Surgical Technique for Osteocutaneous Pedicle Flap Transfer for Salvage of Transtibial Amputation After Severe Lower-Extremity Injury

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Introduction

Osteocutaneous pedicle flap transfer from the foot can be used to “salvage” a transtibial amputation level when the severity of an injury precludes a transtibial amputation.

Some injuries generate massive bone loss from the tibia and/or soft-tissue destruction around the proximal part of the tibia and the knee that preclude the performance of a transtibial amputation; thus, the patient requires an amputation at a more proximal level, such as a knee disarticulation or transfemoral amputation. Each of those procedures results in loss of the native knee and loss of length of the mechanical lever arm of the limb, which greatly increases the amount of energy required to walk, even with a prosthesis¹⁻⁴. An alternative technique is to “salvage” a transtibial amputation level by using a rotational osteocutaneous pedicle flap transfer from the foot^{5,6}. Osseous length and soft-tissue coverage are augmented with this flap to provide a functional transtibial level. This procedure is possible if the foot on the same leg is uninjured or minimally injured. Portions of the calcaneus and its associated skin and soft tissues are secured to the remaining proximal part of the tibia and surrounding soft tissues, preventing flap migration. The neural and vascular attachments to the hind-foot structures are maintained, providing a durable, sensate end-bearing surface for prosthetic fitting.

The filet-of-foot pedicle flap⁵ is indicated for a limb injury in which the knee has been spared, the extensor mechanism is intact, the foot is viable, and the tissue damage between the knee and ankle is so extensive that amputation of the limb is preferred to salvage (Figs. 1-A, 1-B, and 1-C). As a result of the narrow indications, few patients warrant this procedure; at our institution, one or two patients qualify per year. The procedure is rarely if ever done without

consultation with the patient and the patient's family. It is important for the patient to comprehend the rationale, the benefit of using a part of the body that would otherwise be discarded, and most importantly the cosmetic appearance and function of the limb following surgery.

The procedure is done in eight steps:

Step 1: Preoperative assessment

Step 2: Remove provisional implants

Step 3: Develop the flap

Step 4: Contour the calcaneus

Step 5: Prepare the proximal part of the tibia and surrounding tissues

Step 6: Secure the calcaneus to the tibia

Step 7: Repair and reconstruct the soft tissues

Step 8: Postoperative care and rehabilitation

Step 1: Preoperative Assessment

If the posterior tibial artery is not palpable, obtain an angiogram to determine the vascular supply distal to the traumatic zone and to prepare for conversion to a composite free microvascular transfer.

- Evaluate the extensor mechanism; obtain orthogonal radiographs of the tibia, ankle, and foot; and carefully assess the vascular supply distal to the zone of injury.
- Patients do not require an angiogram if the posterior tibial artery is normal on examination. Doppler evaluation can confirm the patency of the posterior tibial artery, and a strong triphasic signal precludes angiography.
- The pedicle flap can be based on the anterior tibial artery by preserving the communication

of the anterior and posterior tibial arteries through the dorsalis pedis and the deep plantar arch of the foot. However, if the posterior tibial artery is not palpable on examination, obtain an angiogram to determine the vascular supply distal to the traumatic zone and to prepare for conversion to a composite free microvascular transfer.

- Consult with a specialist in plastic surgery. Our initial procedures were performed in conjunction with the plastic surgery department. Although the pedicle flap procedure can be done with a knowledge of the anatomy of the lower limb, make sure a microsurgical team is available if the pedicle fails and requires conversion to a free microvascular composite flap transfer.

Step 2: Remove Provisional Implants

Remove provisional stabilization implants and minimize surgery about the knee.

- Position the patient supine on a radiolucent operating table, and apply a tourniquet to the proximal part of the thigh.
- Provisional stabilization of the damaged limb is ideally achieved by external fixation or internal fixation with a plate. Remove these implants before you develop the pedicle flap and minimize the surgery about the knee.

Step 3: Develop the Flap

The dissection about the tarsal tunnel is the critical portion of the operative technique.

- Elevate the leg to exsanguinate it by gravity, and inflate the tourniquet to 100 mm Hg above the systolic blood pressure. Extend the traumatic wound along the lower leg in line with the posterior-medial border of the tibia, curving distally at the level of the medial malleolus parallel with the course of the posterior tibialis tendon. Continue the surgical incision along the medial side of the foot, turning it at a right angle just distal to the sesamoids and along the distal aspect of the plantar fat pad to the head of the fifth metatarsal.
- The dissection about the tarsal tunnel is the critical portion of the operative technique. A number-10 scalpel is the instrument of choice. Incise the deltoid ligament sharply and resect the posterior tibial, flexor hallucis longus, and flexor digitorum longus tendons to leave the posterior tibial nerve and artery as the remain-

ing structures in the tarsal tunnel (Figs. 2-A and 2-B). Protect the neurovascular bundle with a vessel loop. It is important to preserve tibial nerve function to preserve a sensate foot.

