Lower-Extremity Local Flaps

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Abstract

Some soft-tissue defects of the lower extremities can be covered reliably with local flaps. Five such flaps—-the tensor fascia lata, gastrocnemius, soleus, posterior tibial artery fasciocutaneous, and dorsalis pedis flaps—-are described. If the indications for each flap are understood and the vascular pedicle is carefully preserved, these flaps can be used to provide relatively simple and reliable coverage of selected soft-tissue defects on the lower extremities. However, the indications must not be overextended in an attempt to avoid a free-tissue transfer. The gastrocnemius flap is most often used. It reliably covers common defects about the knee and the proximal tibia. A skin graft is required for the gastrocnemius flap, as well as the soleus flap, which covers the midportion of the tibia. The soleus requires deeper dissection of the calf for elevation. The tensor fascia lata flap and the more recently described posterior tibial artery fasciocutaneous flap are relatively easy to raise, but there are fewer orthopaedic indications for their use. The dorsalis pedis cutaneous flap is technically more demanding, but it can be used to cover difficult defects around the ankle.

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Orthopaedic surgeons increasingly are facing situations that require soft-tissue coverage of lower-extremity defects. Severe open tibial fractures often require coverage of exposed bone fragments with well-vascularized tissue, thereby preserving bone viability and reducing the potential for osteomyelitis. After total knee arthroplasty, wound-healing problems may be successfully treated with gastrocnemius flaps. Limb-preserving oncologic surgery presents opportunities for creative flaps. However, procedures to gain soft-tissue coverage in these and other situations are often referred to surgeons who have more training and experience with such procedures.

In the 25 years since Ger[1] popularized local muscle flaps to cover soft-tissue defects over the anterior tibia, a multitude of other local and free flaps have been described and perfected. Complex local flaps and free flaps have greatly expanded limb-salvage indications. Some bone and soft-tissue defects can now be successfully treated with the bone and soft-tissue transport techniques initially popularized by Ilizarov.

Some lower-extremity local flaps offer predictable results and are relatively easy to perform. They are not applicable in all situations, and the indications and limitations of each flap must be clearly understood. This review will describe five lower-extremity local flaps that, in our opinion, can be used effectively by orthopaedic surgeons. These flaps were chosen for description because of the relative ease of surgery, reliability, and minimal donor-site morbidity. However, they are not useful in the region above the ankle and on many areas on the foot. While the dorsalis pedis island flap can be utilized in the repair of defects around the ankle, there are many technical pitfalls in its use. Use of a free flap or complex local flap is often necessary on the distal part of the lower extremity.

General Considerations

Flaps are named for the types of tissue moved. A muscle flap moves only muscle and often requires a skin graft on the transposed muscle to complete closure of the defect. A musculocutaneous flap transports muscle and skin. The more recently described fasciocutaneous flaps utilize the blood supply to the fascia, usually near a deep intermuscular septum, to increase the blood supply to the skin being transported. Direct cutaneous, or axial-pattern, flaps utilize subcutaneous arteries and veins in specific body sites to transport

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only cutaneous tissue. A flap transporting skin may require a split-thickness skin graft at the donor site for closure. Alterations in the contour of the donor site or in the recipient bed may lead to an unacceptable cosmetic result. This is particularly true in the thighs of heavy women where cosmetic flap revision may be required at a later date.

Mathes and Nahai[2] have provided a useful classification of muscle flaps, although the principles of the classification are often applied to other types of flaps. A type I flap has a single vascular pedicle and is easiest to transfer. The tensor fascia lata (TFL) and gastrocnemius muscle flaps are examples. The type II flap has one or more dominant pedicles, as well as minor pedicles on the distal end of the muscle, which must be severed to rotate the flap. Occasionally there are problems with vascularity at the end of the flap distant from the major pedicle. Type III (two major pedicles), type IV (segmental pedicles), and type V (one dominant and multiple secondary pedicles) flaps have more complex vascular patterns and are not included in this review.

This classification points out the necessity of always being aware of the vascular supply of the tissue to be moved. Separation of the major vascular pedicle dooms the transfer, as does excessive tension or twisting of the pedicle. When the flap is used for coverage, preservation of the neurologic pedicle is unnecessary.[3] In fact, preservation of the neurologic pedicle may lead to delayed healing of a skin graft due to movement in the flap. Abnormal sensations may be present, although this has not been a major problem in our experience. When a flap is used to provide coverage for an area of insensate broken-down skin, neurologic pedicle preservation may be beneficial, but is beyond the scope of this review.

Local flaps rotate about their vascular pedicle and not about the origin of the muscle. This characteristic may be used to advantage; for example, in the gastrocnemius muscle, the origin can be detached from the femur to gain more length. However, the surgeon must always be careful to avoid overestimating the ability of the flap to cover a defect. The vascular pedicle must be kept in mind as the flap is elevated to avoid tension or even disruption of the vessels and failure of the flap.

