Chapter 21

FRACTURES OF THE TIBIA AND FIBULA

KEY FIGURES:

Calf anatomy
How to do fasciotomy
Gastrocnemius and neighboring structures
Longstanding open fracture
Gastrocnemius flap

Fractures of the tibia and fibula are a special concern because missing early warning signs can result in a useless leg.

The tibia and the fibula are the two long bones of the calf. Fractures of these bones often result from a sport-related injury or motor vehicle accident. Most fractures of the tibia and fibula (tib-fib fractures) heal without complication, and the patient is able to resume his or her normal activities.

However, potentially serious complications can develop, and you must be aware of their early warning signs. With this knowledge, you can intervene before permanent tissue damage develops. Early intervention may make the difference between a normally functioning patient with a well-healed fracture and disaster.

Case Example

An 18-year-old boy was playing football and collided with another player, injuring his right leg. He tried to keep playing, but because the pain was so intense he could not place any weight on the leg. He sat out the rest of the game and then came in for evaluation.

The calf was swollen and tender, and the x-ray showed a minimally displaced mid-shaft tib-fib fracture. No orthopedic surgeon was available. After finding the fracture in *Campbell's Orthopaedics*, you placed him in a cast, gave him crutches and pain medications, and sent him home.

He returns a few days later in horrible pain. You remove the cast. His calf is very tight and swollen, and except for the lateral aspect he has no sensation in his foot. When you move his ankle, the pain intensifies in his calf. You check for pulses in his feet, and they are present.

A general surgeon takes one look at the patient, and immediately sends him to the operating room. Incisions are made in the calf, and much of the calf muscle is dead.

The boy's leg will never function as it did before the injury. He will have a life-long disability.

What happened? First you need some basic background information.

Closed vs. Open Fractures

Fractures are usually classified as closed or open.

A **closed fracture** means that the skin around the fracture site is intact. In terms of bone healing, closed fractures have a favorable prognosis because of the low risk for infection of the bone (osteomyelitis) at the fracture site. However, complications may arise, as illustrated by the case example.

In an **open fracture**, also called a compound fracture, the skin around the fracture site has been punctured. Open fractures are more serious injuries because it generally takes greater forces to disrupt the skin and fracture the bones. An open fracture greatly increases the risk for the development of osteomyelitis, and osteomyelitis increases the risk for poor healing.

The quality of the soft tissue around the fractured bones plays a role in fracture healing. Feel your own calf. The anterior surface of the tibia is covered only by skin; there is not much padding around this bone. Significant injury to the skin around the tibia can result in exposure of the bone and thus a greater risk for poor healing of the fracture.

The higher the energy of the injury, the more significant the injury to the soft tissue and the greater the potential for problems. Falling off a step results in a low-energy injury; being hit by a car results in a high-energy injury.

Essential Elements of the Physical Examination

1. Is the skin intact? (open vs. closed fracture)
2. If the skin is punctured, what can you see in the wound? Foreign material must be removed, and dead muscle or skin should be cut out. If the fracture site is exposed, soft tissue coverage may be needed.

3. What is the vascular status of the leg? Check capillary refill. Check the pulses on the top of the foot (dorsalis pedis) and behind the medial malleolus (posterior tibial artery). If capillary refill or pulses are not present, the patient may have a serious arterial injury.
4. What is the neurologic status of the leg? Evaluate the patient for evidence of nerve dysfunction or injury. Check sensation in the following areas:
   - The first web space on the dorsum of the foot between the great toe and the second toe: deep peroneal nerve
   - The plantar surface of the foot: posterior tibial nerve
   - The lateral aspect of the foot: sural nerve

   Check active ankle motion and toe motion:
   - Plantarflexion of the ankle and toes (pointing of toes and foot): posterior tibial nerve
   - Dorsiflexion of the ankle and toes (bringing the toes and foot upward toward the front of the calf): anterior tibial nerve
   - Eversion (elevating the lateral side of the foot): peroneal nerve
5. What are the radiographic findings? A single break in each of the bones usually heals with fewer complications than when the bones are broken into many pieces (a comminuted fracture). A large number of fragments indicates a higher-energy injury, which is associated with a higher rate of complications.
6. Evaluate the patient for signs and symptoms of compartment syndrome. If they are present, you have a surgical emergency on your hands (see below).

Compartment Syndrome

A compartment syndrome develops when pressure builds up within a fixed, well-defined space. The increase in pressure prevents venous and lymphatic outflow, and fluid build-up leads to a further increase in pressure in the tissues. High pressures can cause tissue injury and death.