- Excision of the talus greatly simplifies the procedure. Remove the talus by incising the robust soft-tissue attachments, while maintaining tension with a large Weber clamp on the talus. This exposes the calcaneus and facilitates access to the neurovascular bundle as it courses to the deep plantar arch.
- Following removal of the talus, direct the scalpel distally along the plantar cortex of the navicular, along the medial cuneiform and along the plantar surface of the first metatarsal. Return the dissection to the Chopart level and incise the attachments with the navicular and cuboid to remove them, leaving the calcaneus alone in continuity with the plantar flap.
- The posterior tibial artery arborizes with the deep plantar arch in the interosseous muscles of the foot such that “keeping to bone” on the plantar surface of the midfoot and forefoot will preserve the vascular tree. We recommend sharp dissection with a scalpel, avoiding electrocautery to minimize thermal necrosis and increased wound burden. Sharply divide the interosseous muscles along the metatarsals from the medial arch to the plantar aspect of the fifth metatarsal. Resect the first metatarsal, carefully preserving the dorsalis pedis artery as it descends between the bases of the first and second rays. Preservation of the dorsalis pedis artery is essential in the absence of a patent posterior tibial artery. In this situation, you can consider conversion to a free tissue transfer.
- Remove the lesser metatarsals and toes to separate them from the calcaneal composite flap (Fig. 2-C). Retain lateral hindfoot soft tissue. Keep the flap warm and moist with saline solution-soaked sponges.

Step 4: Contour the Calcaneus

Any deviation from perpendicular will translate to an axial deformity in the reconstructed limb.

- Contour the calcaneus with an oscillating saw. Resect the posterior facet parallel to the plantar aspect of the bone at the articular junction of the facet with the tuberosity, and resect the anterior process immediately proximal to the calcaneocuboid articular surface perpendicular to the long axis of the calcaneus. Cut the medial sustentaculum, including a good por-

tion of the middle facet, flush with the medial border of the calcaneus (Figs. 3-A, 3-B, and 3-C).

- Osseous resection as described transforms the undulating form of the heel into a box shape. The osteotomy at the distal end of the calcaneus will determine the alignment of the limb following osteosynthesis with it to the tibia. Any deviation from perpendicular will translate to an axial deformity in the reconstructed limb.

Step 5: Prepare the Proximal Part of the Tibia and Surrounding Tissues

Retain viable soft tissues and bone, but resect the fibula obliquely.

- Sharply dissect the intercalary soft tissue and the remaining bone from the proximal fracture in the tibia and from the ankle, leaving a cuff of soft tissue about the posterior neurovascular bundle. A vascular clip is useful for managing small perforators emanating from the artery. Do not skeletonize the bundle. In cross section, it is slightly smaller than a large Penrose drain (approximately 0.5 × 1.5 cm).
- Osteotomize the proximal part of the tibia transversely, adjacent to the inferior aspect of the tibial tubercle, using an oscillating saw (Fig. 4). Transect the gastrocnemius and soleus muscles at this level or distally, on the basis of their viability. Resect the fibula obliquely at the level of the tibial osteotomy.

Step 6: Secure the Calcaneus to the Tibia

Avoid varus and recurvatum malalignment.

- Release the tourniquet to assess the viability of the pedicle flap and to manage substantial bleeding. Achieve hemostasis with gentle compression of the flap and minimal electrocautery. The pulse is visible, and bright red bleeding is noted at the distal cut edge of the plantar pedicle flap. Remove the flexor tendons and the volar plates from the sole of the foot (Fig. 5-A). Cutaneous circulation in the lateral foot area can be sluggish, as this is the distal extent of the collaterals to a watershed area predominantly supplied by the extinct peroneal artery.
- Gently coil the posterior tibial artery, vein, and nerve in a large loop and rotate the calcaneus cephalad with its distal end, the anterior

process, mated to the remaining inferior part of the tibia. Rotate the calcaneus slightly about its long axis to position the sole of the foot in the most desirable location based on the coverage needs dictated by the zone of injury.