The availability of local flaps is often influenced by associated trauma, particularly in the area of the flap. Crushed tissue or tissue with avulsed or traumatized pedicles will not survive rotation. A preoperative arteriogram may be required to document adequate circulation in situations with trauma or previous surgery near the tissue to be transferred. Nearby trauma is especially harmful to fasciocutaneous flaps that have multiple small perforating vessels through the fascia into the skin. Avulsion of these small vessels during surgery may be prevented by placing temporary sutures at the edge of the flap to hold subcutaneous tissues to the fascia while the flap is being manipulated. Care must also be taken to avoid vascular compromise of tissues near the donor site, as in the case of the tunnel under the skin commonly used with gastrocnemius transfer. The area of undamaged skin over a tunnel should be at least 7 cm wide to avoid vascular compromise. Whenever possible, veins should be preserved with the transferred tissue to avoid vascular congestion in the flap. With the exception of the dorsalis pedis island flap, we do not feel that preoperative vascular studies are necessary for the flaps described unless there is associated trauma, as noted above.

Tensor Fascia Lata Musculocutaneous Flap

The TFL musculocutaneous flap is a type I flap consisting of the TFL muscle, the fascia lata tendon, and the overlying skin.[4] The pedicle for this flap is the ascending branch of the lateral femoral circumflex artery and vein. The flap can be used to cover groin, ischial, trochanteric, and thigh deficits on the lower extremity (Fig. 1).

There are many advantages to this flap. It has a reliable blood supply and can be raised easily as a pedicle flap. Potentially, one can raise a large flap extending superiorly from the anterior superior iliac spine to 10 cm above the knee and from the midline anteriorly to the midline posteriorly. However, most flaps are smaller and do not extend closer than 15 cm above the knee. The TFL functions as an accessory hip flexor, hip abductor, and internal rotator of the thigh. It is not the primary muscle for any of these functions, making it functionally expendable. A sensory myocutaneous flap can be constructed if the limitations in size described by Strauch and Yu[5] are followed. The sensory TFL flap is not described in this review.

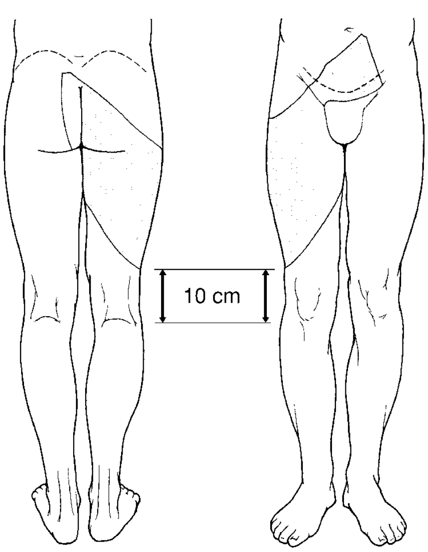

Fig. 1 Potential areas of coverage available with the TFL flap. The end of the flap can be as close as 10 cm, but is preferably 15 cm, from the knee-joint line.

There are some disadvantages with this pedicle flap. The secondary defect in the thigh may not close primarily if the width of the TFL flap exceeds 6 cm in a patient with normal habitus. Therefore, a split-thickness skin graft will be required for closure. In the thin male patient this is not a major cosmetic problem, but in a woman with heavy thighs a significant contour defect results. In addition, in heavy patients the thickness of the flap may necessitate later surgery to recontour and thin the transported flap.

Another disadvantage results from the fascia lata itself, which comprises the undersurface of the distal half of the flap. This fascia is stiff and does not fold well over concave surfaces or tuck well into deep holes. Also, the fascia lata does not adhere well to the underlying defect, and in contaminated wounds the potential dead space between the flap and the wound can be a source of hematoma or abscess. In patients with surgical scars in this area, this flap should not be attempted unless an arteriogram documents patency of the pedicle, because the vascular pedicle to the flap is often severed in the routine anterior or anterolateral surgical approach to the hip.

Anatomy

The TFL muscle arises from the ilium between the origin of the gluteus minimus and the anterior part of the iliac crest.[6] The muscle lies between the laminae of the iliotibial tract and inserts into the tract just below the level of the greater trochanter. The muscle is about 5 cm wide. Its posterior border runs from a point 5 cm posterior to the anterior superior iliac spine down to the iliotibial tract, passing just anterior to the greater trochanter. The surface marking of the muscle is easily demonstrated by having the supine patient elevate the leg with the knee extended. The muscle stands out readily, and the axis of any proposed flap should be marked preoperatively along the course of the demonstrated muscle.

The arterial supply is from the ascending branch of the lateral femoral circumflex artery, which is usually a branch of the deep femoral artery. This 2-mm-diameter vessel passes laterally deep to the sartorius and rectus femoris muscles, under which it divides into ascending and descending branches. The ascending branch courses along the intertrochanteric line at the site of origin of the vastus intermedius and lateralis muscles under cover of the rectus femoris. Here it enters the TFL muscle on its deep surface at the level of the greater trochanter (Fig. 2).

