

Transtibial Amputation with Extended Flap and Bone Bridging

Pre-Op Plan:

Amputation indication: four years status post a crush injury to his left foot. Patient experiences chronic pain and dysfunction after several reconstructive surgeries.

One very critical decision is where exactly to cut the tibia and fibula for this particular individual. Several factors must be taken into consideration when choosing where to cut the bone.

1. Historically, many surgeons recommended a tibial bone cut that was always one hand's breadth distal to the tibial tubercle. This gives a tibial length of between 10 and 15 cm depending on the size of the surgeon's hand.
2. Recently it has been recognized that additional tibial length may have some value up to a certain level.
3. It is almost always recommended to avoid amputation in the distal 1/3 to 1/4 of the tibia, as there is very little muscular tissue for padding in the distal most portion of the lower limb.
4. Calves vary dramatically in their anterior to posterior diameter, so ideally the tibia would be divided at a point where the distal edge of the appropriate length posterior flap would occur at the junction of the soleus muscle and the Achilles tendon.
5. When the transtibial amputee is standing up, the distance between the ground and the end of the residual limb allows adequate space for the liner, socket, proximal connector, pylon, distal connector, and foot.
 1. 4 to 6 inches of space allows for the use of most standard prosthetic feet and a pin lock suspension system.
 2. 6 to 8 inches allows for the addition of a shock absorbing component to the above standard prosthetic system.
 3. 8 to 10 inches is required for the use of most integrated high-impact foot/pylon/shock absorbing systems.
6. Practically, the tibial bone cut is planned to keep one third to one half of the length of the tibia. The exact location is based most commonly on the quality of the soft tissue envelope, the shape and size of the calf muscle, the overall height of the individual, and the location of scars, ulcerations or soft tissue defects.

Skin Incisions and Flaps:

Measure the anterior to posterior diameter of the limb, at the level of the tibial bone cut. In this case the diameter is 12 cm. The skin of the flap needs to rotate all the way from the posterior aspect of the limb up and over the distal end, to join the anterior skin in a tension free closure. This flap has an axis of rotation that is just posterior to the limb, not at the mid-limb as is still shown in some older texts. Therefore, the traditional flap length needs to be equal to the AP diameter of the limb, plus an additional cm to allow for the curvature of the tissue around the end of the limb.

In the case of the **extended** posterior soft tissue flap, an additional 5cm must be added to that measurement. Therefore, in this case the length of the flap is 18 cm. (the 12 cm diameter plus 1 cm for rotation plus 5cm of added length).

Draw incision lines:

The skin incisions are drawn out based on the proposed level of the tibial bone cut.

1. The **medial** and **lateral** extensions are drawn straight distally, and do not drift posteriorly. The length of the extensions is equal to the AP diameter of the limb at the proposed level of the tibial bone cut, plus 6 additional cm. The extended flap is approximately 5cm longer than the traditional posterior flap.
2. **Anterior** incision – down approx half diameter of limb. Medially this extends down to an inflection at the edge of gastrocnemius muscle. Laterally, this extends down to the posterior edge of fibula. The incisions curve very slightly from distal to proximal as it moves from anterior to posterior.
3. **Posterior** incision is drawn straight around the back of the leg, connecting the ends of the medial and lateral incisions.

Incisions should be made in a decisive fashion to provide a clean and pure incision through skin, subcutaneous tissue, down to and through the fascia. One should avoid feathered or beveled edges, and avoid irregularly cut surfaces that can lead to devitalized tissue which may be a focus for non-healing or infection.

Nerves:

There are 5 nerves to isolate in the transtibial amputation. All 5 nerves *should* be carefully identified, isolated, drawn down and divided in order to avoid having the nerve endings in the area of scar, pulsating vessels or closure. Nerve endings should also be positioned to be away from areas of pressure in a standard prosthesis.