- Initially, we used a 90-90 wiring technique for osteosynthesis (Fig. 5-B), which was supplemented with an early postoperative plaster cast. For several years, we have used a six or seven-hole large-fragment dynamic compression plate instead. Apply the plate to compress the calcaneus to the tibia in a position that favors optimal position of the sole as it rests on the anterior aspect of the limb (Figs. 5-C and 5-D). In most circumstances, the plate rests on the medial surfaces of the tibia and calcaneus.
- Use intraoperative radiography to ensure reasonable alignment of the reconstruction. Prosthetic management can compensate for most minor malalignments. Avoid varus angulation and, especially, recurvatum. A prominent calcaneus with an axis anterior to the anatomic extension of the tibia complicates prosthetic management and may substantially alter gait.

Step 7: Repair and Reconstruct the Soft Tissues

The injured limb is routinely very swollen, and in some cases complete coverage requires split-thickness skin-grafting.

- Close the soft tissues in layers.
- Completion of the tibiocalcaneal osteosynthesis leads to inseting of the flap and contouring of the limb. The adjacent soft-tissue planes are paired so that layered closure may be performed and mismatch of adjacent tissue contours is minimized.
- The injured limb is routinely very swollen, and in some cases complete coverage requires some split-thickness skin-grafting. Skin-grafting can be done at the time of the pedicle graft or deferred for a few days (Fig. 6). When it is delayed, use a negative-pressure-dressing technique to reduce the edema and maintain wound hygiene and viability.

Step 8: Postoperative Care and Rehabilitation

As the initial reconstruction is sometimes extremely bulbous, continually advise the patient that the shape will improve dramatically over time with shrinkage of the limb.

- Dress the limb with nonadherent medicated gauze, bulky absorbent pads, and a compressive circumferential wrap. Dress skin grafts with a negative pressure dressing, or provide a bolster with Xeroform gauze (Covidien, Mansfield, Massachusetts) and cotton balls soaked in mineral oil. Apply a thick posterior plaster splint with the knee in full extension.
- Elevate the limb and mobilize the patient with a walker on postoperative day two. Inspect the wound on approximately day five. Perform dressing changes as needed, and apply a compressive wrap and/or a limb shrinker, which should be used continuously for several weeks.
- The initial reconstruction is sometimes extremely bulbous (Fig. 7-A). Thoughtfully counsel the patient and continually advise him or her that the shape will improve dramatically over time with shrinkage of the limb (Figs. 7-B and 7-C).
- Physical therapy for quadriceps training and knee range of motion and a program of limb sensitization are recommended. Obtain biplanar radiographs at six to eight weeks to assess stability and healing of the tibia and calcaneus. Patients are generally ready for a temporary prosthesis and weight-bearing at eight to ten weeks.

Results

In our original study, ten men and four women with a mean age of 43.2 years (range, twenty-four to sixty-four years) underwent an osteocutaneous pedicle flap transfer with use of the ipsilateral foot for salvage to achieve a transtibial amputation level⁷. Because of bone and/or soft-tissue injury, none of these patients could have been treated with conventional transtibial amputation providing a functional length and durable stump. The initial injuries of the twelve patients who were followed for more than twenty-four months consisted of a type-IIIB open tibial fracture in eleven and extensive soft-tissue loss secondary to a burn without an underlying fracture in one.

Initial surgical debridement of open fractures was performed within six hours in all cases. Provisional stabilization was achieved with external fixation (n = 8), plate fixation (n = 2), or intramedullary nailing of the tibia (n = 1). One patient had dual plate fixation of an ipsilateral bicondylar tibial plateau fracture on postoperative day two. Osteocutaneous pedicle flap transfer was performed at a mean of 9.4 days (range, four to twenty-one days) after the injury. A mean of 3.4 procedures for debridement and provisional stabi-

lization of the leg were undertaken prior to the flap procedure. On average, an additional 7.1 cm (range, 5.8 to 8.2 cm) of osseous length was obtained when the calcaneus was secured to the tibia.

Seven of the fourteen patients required a total of twelve additional procedures in the early postoperative period for wound debridement, delayed wound closure, or skin-grafting. All wounds were healed within ten weeks. Prosthesis usage began at a mean of 11.4 weeks (range, eight to fifteen weeks). Four of the fourteen patients were treated for infection; two of the infections were superficial and two were deep. None of the infections recurred, and no patient required subsequent revision to a transfemoral level. There were no nonunions of the calcaneus to the tibia. Three patients underwent three late procedures to improve stump integrity and prosthetic fit, promoting longer daytime prosthetic wear. Two of them had scar revision and excision of heterotopic bone, and one had scar revision and implant removal.