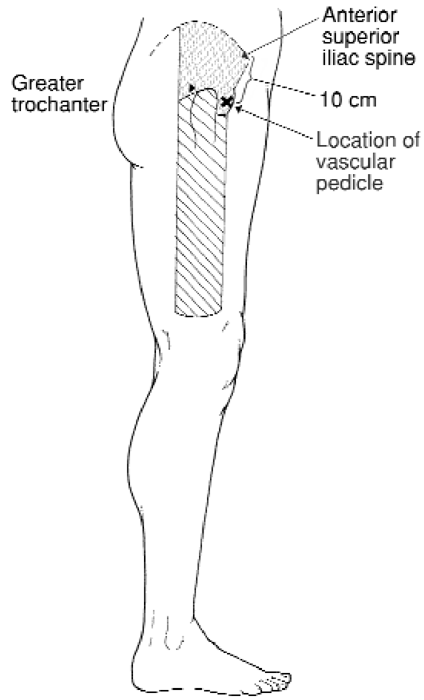

Fig. 2 Outline of a typical TFL flap. A wider flap would necessitate a skin graft for closure of the donor site. The TFL muscle area is shaded.

Flap Elevation

The flap usually measures 8 to 12 cm in width and is always centered over the muscle with the upper border being the iliac crest. Flaps can be raised to a length of about 30 cm or to within 10 cm, but preferably 15 cm, from the knee joint. Usually the cutaneous anterior boundary of the TFL flap is defined by a line from the anterior superior iliac spine to the lateral femoral condyle, but it can extend as far as the midline of the thigh. The posterior border follows a line from the posterior edge of the greater trochanter to the center of the lateral femoral condyle, although a wider flap extending to the edge of the biceps femoris muscle can be designed.

The dissection is started inferiorly with an incision through the skin and fascia onto the vastus lateralis muscle. The fascia is sutured to the skin to avoid shearing of the skin from the underlying fascia. The anterior and posterior margins are incised, and the flap is elevated from distal to proximal by using blunt finger dissection to gently separate the fascia from the underlying vastus lateralis. The posterior incision can be safely extended to the iliac crest to help mobilize the flap, since the pedicle enters on the anterior border. Proximally, the anterior incision should stop about 10 cm below the anterior superior iliac spine, as this is where the vascular pedicle is located (Fig. 2). Exposure of the pedicle is not necessary unless a greater degree of mobilization is needed for flap transposition.

The flap is then transposed to cover the defect. The sutures placed previously to avoid shearing are removed, and the flap is sutured in place. During transposition and insetting, the color of the flap and bleeding from the edge of the flap must be watched closely. The pedicle can become kinked, leading to insufficient arterial inflow manifested by pale color or lack of bleeding. Occlusion of the draining veins may make the flap appear dark and congested with excess bleeding. In either case, the flap must be taken down immediately, and the pedicle must be explored and mobilized to restore patency. The donor site is closed primarily if possible, or a split-thickness skin graft is applied.

Gastrocnemius Muscle Flap

Skin-grafted medial or lateral gastrocnemius muscle flaps are the workhorse local transposition flaps for soft-tissue coverage of the knee and the proximal third of the tibia (Fig. 3).[7] Either or both of these type I muscle flaps can be raised by a surgeon with a basic understanding of the anatomy of the posterior compartment of the leg.

Although the gastrocnemius is the largest muscle of the posterior leg compartment, the actual size of the muscle varies greatly depending on the patient's habitus. The surgeon must try to determine preoperatively if the bulk of gastrocnemius muscle is adequate to cover the wound defect. In a young trauma patient the muscle is usually well developed. However, in the elderly patient who has undergone total knee arthroplasty and who has a wound dehiscence, it may be quite small. If the patient has well-developed calves and muscular legs, a large gastrocnemius muscle will be present. If the patient has long, thin legs or is malnourished with poor muscle development, the muscle will have little bulk and will supply poor coverage. The bulk of the transferred gastrocnemius muscle is occasionally a source of cosmetic complaint by patients.

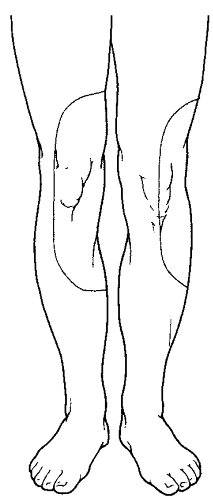

Fig. 3 Areas of potential anterior coverage from medial and lateral gastrocnemius muscle flaps.

A musculocutaneous gastrocnemius flap can be used to increase flap length. The extended length adds only cutaneous tissue and requires a split-thickness skin graft to close the donor site. The cosmetic result may be unacceptable due to the donor-site contour defect. The musculocutaneous gastrocnemius flap is not described in this review.