High pressures also prevent blood and nutrients from reaching the tissues, causing further injury. Without appropriate intervention to relieve pressure build-up, a vicious cycle develops. This is essentially the definition of a compartment syndrome.

Muscle and nerve are the tissues most prone to injury. If a compartment syndrome remains untreated even for a few hours, the result is muscle death, which translates into tissue loss and permanent disability.

The death of muscle tissue can also be a very serious problem for the patient's overall health. A muscle breakdown byproduct, myoglobin,

is released into the bloodstream and can cause permanent kidney damage. Thus a compartment syndrome not only endangers normal function; it can also threaten the patient's life. For these reasons, the treatment of a compartment syndrome is a surgical emergency.

Anatomy of the Calf

The anatomy of the calf puts it at increased risk for the development of a compartment syndrome. The muscles of the calf are segregated into four well-defined compartments, surrounded by tight, unyielding fascia. Build-up of pressure in one compartment cannot decompress into another uninjured compartment. In the thigh, on the other hand, the separation of the muscle compartments is not as tight and well defined. An increase in pressure of the anterior thigh muscle compartment can be absorbed by the posterior compartment. This dissipation of pressure does not occur in the calf.

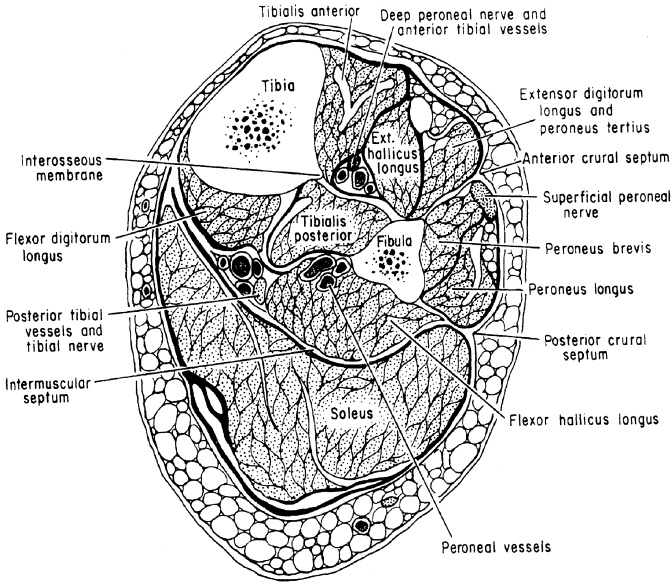
Understanding the nerves and muscles in each of the four compartments of the calf facilitates examination of an injured leg.

Table 1. Compartments of the Calf

Compartment	Nerve	Motor Function	Sensory Distribution
Anterior	Deep peroneal	Dorsiflexion of foot and toes	Dorsal first web space
Lateral	Superficial peroneal	Eversion of foot	Dorsal aspect of foot except for area noted above
Posterior	*	Plantarflexion of foot	*
Deep posterior	Posterior tibial	Inversion of foot, plantarflexion of toes	Plantar surface of foot

* The sural nerve runs in the subcutaneous tissue of the posterior calf skin; it does not run in the posterior compartment of the calf. The sural nerve provides sensation to the lateral aspect of the foot. This is often spared in the patient with a pending compartment syndrome.

In patients with a tib/fib fracture, the force of the injury leads to bleeding at the fracture site and in the muscle, along with additional swelling of the muscle and soft tissues in the calf. Swelling may impair venous return, which can start the vicious cycle leading to the development of a compartment syndrome.



Axial section through the middle third of the calf showing the four compartments. (From Jurkiewicz MJ, et al (eds): Plastic Surgery: Principles and Practice. St. Louis, Mosby, 1990, with permission.)

Signs and Symptoms

It is important to be aware of the potential development of compartment syndrome and to warn patients about the early warning signs. The key is to catch the problem early so that intervention can prevent permanent damage. An untreated compartment syndrome can lead to severe morbidity, extremity loss, and potentially life-threatening complications. The following signs and symptoms should be kept in mind:

- Severe pain in the calf, out of proportion to that expected from the injury
- Significant calf tightness
- Pain with passive stretch of a muscle group; for example, pain in the front of the calf with pointing of the toes and plantarflexing the ankle, or pain in the back of the calf with dorsiflexion of the ankle.
- Tingling or numbness in the foot, along the peroneal and posterior tibial distribution, but *not* necessarily along the lateral aspect of the foot.