1. Saphenous Nerve – find the saphenous vein, nerve is usually just lateral to the vein. Separate vein and nerve, drawn down nerve and cut, no need to suture ligate this nerve. Ligate the saphenous vein with absorbable suture.
2. Deep Peroneal Nerve – Throughout its course, it runs with the anterior tibial vessels. Most commonly missed nerve. If ligated to the vessels, may sense the cadence of the pulse and cause throbbing local pain or throbbing phantom sensation. Separate this nerve, clamp the vessels, then drawn down the nerve and ligate. No need to suture ligate this nerve. Then Double ligation of anterior tibial vessels.
3. Superficial Peroneal Nerve – In the lateral compartment, the course of the superficial peroneal nerve changes dramatically from proximal to distal. Proximally, it is found between the peroneus longus and peroneus brevis muscle. Distally, it can pierce the fascia and change from the lateral to the anterior compartment. Find the nerve, drawn down and ligate. No need to suture ligate this nerve.
4. Tibial Nerve – This nerve runs throughout its course with the posterior tibial vessels. It is the largest nerve in the lower leg. Separate from the posterior tibial vessels by opening the perineurium and physically pulling away from the vessels. Clamp the posterior tibial vessels to exclude the nerve. Draw the nerve down and divide. Ligation of this nerve to prevent bleeding from the nerve is controversial. I rarely ligate the nerve, and only do so if I visibly see small vessels that may bleed.
5. Sural nerve – This superficial nerve runs in the posterior flap, and is located between the skin and the superficial fascia. It runs just lateral to the small saphenous vein (why it is not called the sural vein I will never know). The vein is isolated and ligated. The Sural nerve needs to be shortened dramatically (pull down 10-15cm and ligate) so as to position the nerve ending not just away from the incision, but well up posteriorly and not in the tissue covering the distal end of the amputation.

Muscles:

The muscles to be managed in a transtibial amputation are located in the four anatomic compartments of the lower limb.

1. Anterior compartment
 1. Anterior Tibialis (AT), Extensor Hallucis Longus (EHL), and Extensor Digitorum Longus (EDL)
 2. The anterior compartment muscles are transected at the level of the tibial bone cut early in the operation. The anterior tibial vessels and the deep peroneal nerve are located at the depth of the anterior compartment, just anterior to the syndesmotomic membrane.
2. Lateral Compartment
 1. Peroneus Longus (PL) and Peroneal Brevis (PB).
 2. These muscles are transected at the same level as the anterior compartment muscles, at the level of the tibial bone cut.
3. Deep Posterior Compartment
 1. Posterior Tibialis (PT), Flexor Hallucis Longus (FHL), and Flexor Digitorum Longus (FDL).
 2. These muscles are carefully isolated, and the posterior tibial vessels and peroneal vessels dissected free before transection. After dissecting down the back of the tibia and fibula to remove the foot, the deep posterior compartment is carefully lifted off of the soleus. Care is taken to keep the muscular investing fascia with the soleus. Care is also taken to find and clamp the small perforating vessels that go from the posterior tibial and peroneal vessels down into the soleus, so that these perforating vessels do not retract down below the fascia and cause bleeding that may be difficult to control.
 3. After separating out the posterior tibial vessels, the tibial nerve, and the peroneal vessels – the PT, FHL, and FDL are transected at or just distal to the level of the tibial bone cut.

4. Superficial Posterior Compartment

1. Soleus, Gastrocnemius
2. These two muscles make up the muscular padding of the long posterior flap.
3. Care is taken not to separate the skin and subcutaneous tissue away from the fascia of the superficial posterior compartment, as this may compromise vascular flow to the skin and impair healing.
4. It is important to understand that these muscles get their vascular supply from very different sources. Soleus originates below the knee joint in the tibia, and get its vascular supply from pedicles from popliteal, peroneal, and posterior tibial arteries. The majority of the blood supply is below the trifurcation of the vessels.
5. The gastrocnemius originates above the knee joint on the distal femur, and gets its blood supply proximally from branches off of the popliteal artery, above the trifurcation.
6. Occasionally the soleus can have poor arterial perfusion while the gastrocnemius has excellent perfusion. In other instances, the soleus has large venous channels and is very edematous and swollen. In these types of cases, the soleus muscle can be resected up near its origin preserving the gastrocnemius muscle. The posterior myofascialcutaneous flap can survive very well with only thegastrocnemius muscle, if its fascia is carefully preserved.

Vessels:

There are 3 major vessel groups to isolate and securely ligate in the transtibial amputation: the anterior tibial vessels, the posterior tibial vessels and the peroneal vessels. These named vessel groups are typically doubly ligated first with a stick tie through the artery so that it will not pulse off of the vessel. Proximal to this, a free tie is used to avoid the possible bleeding form the stick tie, or the possibility of a small arterial-venous fistula or pseudo aneurysm forming at the stick tie site.

1. The Anterior tibial vessels are located within the anterior muscle compartment, at the deepest or most posterior surface, just anterior to the syndesmotic membrane. They are most easily visualized after transecting the anterior muscles and finding the transected vessels at the posterior aspect of the anterior compartment.
2. The Posterior tibial Vessels are located within the fascia of the deep posterior muscle compartment. They are easily visualized after gently lifting the deep posterior compartment off of the superficial compartment by manually separating the fascial plane between the soleus and deep compartment, starting on the medial edge, at the proximal portion of the flap. If the interval between the soleus and gastrocnemius is entered inadvertently, this becomes obvious when the plantaris tendon comes into view.
3. The Peroneal vessels are also within the deep posterior muscle compartment, but are not as obviously identified as the posterior tibial vessels. They lie lateral to the posterior tibial vessels, and are between the FHL muscle and the PT muscle, very close to the deep edge of the fibula. The large veins are occasionally torn during the transection of the fibula, and occasionally bleeding that appears to be coming from the fibula, is actually coming from the peroneal veins. If this is the case, placing a bone hook into the fibula, and lifting the limb by the fibula allows the peroneal vessels to fall away from the bone so they can be clamped more proximally and ligated at the site of bleeding under direct visualization.