The superficial posterior location of the muscle allows relative ease of elevation of the flaps. This location also protects the muscle from damage in most injuries, since wounds are more often anterior over the subcutaneous border of the tibia. One exception is the crushing injury (e.g., a bumper injury) in which the posterior muscles have been damaged. In this situation, the gastrocnemius muscle may be unfit for local transposition, and a free flap may be required.

Anatomy

The medial and lateral heads of the gastrocnemius muscle take origin from their respective femoral condyles and join just distal to the knee. The muscle becomes tendinous near the junction of the middle and distal thirds of the leg and joins the soleus tendon to form the Achilles tendon.

The medial head is larger and longer (3.0 to 4.0 cm) than the lateral head and is the preferred head of the gastrocnemius for local transposition flaps if allowed by the location of the defect. The medial head is adjacent to the tibia, allowing the muscle to be easily transposed over the typical proximal anterior tibial wound as far as the lateral border of the patella.

The lateral head is separated from the tibia by the fibula, the lateral compartment, and the anterior compartment, making the reach to the tibia longer. Even so, it can easily reach the lateral border of the patella. If it is necessary to gain additional length, the lateral head can be tunneled under the lateral and anterior compartments after a fibulectomy to decrease the distance to the defect. This must be done with extreme care so that the pedicle to the muscle does not become kinked under the anterior and lateral compartments. Fibulectomy can lead to other problems. For example, it may preclude later reconstructive procedures, such as fibula-to-tibia grafts to achieve fracture union.

Because the sural artery is the single proximal dominant vascular pedicle to each head of the muscle, the gastrocnemius muscle flap is a type I flap. Each head has a separate sural artery, which is a branch of the popliteal artery at the level of the femoral condyle. Each artery enters the muscle just beneath the level of the joint space and arborizes in the proximal muscle. It supplies the skin over the muscle and distal to the muscle belly through a fasciocutaneous circulation. The blood supply is very reliable unless there has been a knee dislocation or a significantly displaced supracondylar femoral fracture. These injuries can result in damage to the sural arteries, rendering the gastrocnemius nonviable if raised on this pedicle. A similar situation may exist if the patient has had a femoral popliteal vascular bypass because of either trauma or peripheral vascular disease. If that is the case, an arteriogram must be obtained to document patency of the sural arteries before a local gastrocnemius transposition flap is attempted.

Flap Elevation

Medial Gastrocnemius Muscle Flap

The muscle is exposed using a longitudinal incision that parallels the medial border of the tibia.[8] If the flap is to be tunneled under a skin bridge, the incision is placed posteriorly so that the bipedicle flap created between the incision and the anterior defect is at least 7 cm in width. This is necessary to prevent skin necrosis when this bridge of skin is raised to allow transposition of the muscle under the skin bridge and into the anterior wound (Fig. 4). The incision extends from the tibial plateau to 8 to 10 cm above the ankle. The saphenous vein should be left attached to the superficial fascia to maintain maximum venous outflow from the damaged leg.

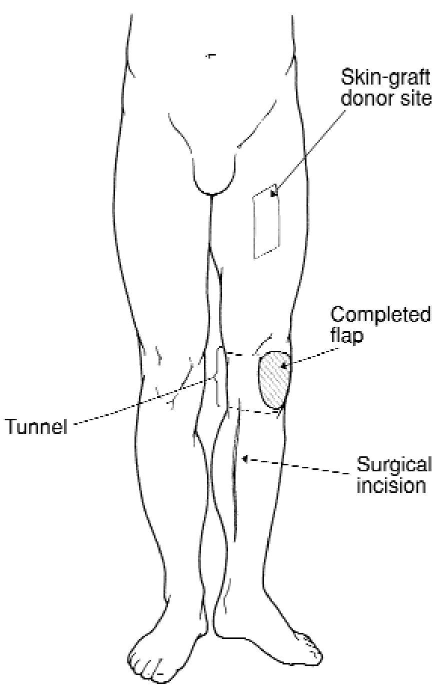

Fig. 4 Completed medial gastrocnemius flap performed by using a subcutaneous tunnel with a minimum of 7 cm between the incision and the defect. Flap area is shaded.

The muscle is easily separated from the overlying subcutaneous tissue and fascia by blunt dissection. The plane between the soleus and the medial head of gastrocnemius is developed with finger dissection. The location of the few small vessels in this interval should be noted before they are carefully coagulated, since they may help define the location of the median raphe.

The medial head is then separated from the lateral head by identifying the raphe between them. This raphe is difficult to see in well-developed individuals, but there are other clues to the proper line of separation. On the superficial posterior surface of the gastrocnemius muscle, the interval is defined by the sural nerve. On the deep surface of the gastrocnemius, multiple small vessels connect the soleus to the gastrocnemius in a longitudinal fashion along the raphe. This anatomic feature helps define the interval. Proximally, the raphe may be defined by careful finger dissection into the popliteal fossa where the two heads separate.