Note: Pulses in the foot and ankle may be completely *normal* even with a significant build-up of pressure in the calf compartments.

Prevention

It is vital that the patient keep the leg elevated and not let it dangle in a dependent position. If you have any concerns about the patient's ability to follow these recommendations, the patient should be admitted to the hospital for leg elevation and close observation.

Be careful not to cast the leg too tightly. A tight cast can increase tissue pressure. If swelling in the calf is significant or if you do not have much experience making a cast, consider putting the leg in a splint for the first few days. A splint (sometimes called a backslab in rural areas) is a plaster half-cast placed over padding on the posterior aspect of the calf onto the foot. It is held in place by a loosely applied Ace wrap.

If the patient complains at all that the cast seems too tight, bivalve the cast. Make cuts in the cast along the medial and lateral sides, and separate the underlying padding. This technique may relieve symptoms of pressure. If bivalving the cast does not relieve the symptoms, remove the cast and reevaluate the leg to be sure that a compartment syndrome has not developed.

In patients with an open fracture, do not close the skin if it seems tight. It is better to have an open wound in need of coverage than to risk the development of a compartment syndrome by tightly closing the skin.

Have a high index of suspicion. Remember: a compartment syndrome can occur even with an open fracture and even when the patient has normal pulses.

Treatment

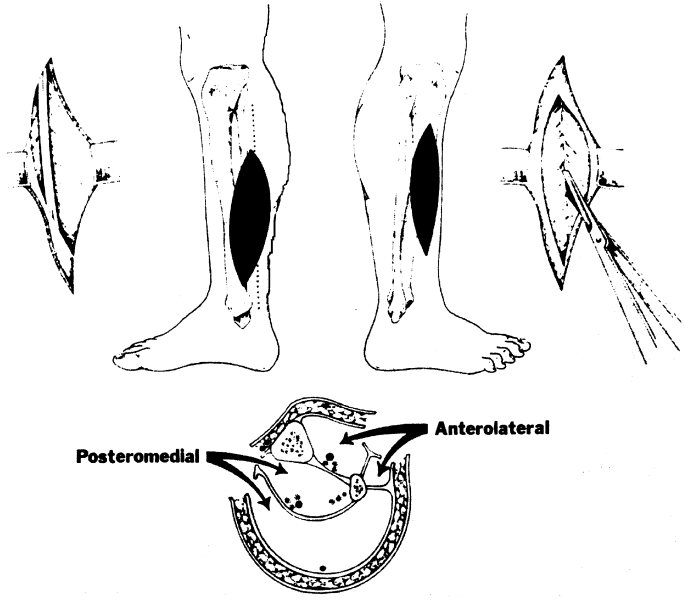
The key to treatment is to open the involved compartments before permanent tissue damage has occurred. Treatment is emergent. You should not wait for many hours or days for a specialist to be available. Each compartment must be individually opened (see diagrams and descriptions).

Often, when you open the compartment, the bulging muscle initially looks purple and dead. Give the tissue a few minutes; it often becomes pinker and healthier-looking. Muscle that remains dark and purple, however, is dead and should be excised.

The incisions should be left open. Saline dressings are a good choice for wound care.

Further surgery is needed for wound closure. Wait at least 3–4 days for the swelling to lessen. A split-thickness skin graft (STSG) is almost always required for wound closure. If you attempt to close one of the incisions primarily, be sure that there is no tension on the skin closure.

Adequate stabilization of the fracture is also required. Usually temporary stabilization can be attained with a posterior splint. If an orthopedic surgeon is available, more definitive stabilization should be done.



Adequate treatment of a compartment syndrome requires two incisions on the calf. One incision is made along the medial aspect of the calf, 2–3 cm posterior to the medial edge of the tibia. This incision allows access to the two posterior compartments. The second incision—on the lateral aspect of the calf, immediately in front of the fibula—allows access to the anterior and lateral compartments. (From Cameron JL (ed): Current Surgical Therapy, 4th ed. St. Louis, Mosby, 1992, with permission.)

Back to our case example. As you may have guessed, he developed a compartment syndrome that was not recognized.

Open Fractures

The ultimate treatment of open fractures requires specialists, but as a nonspecialist you can take steps to improve the patient's chances for a good outcome until specialty care is available.

Open fractures of the lower leg are a major cause of morbidity because of the high propensity for development of osteomyelitis and inadequate bone healing.

