred skin over medial aspect of leg: medial gastrocnemius flap was used with longitudinal scoring of the muscle fascia and STSG. Scar was excised in this case.

**Saphenous Flap and Cross Leg Flap** are thin fasciocutaneous flaps supplied by the small saphenous artery which runs along with the saphenous vein on the medial side of the leg. This flap 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 with 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 the donor site is closed with a meshed skin graft. This flap uses the superficial fascia not the fascia over the gastrocnemius muscle—see center picture below with muscle fascia on muscle.

This flap is also the one commonly used in the cross leg flap which still remains a valuable flap in Sub-Saharan Africa. (See Chapter on Burn Reconstruction) The donor site must be grafted and dressed before the inset of the flap. A stent dressing is applied using Vaseline or non-adherent gauze, wet cotton balls to hold the skin graft in the crevices, wet and dry gauze with stent sutures tied over this dressing to hold it in place. This is not a bulky dressing. 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 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. It is easy to elevate the legs with the external fixator. In addition, 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. Final inset of the flap is best delayed for a week after division. (After flap division, the flap is loosely inset, but careful inset is performed a few days to a week later.)

Saphenous flap: the muscle fascia of the medial gastrocnemius muscle can be left on the muscle—see arrow. The flap still contains the superficial fascia.

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 used for another area.

Medial head of gastrocnemius muscle used to cover popliteal fossa when saphenous flap alone was not adequate.
Middle Third Defects:

**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. 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.
This is a similar case where soleus muscle was used for middle third tibial fracture. Note the scoring (arrow) of the muscle to increase the width.

Reconstruction of large tibial defect with both medial gastrocnemius and soleus muscles. Patient will do well with lateral gastrocnemius. Note scoring of soleus muscle.

The soleus has also been raised as a distally based flap on the distal perforators 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.)

**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 **sural artery flap** is a very reliable flap when it is taken with the parameters described below.

**Technique for the Sural Artery or Reversed Leg 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 3 fingers’ breadth (5 cm.) above the lateral malleolus. So 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** unless it is delayed. 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 reversed blood supply or the need to extend the flap proximally, beyond 20 cm, for distal coverage. The **center of the flap** is the short saphenous vein. Once this vein is found proximally between the two heads of the gastrocnemius, the flap can be outlined.

![Fig 24](image1.png) ![Fig 25](image2.png)

Postop 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 also delayed once to allow radical débridement of two week old wound.
The **sural nerve must be taken** with the flap to ensure viability. 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, one can take a wider flap based on perforators from both the peroneal and posterior tibial arteries and delay the flap (see below).

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**Chronic distal third wound—12 days old:** wound debrided three times and the reverse posterior leg flap (modified reverse sural artery flap) was delayed and lengthened at each débridement. The flap was based on mainly the posterior tibial artery because of the injury on the lateral side of the distal leg.

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**Sural Artery flap design, elevation, delay, inset and final result.** Note VAC over heel and narrow pedicle. (Courtesy Dr. Blair Summitt)
Posterior Tibial Perforator Flaps

These are excellent flaps for coverage of lower extremity wounds. It can be based on one or more perforators from the posterior tibial artery. A description of this flap is in the Perforator Flap chapter.

Keystone Island Perforator Flaps

These are island fasciocutaneous flaps taken in a “keystone” design adjacent to the defect. They are based on perforators adjacent in the tissue adjacent to the defect. (See under Perforator Flaps)

Fasciocutaneous Flaps

Many other fasciocutaneous flaps can be taken in the lower extremity. Unless based on a definite vessel or perforator but care must be taken not to take the flap longer than 2 X the width. Additional care should be taken to gently rotate the flap into position. If necessary the flap can be delayed once or twice to gain more length. A small backcut can also be made. Retrograde flaps can be taken based on known perforators. In all these flaps, 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 (Negative Pressure Therapy) is an excellent addition to the armamentarium of the plastic surgeon. The VAC can be used to clean wounds and create angiogenesis and granulation tissue over bone and tendons and prepare the wound for skin grafting. This technique is described in detail in the Chronic Wound and Wound Closure with VAC chapters. Using perforator flaps from the posterior tibial or peroneal arteries is a newer method and is described in the chapter on Perforator Flaps. In addition there is a newer variant of perforator flaps called the “Keystone Island Perforator Flap.” It is described at the end of the perforator flap chapter.

Foot Defects:

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.

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. This will require loupe magnification to dissect these branches from the digital nerves which are not sacrificed.

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
fascial flap the longitudinal fibrous septae 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 septae. 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 43**
Medial plantar flap used to reconstruct the heel after excision of a malignant melanoma.
An innervated flap was used. This patient refused amputation.

**Achilles tendon injuries** (see Tendon Injuries)

Acute open injuries can be repaired with several core weave sutures as in flexor tendon injuries or a Krachow whip stitch with a large braided non-absorbable suture—probably the largest available in the hospital (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.

Krachow suture is shown below. Many now add a second suture to give four strands for both Achilles tendon and biceps tendon repairs.
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. 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 the problem is corrected early.