The attachment of the medial head to the Achilles tendon is sharply released, leaving a small amount of tendon still attached to the muscle for later suture placement. The two heads are then separated using sharp and blunt dissection. As the dissection approaches the knee joint, finger dissection is preferred to avoid damage to the sural vessels. The bridge of skin and subcutaneous tissue separating the traumatic wound and the incision is raised, making sure that there is adequate space to avoid pressure on the transposed muscle.

If the width of the flap is inadequate, the deep fascia of the muscle can be removed or incised longitudinally to allow the muscle to spread out and cover more area. The small amount of tendon on the distal end of the muscle is used to set the flap into the defect. If the medial head does not reach the wound, it can be further mobilized by releasing the muscle from its origin on the medial femoral condyle, taking care to preserve the vascular pedicle, which enters the muscle about 3 cm above the joint line. The flap can be inverted if necessary for better coverage or contour. It is then grafted with a meshed split-thickness skin graft. If the exposed fascia on the flap is thick, it can be carefully stripped from the flap, or multiple small incisions can be made in the fascia ("pie-crusting") for better take of the skin graft. Wounds are closed over suction drains.

Lateral Gastrocnemius Muscle Flap

To mobilize the lateral head, a longitudinal incision is made 2 or 3 cm posterior to the fibula. The incision may have to be placed more posteriorly to allow for an adequate width of skin between the anterolateral defect and the posterolateral longitudinal incision if a tunnel is to be used. The peroneal nerve is identified at the neck of the fibula and is protected throughout the dissection. The skin is separated from the muscle, and the lateral head is separated from the medial as previously described. The muscle is then transposed into position, often under the mobilized bridge of skin. The peroneal nerve is again checked to avoid possible tension on the nerve by the transposed muscle. The muscle is skin-grafted, and the wound is closed as previously described.

Soleus Muscle Flap

The soleus muscle flap is second only to the gastrocnemius flap as a local flap for soft-tissue coverage of the tibia. This type II flap is the preferred local flap for coverage of the middle third of the tibia (Fig. 5). The soleus is expendable, especially when transferred as a "hemisoleus," and harvest leaves a very subtle donor-site deformity.[9] However, this flap is more difficult to raise than the gastrocnemius flap because attention must be paid to the adjacent posterior tibial neurovascular bundle. A significant disadvantage of the soleus flap is that circulation to the distal end of the flap is unreliable. This is especially true in the case of a high-energy fracture.

Although the soleus occupies the posterior compartment of the leg with the gastrocnemius, it is affected differently in many open fractures. Since the soleus is closely adherent to the deep posterior surface of the interosseous membrane and the tibia and fibula, it is often damaged in open high-energy or crush fractures of the tibia. The resultant muscle injury is often severe enough to preclude its use as a transposition flap.

Judgment is key in selecting reliable soleus transposition flaps. If the preoperative evaluation shows a great deal of ecchymosis and swelling in the posterior compartment and there is gross instability of the fracture, one can assume significant fracture displacement and damage to the soleus. If the initial radiographs, especially the lateral view, show gross displacement of the fracture, posterior-compartment muscle damage is likely. During the initial debridement of the wound, digital exploration will occasionally reveal penetration of the soleus by the fractured tibia, making the muscle unsuitable for transposition. In these situations, free-tissue transfer is a better choice for middle-third tibial coverage.

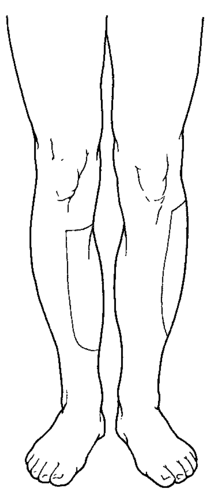

Fig. 5 Areas of potential anterior coverage from medial and lateral transposition of the soleus muscle. Transposition around the lateral side is seldom used.

Anatomy

The soleus is a muscle of the superficial posterior compartment of the leg and is located deep to the gastrocnemius muscle. It extends the entire length and width of the leg. Unlike the gastrocnemius, which has no direct origin on the tibia, the soleus originates from the posterior surface of the tibia, the interosseous membrane, and the proximal third of the fibula. The muscle joins with the gastrocnemius and inserts into the calcaneus. In the proximal third of the leg, it is covered by the belly of the gastrocnemius; in the middle third, it is located beneath the tendon of the gastrocnemius; and in the distal third, it blends with the tendon of the gastrocnemius.

The soleus is a bipenniform muscle. The medial head originates from the posterior surface of the tibia. The lateral head originates from the proximal fibula. The medial and lateral heads are fused proximally, and in their distal half they are separated by a well-defined septum before they fuse with the gastrocnemius tendon.

