Three-Step Approach to the Harvest of the Fibula Osteoseptocutaneous Flap

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Introduction: The ability to reliably include a skin paddle with the fibula osteoseptocutaneous (OSC) flap is crucial both from the perspective soft tissue reconstruction and flap monitoring. In this study, we describe a three-step approach to the harvest of the fibula OSC flap that is reliable and versatile.

Methods and Materials: Step 1 starts by exploring the posterior crural septum from the anterior incision of the skin island with the aim being to identify the septocutaneous vessels that will supply the skin. Step 2 proceeds from the posterior aspect of the skin island. The septocutaneous vessel is traced to its origin, and the peroneal artery is detached from flexor hallucis longus that covers the posterior aspect of the artery. Finally, step 3 entails detaching all muscles attached to the fibula from anteriorly and can be expediently completed as vessels supplying the skin component have already been secured.

Results: This technique was used successfully in 52 flap harvests. Absent septal vessels was noted in 4% of cases. In both cases, musculocutaneous perforators arising from the soleus muscle was used to supply the skin component. In one case, the septocutaneous vessel was noted to arise from the posterior tibial artery. Flap harvest was successful in all cases.

Conclusion: The three-step approach allowed us to reliably harvest the fibula OSC flap. We were able to visualize the anatomy clearly with this technique, and this has enabled us to detect anomalous anatomy early on in the dissection. These were successfully managed by using musculocutaneous perforators to the skin island that would normally be cut.

Key Words: Fibula, Flap, Technique, Approach, Safety, Reliability, Anatomy, Surgical, Surgery.

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The fibula flap is the gold standard for vascularized bone transfer.[1–10] The ability to reliably include a skin paddle with the flap is an important because many bony defects are associated with soft tissue losses. To do this, early descriptions have advocated the inclusion of a significant cuff of soleus and flexor hallucis longus (FHL) muscles with the lateral leg skin.[11–14] This design relies on musculocutaneous perforators from the peroneal artery to perfuse the skin flap. Such approach to harvesting the fibula osteocutaneous

flap was however reputed to be unreliable.[15–17] Wei et al.[3] then demonstrated that a large skin paddle could reliably be vascularized by septocutaneous vessel running within the posterior crural septum in the distal leg. The viability of the skin component is dependent on (1) the inclusion of the septocutaneous vessel in the posterior crural septum and (2) the septocutaneous vessel originating from the peroneal artery. In this article, we describe a three-step approach to the harvest of the fibula osteoseptocutaneous flap that ensures skin survival. Our clinical experience with the use of this approach was also presented.

SURGICAL TECHNIQUE

Preoperatively, the intended donor site is examined clinically by palpating for the dorsalis pedis and posterior tibial pulses. The fibula bone is marked, and a hand-held Doppler is used to locate vessels supplying the skin. These septocutaneous vessels, numbered 1 to 4, are located within the posterior crural septum, which is located at approximately the posterior border of the fibula. We routinely mark a skin island that spans the entire length of the fibula to ensure inclusion of all septal vessels.

The flap is harvested under tourniquet inflated to 350 mm Hg. Step 1 of the procedure starts by incising the anterior border of the marked skin island with the aim being to locate the septocutaneous vessel within the posterior crural septum (Fig. 1). The incision is made first and carried down to the deep fascia. The flap is then raised suprafascially until the posterior margin of the tendon of the peroneus longus muscle is reached. At this point, the deep fascia is cut and dissection proceeds in the subfascial plane (Fig. 2). This is an important technical point and is done for the following reasons; firstly, it ensures that one is past the anterior crural septum before entering the subfascial plane. This assures that the first septum encountered after one enters the subfascial plane is the posterior crural septum in which the septocutaneous vessels supplying the skin paddle are located. Secondly, it ensures the preservation of the superficial peroneal nerve, which is located anterior to the peroneus longus tendon, in the subfascial plane. Lastly, this maneuver preserves the deep fascia covering the tendon of the peroneus longus muscle. This provides a more favorable bed for skin grafting if this is needed. The skin is raised to the posterior septum, and it is then carefully inspected for the septocutaneous vessels. The posterior crural septum is then dissected off the peroneus
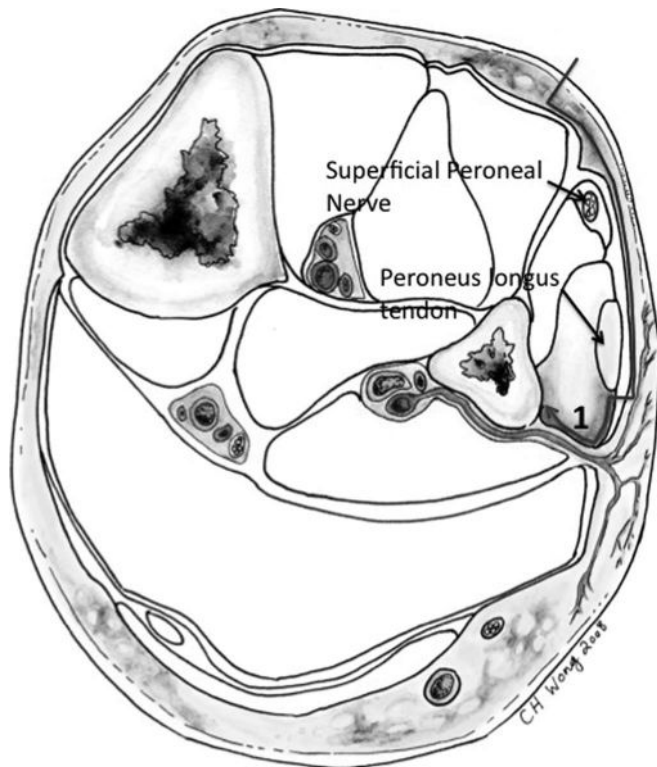
Figure 1. Step 1.