Bones/Bridge:

Tibial Osteoperiosteal Flap:

A longitudinal incision is made to enable dissection of the skin and subcutaneous tissue off of the periosteum. The tibial periosteum is preserved to help build a reconstructive bone bridge across the distal tib-fib. The periosteum is divided on the anterior and posterior edges of the tibia, and transected distally.

A sharp osteotome is used to elevate an osteoperiosteal flap. The flap should be a full thickness periosteal flap with small pieces of cortical bone adherent to the flap.

The periosteum is transected proximally up past the area where the tibia will be transected. The flap is left attached proximally to maintain blood supply.

Tibia:

- the tibia is typically divided at the level of the anterior skin incision. The tibia is initially transected with an oscillating saw perpendicular to its long axis. Take care to preserve the attachment of the osteoperiosteal flap. Just before closure, the tibia is shaped with an anterior bevel to better accommodate prosthetic fitting.
- The tibia is triangular in shape, and the anterior corner can be quite sharp and lead to a painful bone prominence at the distal and anterior aspect of the amputation site.
- A tibial bevel is created to re-shape the tibia and remove the anterior 1/3 of the tibia. I prefer to cut from the transected surface of the bone, starting just anterior to the medullary canal and beveling up at 45° to a point approximately one cm proximal to the original cut. The edges of the tibia are then smoothed and shaped with either the saw blade, a rasp, or the rongeur.

Fibula:

- the fibula is traditionally divided between 1 and 2 cm **proximal** to the level of the divided tibia. However, in the bone bridge procedure it is cut approximately 3cm **distal** to the cut of the tibia in order to have extra fibular bone available for the bone bridge. The fibula is cut perpendicular to its long axis.

Bridging:

1. Measure resting distance: Typically 1.3cm to 1.6cm.
2. Elevate fibular osteo-periosteal flap: Elevate an osteo-periosteal flap from the anterior and medial surface of the fibula. Hold the distal end of the fibula with a bone clamp to stabilize the fibula and facilitate elevation of the osteo-periosteal flap with the osteotome.
3. Create segmental osteotomy: Use the saw to create two cuts in the fibula and remove the interval segment. The proximal cut is at the same level as the end of the tibia. The distal cut creates a 1.5cm soft tissue gap and leaves soft tissue attached to the distal piece of fibula which will be used as the bone bridge.
4. Cut graft to size: Mark the length of the fibular graft needed to fit the space (1.5cm). Cut the excess from the graft while keeping some soft tissue attachment.
5. Position the graft: Position the bone bridge graft between the fibula and tibia.
6. Compress with bone clamp: Use a large pointed bone clamp to capture the strut graft and compress it between the tibia and the fibula.
7. Drill fibula and graft: The fibula and graft are over drilled with a 3.5mm bit. This allows compression screw fixation to the tibia. Use irrigation to keep bit cool and minimize thermal damage.
8. Drill tibia: Place drill sleeve into the 3.5mm fibular hole and then drill the tibia with a 2.5mm bit. Irrigate to keep cool.
9. Depth gauge: Measure the necessary screw length with a depth gauge.
10. Depth gauge: Measure the necessary screw length.
11. Tap the tibia: Tap the drill hole with a 3.5mm tap. The tibial cortex is very hard and tapping facilitates placement of the screw and its purchase for stronger resistance to pull out.
12. Place screw: Because of over drilling (3.5mm) the fibula and graft and tapping the tibia, the screw will compress the graft between the fibula and tibia.
13. Flap positioning: Position the fibular osteo-periosteal flap proximal to the bone bridge. Then position the tibial osteo-periosteal flap distally over the bone bridge.
14. Suture flap in place: Suture the tibial osteo-periosteal flap in place with absorbable suture. The periosteum forms a surface below and above the bone bridge. In essence, a tube of periosteum around the fibular graft.
 - suture over the beveled area
 - suture over the fibula and then to its anterior surface
 - suture to the posterior surface of the fibula
15. Trim excess flap: If not trimmed, it will form excess bone in a problematic area.
16. Trim flap at bevel: To avoid extra or hypertrophic bone growth in the area.