Leg of a patient who sustained an open tib-fib fracture 1 year earlier. No soft tissue coverage was provided at the time of injury. The soft tissue never healed over the bone, and the exposed bone is dead. The patient is in constant pain and cannot walk without assistance.

With poor healing of the fracture, the patient may not be able to walk without assist devices (cane or crutches), may have chronic pain, and often is unable to work. Amputation may become necessary to control infection and improve overall function.

The underlying fracture must be anatomically reduced in a stable position to allow healing of the soft tissues. Healthy soft tissue coverage is vital to healing of the fracture.

Basic Treatment

The goal is to achieve a healed bone, surrounded by healthy soft tissue. Intravenous antibiotics should be started immediately. Both gentamicin and a first-generation cephalosporin (e.g., cephalexin) should be given.

Thoroughly wash out the wound under anesthesia as soon as possible after injury. Be sure to remove all foreign material and dead tissue, and copiously irrigate the wound with saline.

In patients with significant contamination or soft tissue injury, it is best to pack the wound with gauze moistened with antibiotic solution or saline and to immobilize the leg in a splint. Return the patient to the operating room in 24–48 hours to wash out and debride the wound again and to stabilize the fracture.

The patient should keep the leg slightly elevated to minimize swelling. Be sure to watch out for signs and symptoms of compartment syndrome.

If soft tissue can be closed over the bone, do so very loosely. Because of swelling, a tight closure actually increases the chances for further

tissue loss, making the wound more difficult to manage. If muscle around the fracture can be sutured together to cover the bone, do so. If the skin cannot be closed, place a STSG over the muscle. This technique is much preferable to tight skin closure.

If only a small area of bone (< 1–1½ cm in diameter) is exposed, the wound may heal secondarily with dressing changes. For larger wounds, a local muscle flap or distant flap is required to cover the fracture and promote proper healing. Flaps require surgical expertise (see below). Optimally, the fracture site should be covered within the first week after injury.

Local Muscle Flaps

Local muscle flaps should be undertaken only by someone with surgical skills. Several muscles in the calf can be used as a local flap to cover an exposed tib-fib fracture site. Muscle flaps also bring robust circulation to the fracture site and thereby improve healing of the injured bone.

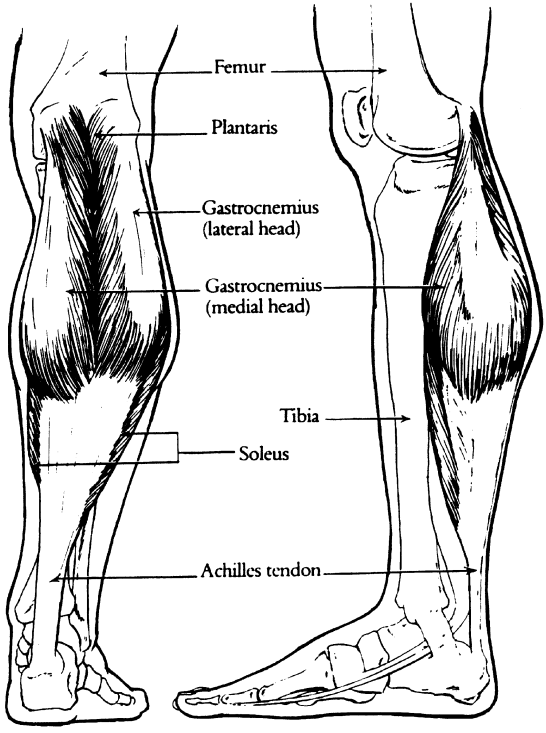
The use of muscle flaps has markedly decreased the morbidity associated with open fractures. Studies have shown that muscle flaps promote fracture healing; the average time for proper healing decreases from 9 to 5 months. The risk of developing osteomyelitis also decreases from 40% to 5%, and the amputation rate decreases from almost 30% to 5% when muscle flap coverage of an exposed bone or fracture is done within the first week after injury.

Proximal and Middle Third of the Calf: Gastrocnemius Flap

The gastrocnemius muscle is the most superficial muscle of the posterior aspect of the calf. It accounts for most of the muscle mass at the top of the calf. The gastrocnemius muscle originates from the distal femur and joins the underlying soleus muscle to form the Achilles tendon.

The main vascular supply enters the gastrocnemius muscle proximally near the knee joint. The muscle can be divided from the Achilles tendon and underlying soleus muscle without interfering with its blood supply. It should be divided longitudinally at its midline so that you take only one-half of the muscle.