muscle until its attachment to the posteriorlateral aspect of the fibula is reached.

One can then proceed to step 2 that starts with incision along the posterior margin of the marked skin island. The aim of step 2 is to confirm the origin of the septocutaneous vessel from the peroneal artery, detach the soleus and FHL from the posterior aspect of the peroneal artery, and thus expose the entire posterior aspect of the artery (Fig. 3). When making the posterior incision, care should be taken to preserve the sural nerve and the short saphenous vein. These structures are located in the subcutaneous plane, just above the deep fascia. Once located, the deep fascia can be cut lateral to these structures and the skin flap elevated off the soleus muscle. Once the presence of sizable septocutaneous perforators have been seen from the anteriorly, musculocutaneous perforators that supply the skin coming through the soleus muscle can be safely ligated and cut (Fig. 4). The anterior border of the soleus abuts of the posterior crural septum, and this is dissected off the septum. The posterior crural septum will be visualized from the posterior aspect, and the locations of the septocutaneous vessels are again noted. The next muscle that comes into view is the FHL (Fig. 5). The FHL is then progressively dissected sharply off the posterior crural septum and the posterior border of the fibula. During this stage, the plane of dissection follows the course of the septocutaneous vessel within the septum, which is traced to the peroneal artery. Muscle branches supplying the FHL from the peroneal artery can be ligated and cut. The entire course of the peroneal artery should be visualized at this juncture by dissecting the FHL off the posterior aspect of the pedicle
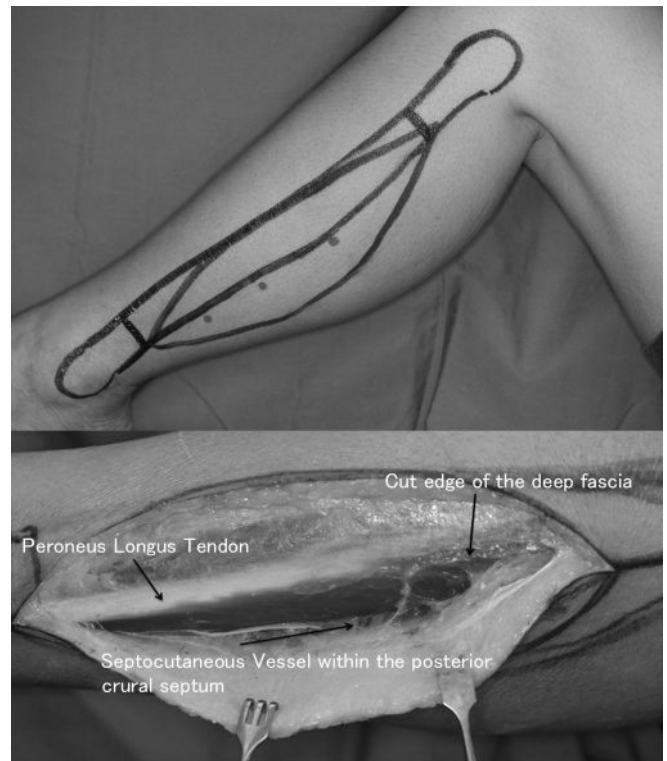

Figure 2. *Top*: Skin markings of the fibula OSC flap. A long skin island spanning the length of the fibula is routinely used to ensure inclusion of the septal vessels. *Bottom*: The flap is elevated suprafascially until one is past the tendon of the peroneus longus. The deep fascia is then cut posterior to the tendon. The septocutaneous vessel is located in the posterior crural septum.