Closure:

Muscular Closure:

1. The skin is marked anteriorly to define the area of inset for the extended posterior flap. The flap is positioned to trial the inset, and a scalpel is used to dissect through the epidermis and dermis. The epidermis and dermis are dissected up off of the subcutaneous tissue. The subq tissue is preserved to provide extra padding for the tibia. The muscular closure should be considered as reconstruction. In the transtibial amputation the fascia of the superficial muscular compartment is advanced up and over the end of the tibia to be sewn into the periosteum of the tibia and to the fascia of the anterior compartment. Since this muscular fascia is sewn to the bone via its periosteum, this is *amyodesis*. Some surgeons prefer to drill holes in the edges of the tibia just medial and lateral to its crest. I personally have found that I am better able to advance the muscle proximally up and over the tibia by sewing to periosteum, and am not able to advance the muscle as well using the drill hole technique
2. To accurately secure this myodesis, typically three or four sutures are carefully placed under direct vision in the periosteum and in the deep and superficial layers of the fascia. The sutures do not grab muscle tissue. They may secure the edge of the Achilles tendon in the longer transtibial amputation. The sutures are all placed and clamped, and only tied after placing all three or four myodesis sutures. If the first suture is tied, it is more difficult to accurately see the layers and accurately place the subsequent myodesis sutures.
3. The myodesis is typically performed with an absorbable suture of moderate strength such as number 1 or 0 suture material.

Fascial Closure: The fascial closure needs to be secure.

1. A deep suction drain is placed prior to the fascial closure. The drain should not exit near the subcutaneous surface of the tibia, as the small scar left from the drain exit site can be a source of pain in a prosthesis. Instead, the drain should be placed so as to exit in the soft tissue of the anterior compartment.
2. The fascial closure is typically performed with an absorbable suture of moderate strength such as 0 suture material.

Subcutaneous Tissue Closure

1. Skin healing in an amputation surgery can take longer than in other surgical procedures. A subcutaneous closure can help re-enforce the approximation of the skin edges and minimize wound dehiscence.
2. The subcutaneous closure is typically performed with an absorbable suture of light strength such as 2-0 suture material.

Skin Closure:

1. As mentioned, skin healing in amputation surgery can take longer than in other surgical procedures. A suture technique that minimizes trauma to the skin edge is needed. I typically use 3-0 nylon suture and prefer it over staples as I can leave the nylon in longer with less irritation. It is not uncommon to leave sutures in 4 or 5 weeks. I have found that skin staples tend to show irritation and redness sooner than nylon suture.
2. The skin closure is typically re-enforced with skin tapes to help take tension off of the sutures.

Appearance of the extended posterior flap: The initial appearance of the extended posterior soft tissue flap is quite bulbous and bulky. However, in a very short period of time the edema and the volume of the extended flap resolve, leaving a residual limb with a very well padded distal tibia and a contour that fits nicely into a prosthesis.

Bandages and Casting:

1. The incision is initially covered with non-stick gauze.
2. Then 4x4 gauze is opened up and carefully layered over the amputation site so as not to form a large single mass of bandages that could potentially shift in position and cause a pressure point inside the cast.
3. Fluff gauze is laid over this to even out the padding.
4. A amputation sock is gently rolled over the gauze to help shape the limb and minimize the post-operative edema.

5. Cotton cast padding is applied over the amputation sock to further pad the amputation site
6. A reticulated distal foam end-pad is placed over the end of the amputation.
7. Tibial crest pads are placed over the anterior-medial and anterior-lateral tibial flare regions. These two regions are loaded in a traditional transtibial prosthetic socket. Padding helps to protect the tibial crest and push the tibia back away from the cast to protect the skin over the distal end of the tibia. The narrow pad goes on the lateral side to avoid pressure on the peroneal nerve. A patellar pad is placed over the patella to identify the location for the patellar-cut as the last step in the final casting procedure.
8. Two rolls of plaster with elastic gauze are used for the initial layers of the cast to both mold the amputation site and to compress the reticulated foam distal end-pad. Care must be taken to not wrap circumferentially as to avoid constricting the limb.
9. A 5 ply plaster splint is added to strengthen both the medial side of the knee area and the distal end of the cast.
10. Two additional rolls of regular cast material with standard non-elastic gauze is used to complete the cast.
11. The casted limb is laid onto a pillow to allow 3 to 5 degrees of knee flexion, avoiding hyperextension of the knee; and to facilitate molding of the cast.
12. A supra-condylar mold is applied to contour the cast above the femoral condyle to control rotation and prevent the cast from falling off the patient. The larger the patient, the larger the supra-condylar mold.
13. The patellar area of the cast is cut out to provide a landmark to assure the nurses, therapists, and physicians that the cast is indeed located properly and has not rotated or moved distally.