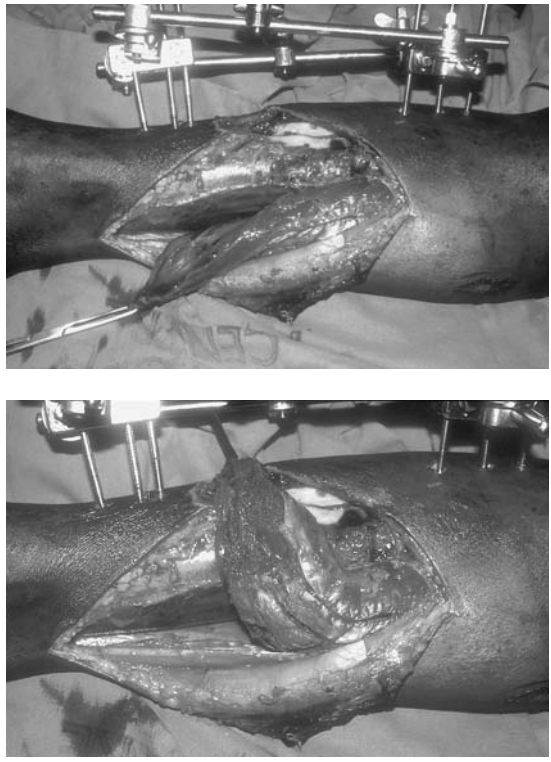
The gastrocnemius muscle then can be easily moved to cover wounds in the middle and proximal third of the calf. Sometimes the origin of the muscle has to be divided to allow increased movement into the wound. Usually the medial gastrocnemius is used. If the lateral muscle is used, it must swing around the fibula, which decreases the range of the flap.



The gastrocnemius muscle and neighboring structures are depicted in posterior and medial views of the leg. The tendon of the gastrocnemius muscle joins with the tendon of the soleus muscle to form the Achilles tendon. (From Strauch B, et al (eds): Grabb's Encyclopedia of Flaps. Boston, Little, Brown, 1990, with permission.)

Operation

1. General or spinal anesthesia is required.
2. Use a tourniquet, if available, for the dissection.
3. Be sure that the wound is adequately debrided and that all dead tissue or bone is completely removed.
4. Do not take overlying skin with the muscle. An STSG is placed over the muscle at the end of the procedure.
5. Extend the open wound onto the medial calf skin to visualize the underlying muscle. Try not to leave skin bridges because they have diminished circulation and may become necrotic.
6. Identify the gastrocnemius muscle. It is the most superficial muscle (closest to the calf skin).



Patient with an exposed, open tib-fib fracture. The injury is less than 48 hours old, and the bone is being covered with a gastrocnemius flap. Note the external fixator, which is stabilizing the fracture.

7. Separate the gastrocnemius muscle from the overlying skin and underlying soleus muscle. This procedure often can be done bluntly or with electrocautery. Be gentle.
8. You will see the vascular pedicle coming into the deep surface of the muscle around the knee. Do not divide or injure these vessels.
9. In the back of the calf, the medial and lateral parts of the muscle come together in the midline. The muscle fibers form a V, whose point marks a natural plane between the two halves of the muscle. The muscle can be divided along this line and then detached from the Achilles tendon using electrocautery.
10. Try to bring the muscle around to the defect. The proximal muscle may need to be freed to allow sufficient length. This procedure can be done safely, but be careful not to injure the vascular pedicle.

11. Once the muscle is freed and seems to reach the wound, remove the tourniquet and ensure hemostasis.
12. The muscle should turn pink and look healthy when the tourniquet is removed. If it remains dark purple, the vascular pedicle has been injured and you are in trouble. Another flap option, perhaps a soleus flap (see below under mid-calf injury) or a distant flap, is necessary.
13. The muscle should be sutured loosely to the wound edges with absorbable sutures. Avoid a tight closure, which may interfere with the circulation to the muscle. Make sure that the blood vessels to the muscle are not kinked.
14. Place a suction drain (if available) or a Penrose drain under the muscle flap and at the donor area. These drains should be brought out through the incisions. They prevent blood and other fluids from accumulating under the muscle flap and under the skin flap that was created when the muscle was dissected free.
15. Place an STSG over the muscle.
16. Place the leg in a posterior splint, and keep it gently elevated.