The soleus is considered to have a type II pattern of blood supply, with the popliteal, posterior tibial, and peroneal arteries giving dominant branches to the proximal third of the two heads of the muscle. The lateral head receives most of its blood supply from the peroneal artery. The distal two thirds of the muscle receives minor pedicles from the posterior tibial artery (PTA). These branches must be severed before flap rotation, and their loss may account for the occasional underperfusion of the distal portion of the flap. The surgeon must closely observe the distal flap circulation before the flap is sutured into position.[8]

Flap Elevation

Under tourniquet control, the soleus is harvested by means of a medial approach through a longitudinal incision paralleling the border of the tibia and extending from just beneath the tibial plateau to just above the medial malleolus. If possible, this incision should incorporate the traumatic wound to avoid creating a skin bridge. Either a hemisoleus or a total soleus flap can be elevated, depending on the size of the traumatic defect and the size of the soleus. If a medial hemisoleus flap is raised, one must split the soleus lateral to the midline to capture the intermuscular artery, which runs down the center of the muscle. This will increase the likelihood of survival of the entire muscle.

If, for some uncommon reason, the lateral approach is used to harvest a soleus flap, the surgeon must be aware that the fibula will limit the arc of rotation. This can be corrected somewhat by removal of the fibula, but it must be accepted that this could lead to problems with late reconstruction of a tibial nonunion.

Ordinarily, the soleus is identified in the proximal third of the leg, where it lies between the gastrocnemius muscle and the deep transverse fascia. The posterior tibial neurovascular bundle is identified and protected. After the muscle has been cleared on both its deep and its superficial surface, it is separated from the Achilles tendon. The width of the harvested muscle is dictated by the defect. Distal small perforators from the posterior tibial vessels are ligated and divided as necessary to allow flap rotation. The flap is rotated into the defect and inset. It is then covered with a meshed split-thickness skin graft, and the incision is closed in standard fashion, using a drain if necessary.

Posterior Tibial Artery Fasciocutaneous Flap

Prior to the introduction of local transposition muscle flaps and microvascular free-tissue transfers, random cutaneous flaps were attempted for soft-tissue coverage in the leg with mixed success. In 1981, Pontén[10] pointed out the significance of the fasciocutaneous circulation. Subsequently, the vascular anatomy of the skin was closely detailed.[11] Fasciocutaneous flaps were designed with more predictable circulation, and acceptable results were reported.[12,13]

There are some disadvantages to the fasciocutaneous flap. Unlike muscle flaps, the fasciocutaneous flap has minimal bulk and cannot be used to obliterate dead space in a wound. The skin flap has less blood supply than a muscle flap, which decreases its ability to resist the contamination often seen in these defects. If the flap is not carefully designed, tip necrosis may result, compromising coverage of the defect. Many high-energy and crushing injuries damage the fasciocutaneous envelope to a degree that contraindicates its use. Patients with diabetes mellitus or peripheral vascular disease and elderly patients are generally not candidates for fasciocutaneous flaps.

In spite of these disadvantages, the PTA fasciocutaneous flap may be successfully applied to some small middle-third and distal-third tibial soft-tissue defects (Fig. 6), provided the defect is at least 10 cm from the ankle. The flap is easy to raise if the principles of fasciocutaneous circulation are applied. Open fractures associated with low-energy injuries and minimal muscle or bone loss are ideal indications. These situations are uncommon but are sometimes seen in fractures associated with an abrasive action. An example is trauma due to striking the leg on the dashboard in a motor-vehicle accident and avulsing the pretibial skin, with or without associated tibial fracture. This is a low-energy injury with exposed bone, but the surrounding fasciocutaneous envelope is in good condition, allowing for a local fasciocutaneous transposition flap. The PTA fasciocutaneous flap can be rotated farther than the commonly used bipedicle (“relaxing incision”) flap in this situation.

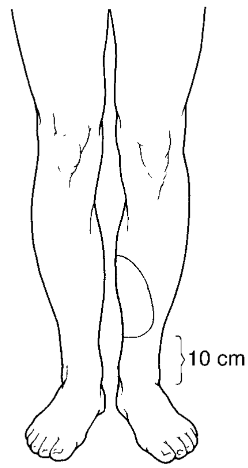

Fig. 6 Area of potential anterior coverage with a PTA fasciocutaneous flap.

Anatomy

The fasciocutaneous perforators of the posteromedial aspect of the leg arise from the PTA. Arterial and venous perforators from the PTA course to the skin through the crural septum between the deep and superficial muscle compartments of the posterior portion of the leg. The skin flap is dependent on these septal perforators for survival. The PTA gives off a series of five or six perforators, which emerge in the crural septum between the soleus and the flexor digitorum longus muscle. They perforate the fascia and connect to a plexus at the level of the deep fascia. The lowest perforators are 5 to 7 cm above the malleolus.