(Fig. 6). This step achieves two objectives; firstly, the origin of the septocutaneous vessel from the peroneal artery can be confirmed, assuring the survival of the skin paddle. Secondly, the posterior aspect of the peroneal artery is completely mobilized the FHL muscle, leaving only the medial and anterior aspect of the pedicle to be mobilized when approaching it from the anterior aspect. Dissection from the posterior side is then stopped here and proceeds from the anterior aspect of the flap.

In step 3, all muscles are detached from the bone, and the adequacy of the anterior and posterior tibial vessels is confirmed (Fig. 7). The peroneus longus muscle is sharply dissected off the lateral aspect of the bone, leaving minimal amount of muscle on the bone. Care should be taken not to injure the periosteum of the bone. The anterior crural septum is then encountered and cut. At this juncture, subperiosteal dissection circumferentially from the anterior and posterior aspect of the fibula is performed with a periosteal elevator at the intended proximal and distal osteotomy sites for a distance of about 1 cm. A Langenbeck retractor is then passed around this subperiosteal plane, protecting the more deeply located peroneal artery. Osteotomy is then performed with a power saw distally and proximally. Bone clamps are then applied at the ends of the bone and gently rotated outward,
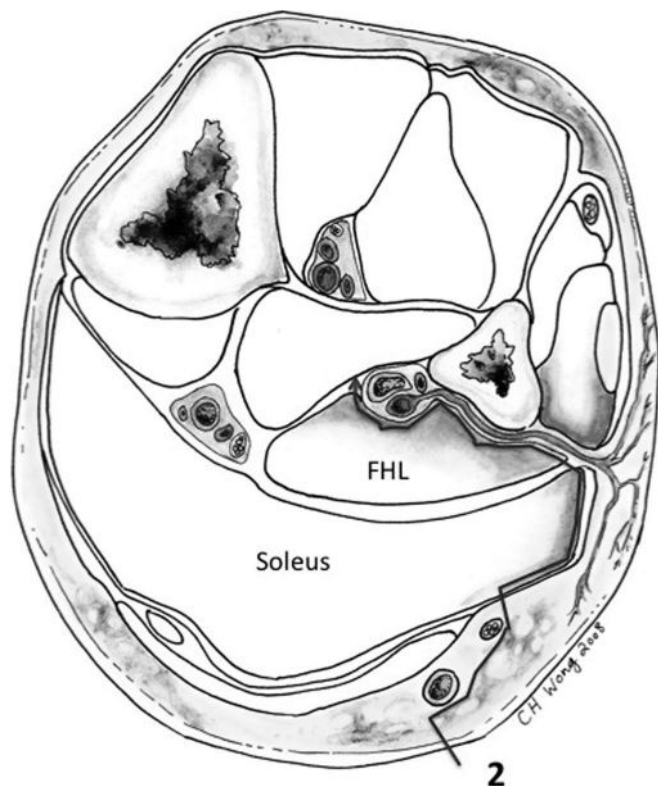
Figure 3. Step 2.

Figure 4. Quite commonly, sizable musculocutaneous perforator arising through the soleus muscle may supply the skin paddle. If a septocutaneous vessel has been seen from the anterior dissection, these can be safely cut. Rarely, however, if septocutaneous vessels are absent, these musculocutaneous perforators can be reliably be used to nourish the skin flap.

Figure 5. *Top*: The posterior incision is then made. The skin flap is elevated off the soleus muscle. *Bottom*: The soleus is then separated from the posterior crural septum, and the FHL comes into view.

Figure 6. The FHL is then separated from the posterior crural septum. The plane of dissection follows the course of the septocutaneous vessel to its origin at the peroneal artery. The FHL is dissected off the posterior aspect of the peroneal artery, taking care to ligate all muscle branches arising from the artery.