The mean knee flexion in the twelve patients who were followed for a minimum of twenty-four months was 139° (range, 120° to 150°), and no patient had a flexion contracture (Figs. 8-A and 8-B). The patients were able to perform the timed walking test in a mean of seventeen seconds (range, six to thirty-one seconds) or 5.9 feet (1.8 m) per second. Eleven patients achieved a walking speed of >4 ft (>1.2 m) per second. Two patients used a cane to assist their walking during the test. Eleven patients reported wearing their prosthesis all day on a regular basis, but two were removing their prosthesis approximately once per day because of mild pain (Figs. 8-C and 8-D).

What to Watch For

Indications (Fig. 1)

- Open tibial fracture with or without bone loss extending to the proximal tibial metaphysis
- Soft-tissue loss in excess of potential coverage with a conventional single free tissue transfer OR inadequate durable soft-tissue coverage with conventional transtibial amputation
- Intact arterial supply to the hindfoot, including the plantar surface

Contraindications

- Comminuted calcaneal fracture
- Plantar degloving injury or devascularization
- Deficient knee extensor mechanism

Pitfalls & Challenges

- Injury to the posterior tibial artery. Preoperative angiography is performed if there is any question regarding the patency of the posterior tibial artery. A complete or partial injury of the posterior tibial artery may necessitate development of the flap with the anterior tibial artery or conversion of the pedicle to a free tissue transfer.
- Proximal tibiofibular dislocation. Ideally, the proximal part of the fibula is retained and reduced and secured to the tibia with small-fragment screws to preserve knee function (Figs. 5-C and 5-D).
- Infection. The risk of early infection is minimized by meticulous, serial surgical debridement and definitive flap transfer within five to ten days. Intravenous antibiotics and negative pressure dressings may reduce the risk of infection prior to the definitive procedure.
- Insufficient soft-tissue coverage after the flap is secured. These areas may occur medially and/or laterally. Negative pressure dressings may be used to control edema and to facilitate healing of small open portions of the wound over healthy muscle by secondary intention. Larger areas may be treated with split-thickness skin-grafting.
- A delay in the decision to perform this procedure. A delay of more than six weeks results in inflammation and stiffness of the neurovascular bundle, making it difficult to coil and contain these structures within the soft tissues proximally as the flap is secured.

Clinical Comments

- This technique is ideally indicated for patients with a large zone of injury involving the tibia, excluding non-repairable damage to the knee extensor mechanism and trauma to the foot. The pattern of injury is typical of a pedestrian or motorcyclist struck by the bumper of a motor vehicle.
- The flap relies on a patent artery to the foot, most commonly the posterior tibial artery. In two of our cases, the pedicle procedure was

successfully converted to a free tissue transfer. The transition to a free flap represents a major change in surgical approach, and planning for the contingency will lessen the difficulties involved in such a change.

- Lateral hindfoot and ankle skin is often redundant but marginally viable (Fig. 9-A). The lateral skin often becomes nonviable following the loss of its primary blood supply and should not be relied on to cover an area more than a few centimeters from the calcaneus. Coverage of questionable areas with skin graft is preferable to “stretching” the lateral skin of the composite flap.
- The limb has a bulbous shape that seems less natural than a typical transtibial amputation. The patient will find the appearance different and strange. The end of the limb is clearly identifiable as a foot, sensation is almost universally retained, and patients may be viewed by those to whom the limb is visible as having an altered human form. Patients will benefit from psychological counseling through the rehabilitation as they adapt to the function and appearance of the limb.
- Remodeling of the limb in the first year often leads to crevice formation at the junction of the sole and the residual limb (Fig. 9-B). Perspiration accumulates in these areas. Revision at the margins of the flap with excision of grafted/scarred areas and primary repair reduces this problem and improves the appearance of the limb.
- The calcaneal tuberosity is not tapered, so patients with a long residual limb may require an endoskeleton that has less of a taper than the normal limb. Matching the skin tones of the endoskeleton improves the cosmetic appearance. Attention to the overall length of the reconstructed limb will minimize the difference in the shape of the prosthesis.