Postoperative Care

1. The leg should remain elevated and immobilized in either a splint or, if an orthopedic surgeon is available, some type of internal or external fixation device. The leg should not be in a dependent position for at least 7 days after surgery.
2. The dressing should be changed daily. Antibiotic ointment and saline-moistened gauze or a wet-to-wet dressing is best to use over the skin graft.
3. Remove the drains after 2–3 days.
4. The flap initially will be quite swollen. Swelling improves dramatically over the first 2–3 weeks and continues to improve over the next several months.
5. After 7 days, when the wounds are healing well, the patient can gradually let the leg dangle for increasing amounts of time. Start with 15 minutes 2 times/day. When the leg is dependent, it should be gently wrapped with an Ace wrap to prevent swelling.

Middle and Possibly Distal Third of the Calf: Soleus Flap

The soleus muscle lies immediately deep to the gastrocnemius muscle and joins with the gastrocnemius distally to form the Achilles tendon.

The soleus flap is most useful for wounds in the middle of the calf. Although sometimes it can be used for wounds of the lower third, it is not as reliable in the lower leg.

The soleus muscle has a somewhat segmental blood supply without one dominant vessel (as seen in the gastrocnemius muscle). The vessel that enters the top half of the muscle can nourish the whole muscle. In addition, a few smaller vessels in the distal portion of the muscle can nourish the entire soleus if the proximal vessel is divided.

The flap is based most commonly and reliably on its proximal, main blood supply, but at times it can be based on the smaller, distal vessels. Judge which vessel to use by looking at the surrounding damage in the leg. In patients with proximal calf soft tissue damage, it may be prudent to base the flap on the distal vessels. If the injury has injured the distal tissues, base the flap on the proximal vessel.

Operation

1. General anesthesia or spinal anesthesia is required.
2. Use a tourniquet, if available, for the dissection.
3. Be sure that the wound is adequately debrided and that all dead tissue or bone is completely removed.
4. Extend the open wound onto the medial calf skin to visualize the underlying muscles. Try not to leave skin bridges, which have diminished circulation and may become necrotic.
5. Identify the gastrocnemius muscle, which is the most superficial muscle (closest to the skin). The plane of dissection is between the gastrocnemius muscle and underlying soleus muscle. Keep the gastrocnemius muscle attached to the overlying skin as you separate it from the underlying soleus. This procedure often can be done bluntly or with electrocautery. Be gentle to avoid tearing of blood vessels.
6. Bluntly separate the soleus muscle from the muscles of the deep posterior compartment, taking care to avoid damage to blood vessels coming off the posterior tibial artery. Determine which way the flap will be based and divide the vessels that are unnecessary.
7. Determine whether the blood vessel on which you want to base the flap is sufficient to supply circulation to the flap. Place a small vascular (noncrushing) clamp across the vessels that you plan to divide before doing so. If the muscle turns purple with the clamp in place, the blood vessel you are basing the flap on will not supply enough circulation to the flap.

8. Divide the muscle from the Achilles tendon (if basing the muscle proximally) or near its origin (if based on distal vessels).
9. Bring the muscle to the exposed fracture site. The muscle may need to be freed from the tissues around the pedicle to allow sufficient length. This procedure can be done safely, but you must be careful not to injure the vascular pedicle.
10. Once the muscle is freed and seems to reach the wound, remove the tourniquet and ensure hemostasis.
11. The muscle should turn pink and look healthy when the tourniquet is removed. If it remains dark purple, the vascular pedicle has been injured and you are in trouble. A distant flap is required to cover the wound.
12. The muscle should be sutured loosely to the wound edges using an absorbable suture. Tight closure may interfere with the circulation to the muscle. Make sure that the blood vessels are not kinked.
13. Place a suction drain (if available) or a Penrose drain under the muscle flap and in the area from which the muscle was taken. These drains should be brought out through the incisions. They prevent blood and other fluids from accumulating under the flap or at the donor site.
14. Place an STSG over the muscle.
15. Place the leg in a splint, and keep the leg gently elevated.

Postoperative Care

Follow the steps described above for the gastrocnemius flap.

Distant Flaps

In high-energy wounds, the muscles in the calf may be too damaged to use for coverage of the fracture site. In this case, a distant flap is required to achieve healing of the fracture and soft tissues.

Although cumbersome for the patient, a cross-leg flap can be quite useful if you have no access to a reconstructive specialist (see chapter 14, "Distant Flaps," for details).

The other option is a free flap, which is preferred if specialist help is available. Free flaps, however, are beyond the ability of clinicians without microsurgical skills. Transfer of the patient is required.

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