Flap Elevation

The flap design is dictated by the defect. Usually, a tongue-shaped flap is fashioned with the flap based proximally and with a maximum length-width ratio of 3:1. The saphenous vein is always included in the flap to aid in venous outflow (Fig. 7). The posterior incision is made in such a fashion as to avoid exposure of the Achilles tendon after transposition. The distal portion of the flap should not extend closer to the malleolus than 2 or 3 cm. After rotation, the flap will not cover defects closer to the ankle than 10 cm. The incisions are carried through the skin, fat, and deep fascia. Sutures

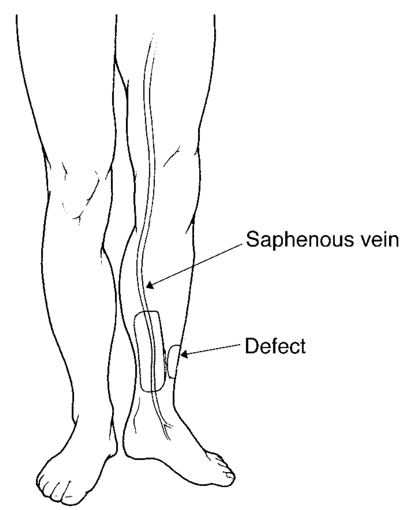

Fig. 7 Outline of a typical PTA fasciocutaneous flap. The long saphenous vein is divided at the distal end of the flap and transposed with the flap. Flap area is shaded.

are placed in the flap to prevent shearing between the skin and the fascia during manipulation.

Once the skin and fascia have been incised, the posterior aspect of the flap can be elevated with finger dissection because only loose alveolar tissue connects the fasciocutaneous flap to the muscles posteriorly. The septum between the deep and superficial compartments of the leg tethers the flap at this point and must be released to allow adequate mobility of the flap. Since this septum contains the septal perforators, it must be released judiciously to allow adequate release for wound coverage. Occasionally, the perforators can be visualized in the septum and can be spared by releasing the fascia without cutting the vessels.

The flap is then transposed over the bone, and the resultant defect in the posteromedial portion of the leg is closed with a meshed split-thickness skin graft. Any unsightly dog-ear created by rotation of the flap should be revised after healing is complete to avoid vascular compromise to the flap.

Dorsalis Pedis Island Flap

Many skin flaps that were once thought to have direct axial blood supply are now thought to be supplied by the fasciocutaneous system. However, the dorsalis pedis island flap remains an example of a direct axial flap. Careful attention to detail is required to successfully raise this skin flap, which relies on a single inflow artery. This is a good local flap for coverage of ankle and hindfoot skin defects (Fig. 8),[14,15] but it is the most technically demanding of the flaps discussed in this review. Care must be taken to achieve good donor-site coverage with a skin graft because of the location on the dorsum of the foot.

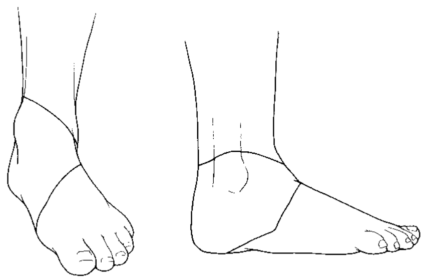

Fig. 8 Areas of potential coverage from the dorsalis pedis island flap.

Anatomy

The anterior tibial artery supplies the dorsum of the foot as it crosses the ankle and continues as the dorsalis pedis artery. Venous outflow from this flap is via the venae comitantes and the long saphenous vein. The dorsalis pedis artery runs along the tarsus to the first intermetatarsal space, where it gives off a branch to the plantar surface and then continues as a nondominant supply to the first and second toes (Fig. 9). The cutaneous branches of the dorsalis pedis artery enter the skin in a fairly small strip extending from the extensor retinaculum to a point halfway along the first interosseous space. Beyond this point the skin is supplied by the first dorsal metatarsal artery (FDMA), a continuation of the dorsalis pedis artery, which lies beneath the tendon of the extensor hallucis brevis muscle.

The origin of the FDMA is crucial to the supply of the distal part of the flap. In as many as 20% of patients, the FDMA has a plantar origin instead of arising from the dorsalis pedis artery. This precludes its use in a local rotation flap, since the arc of rotation is significantly shortened. Also, in the older patient the dorsalis pedis artery can be atherosclerotic, which is another contraindication to use of this flap. In most cases an arteriogram should be obtained preoperatively to evaluate these potential problems and to ensure that the PTA is patent into the foot.

Flap Elevation

The shape of the flap is dictated by the defect, although some guidelines are helpful.[16] Most of the vascularization of the flap comes from the proximal portion of the FDMA. The design of the flap should be such that the central portion overlies this area when possible. A venous tourniquet should be placed on the leg prior to dissection to mark the long saphenous vein and the dorsalis pedis artery. This will allow easy incorporation of the long saphenous vein into the flap. The dorsalis pedis artery should be used as the axis of the flap.

The proximal margin of the flap is at the lower border of the extensor retinaculum. The flap can extend across the width of the dorsum of the foot but should not pass around the borders of the foot. Distally, the incision is made proximal to the web spaces of the toes. Much of the blood supply to the distal part of the flap comes from the FDMA, and the variable arrangement of this vessel may determine the tendency for marginal necrosis at the distal end. For this reason, the flap is seldom larger than 10×10 cm.