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References

1. Ficke JR, Pollak AN. Extremity war injuries: development of clinical treatment principles. *J Am Acad Orthop Surg*. 2007 Oct;15(10):590-5.
2. Hayda RA, Mazurek MT, Powell IV ET, Richardson MW, Frisch HM, Andersen RC, Ficke JR. From Iraq back to Iraq: modern combat orthopaedic care. *Instr Course Lect*. 2008;57:87-99.
3. MacKenzie EJ, Bosse MJ, Castillo RC, Smith DG, Webb LX, Kellam JF, Burgess AR, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM, Trivison TG, McCarthy ML. Functional outcomes following trauma-related lower-extremity amputation. *J Bone Joint Surg Am*. 2004 Aug;86-A(8):1636-45.
4. Waters RL, Perry J, Antonelli D, Hislop H. Energy cost of walking of amputees: the influence of level of amputation. *J Bone Joint Surg Am*. 1976 Jan;58(1):42-6.
5. Hegstad SJ, Smith AA, Patterson BM, Kelly CM, Meland NB. Functional lower limb salvage with an osteocutaneous filet flap of the foot. *Ann Plast Surg*. 1996 Apr;36(4):413-6.
6. Patterson BM, Smith AA, Holdren AM, Sontich JK. Osteocutaneous pedicle flap of the foot for salvage of below-knee amputation level after lower extremity injury. *J Trauma*. 2000 Apr;48(4):767-72.
7. Vallier HA, Fitzgerald SJ, Beddow ME, Sontich JK, Patterson BM. Osteocutaneous pedicle flap transfer for salvage of trans-tibial amputation after severe lower-extremity injury. *J Bone Joint Surg Am*. 2012 Mar 7;94(5):447-54.

Figures

Fig. 1-A

Injury radiograph on hospital day two demonstrating massive bone and soft-tissue destruction about the tibia. The knee extensor mechanism was intact, the ankle and foot were not injured, and the neurovascular supply to the foot was intact.

Fig. 1-B

Clinical photograph on hospital day two demonstrating massive bone and soft-tissue destruction about the tibia. The knee extensor mechanism was intact, the ankle and foot were not injured, and the neurovascular supply to the foot was intact.

Fig. 1-C

Clinical photograph on hospital day two demonstrating massive bone and soft-tissue destruction about the tibia. The knee extensor mechanism was intact, the ankle and foot were not injured, and the neurovascular supply to the foot was intact.

Fig. 2-A

Clinical photograph depicting the initial dissection beginning along the posteromedial border of the tibia and extending to the ankle and hindfoot. The neurovascular bundle is protected.

Fig. 2-B

Excess tissue, including adjacent tendons, is removed.

Fig. 2-C

Ultimately, the metatarsals and forefoot are skeletonized and removed.

Fig. 3-A

Clinical photograph depicting the calcaneus at the dorsal, proximal aspect of the flap with a marker identifying the proposed osteotomy.

Fig. 3-B

The calcaneus is osteotomized.

Fig. 3-C

The tourniquet is released and the flap is viable.

Fig. 4

Clinical photograph depicting the proposed osteotomy of the proximal part of the tibia.

Fig. 5-A

Clinical photograph depicting preparation of the flap for transfer. The flexor tendons and volar plates are removed.

Fig. 5-B

The calcaneus may be wired to the tibia, as depicted here, but our preferred method is plate fixation.

Fig. 5-C

Anteroposterior radiograph depicting plate fixation, our preferred method.

Fig. 5-D

Lateral radiograph depicting plate fixation, our preferred method.

Fig. 6

Clinical photograph showing an example where split-thickness skin-grafting is performed to address residual open areas after the flap has been secured.

Fig. 7-A

Clinical photograph showing that initially the limb can be very swollen and bulbous.

Fig. 7-B

Within several months, the limb is much less swollen as seen from the front. (This is the same patient as seen in Fig. 6.)

Fig. 7-C

Within several months, the limb is much less swollen as seen from the side. (This is the same patient as seen in Fig. 6.)

Fig. 8-A

Lateral view of knee extension after healing.

Fig. 8-B

Lateral view of knee flexion after healing.

Fig. 8-C

The stump is very durable.

Fig. 8-D

The stump is very durable even in patients who are large and/or have heavy activity demands.

Fig. 9-A

Clinical photograph depicting redundant lateral hindfoot skin, which often has a tenuous blood supply.

Fig. 9-B

Crevices in the skin can be problematic.

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 3a

Fig. 3b

Fig. 3c

Fig. 4

Fig. 5a

Fig. 5b

Fig. 5c

Fig. 5d

Fig. 6

Fig. 7a

Fig. 7b

Fig. 7c

Fig. 8a

Fig. 8b

Fig. 8c

Fig. 8d

Fig. 9a

Fig. 9b