After the flap design has been drawn on the dorsum of the foot, using the dorsalis pedis artery as the axis, and the long saphenous vein has been included, the venous tourniquet is released. The distal incision is made first so that the FDMA can be identified. If it is not present or is deep and atrophic, the procedure should be aborted, and free-tissue transfer should be elected. It is important to develop a plane that leaves sufficient peritenon for take of the split-thickness skin graft on the extensor tendons. This step is very important because incomplete take of the split-thickness skin graft on the tendons is the major complication with this flap.

The distal end of the flap is then raised, and the FDMA is identified, divided, and sutured to the distal edge of the flap to prevent shearing between the flap and the vessels, which would cause devascularization. At this point, the flap must be checked for adequate perfusion. If the distal part of the proposed flap is dusky, the incision should be closed, and a free flap should be selected to fill the defect. If vascularity is intact, the incision is extended up the medial border of the flap, with care being taken not to damage the long saphenous vein but to take it with the flap.

As the medial edge of the flap is raised, the tendon of the extensor hallucis longus will be noted. The dissection is continued superficial to this tendon. The vessels are then raised with the flap from distal and lateral to proximal and medial, always watching the vessels to make sure that they are included with the flap. The extensor hallucis brevis tendon must be divided to raise the flap, since the vessel runs deep to the tendon (Fig. 9). The plantar communicating artery will be encountered between the bases of the first and second metatarsals; this must be ligated to raise the flap. The proximal skin incision is made, and mobilization of the flap is completed.

A more proximal longitudinal incision may be necessary to mobilize more of the vessel, extending the length of the pedicle. To accomplish this, the extensor retinaculum is cut, and the extensor tendons are retracted, exposing the dorsalis pedis artery and the anterior tibial vessels.

During the dissection, the exposed extensor tendons must be kept moist to avoid damage to the peritenon, which might compromise take of the skin graft. The flap is sutured into position, and a minimally meshed split-thickness skin graft is placed on the donor site. The pedicle must be inspected again to make sure that kinking did not occur. The foot is dressed with a bolster and is splinted for at least 2 weeks to maximize incorporation of the skin graft.

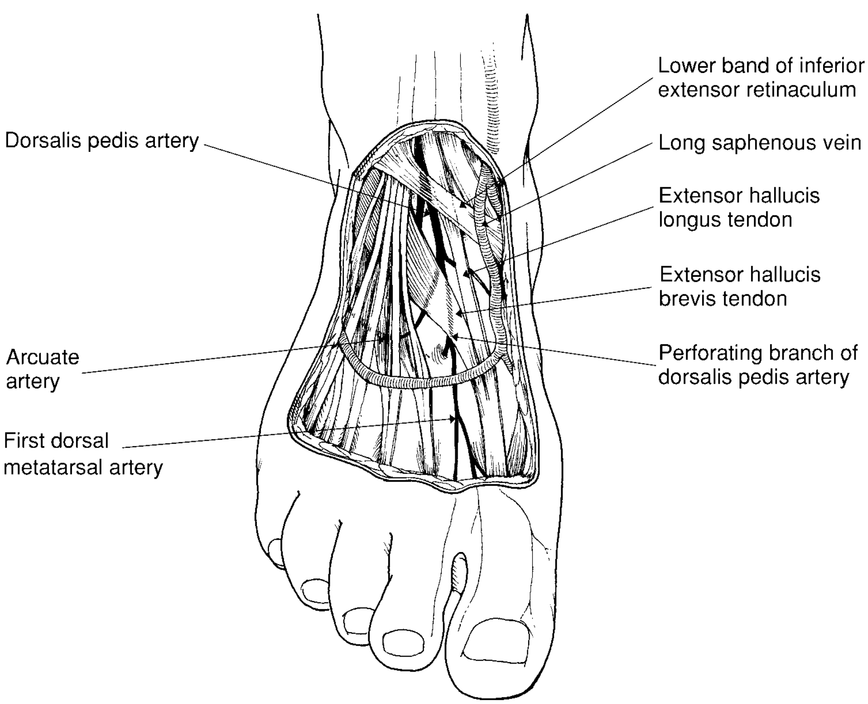

Fig. 9 Anatomic details of the dorsalis pedis artery and its extension as the first dorsal metatarsal artery.

Summary

Of the five lower-extremity local flaps discussed, the gastrocnemius flap is used most often because it covers wounds at the knee and proximal tibia, which are the common sites of defects. This flap is relatively easy to use and has predictably good results. The TFL and PTA fasciocutaneous flaps are also easy to use if the vascular anatomy is respected, but there are relatively few orthopaedic indications for these flaps. The soleus and dorsalis pedis flaps are the most technically demanding of the five flaps. The contraindications and caveats mentioned must be observed for the flaps to be successful. Fortunately, free-flap techniques and more complex local flaps are available in most situations if the described local flaps will not work, as is the case in the area proximal to the ankle and in many areas on the foot.

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