presenting the anteromedial aspect of the bone. The attachment of the extensor digitorum longus and extensor hallucis longus muscles is then sharply dissected off the bone. Here, the anterior tibial artery would be visualized anterior to the interosseous membrane and its size noted. The interosseous membrane is then reached and cut sharply. This membrane should be cut as close to the bone as possible to preserve a significant cuff of the membrane onto which the FHL is repaired at closure. Once cut, one can feel a certain give as
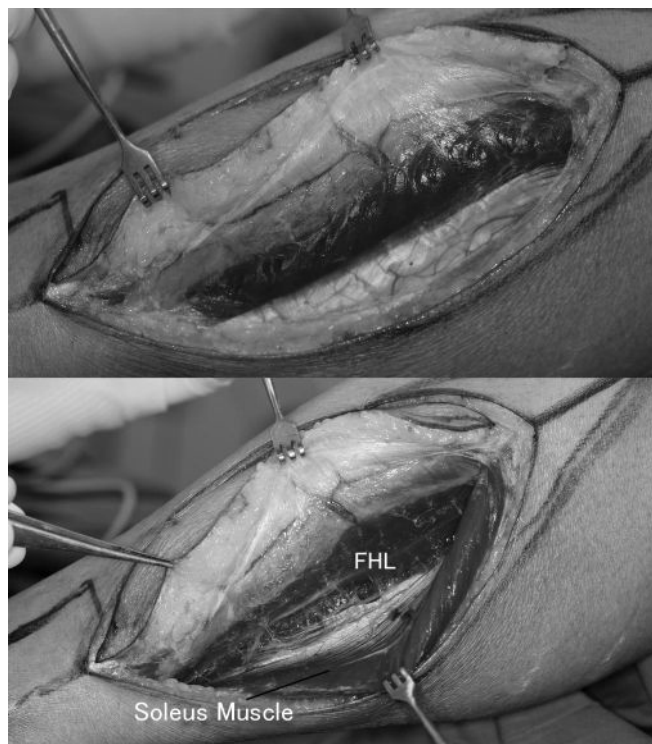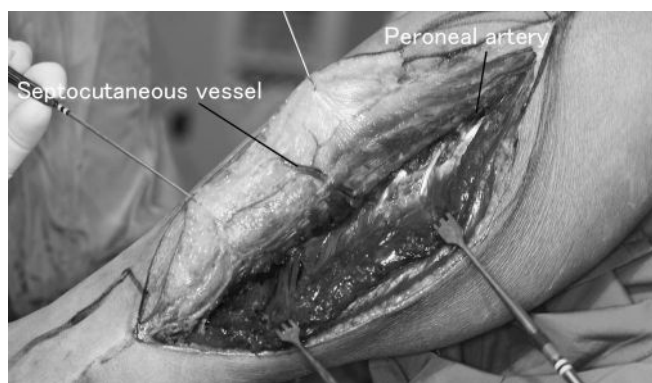
this firm attachment of the fibula to the tibial bone is released. Further, lateral traction on the fibula flap distally gives a better view of this area. The distal end of the peroneal artery and its paired venae comitantes can be seen after cutting the interosseous membrane (Fig. 8). In the proximal two-third, the peroneal artery is covered by the tibialis posterior muscle. This is unroofed from distal to proximal to reveal the pedicle.
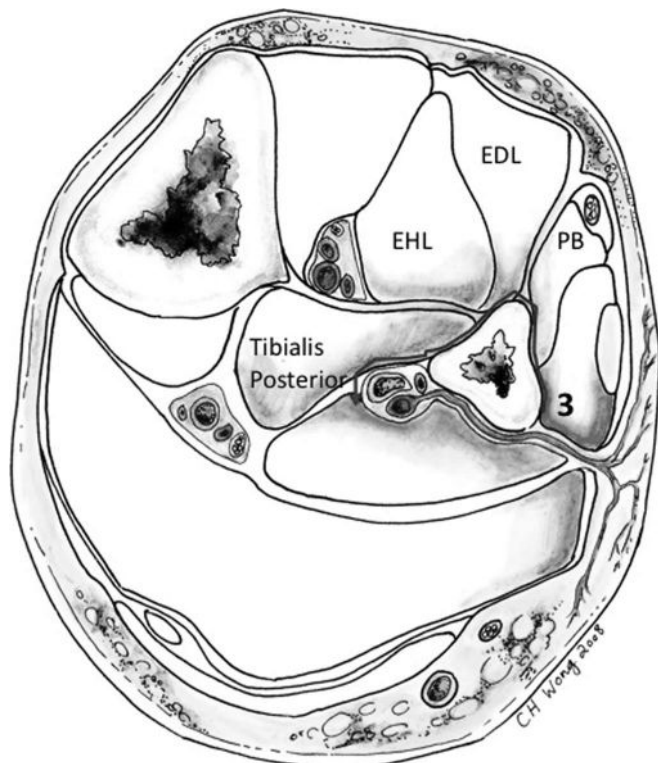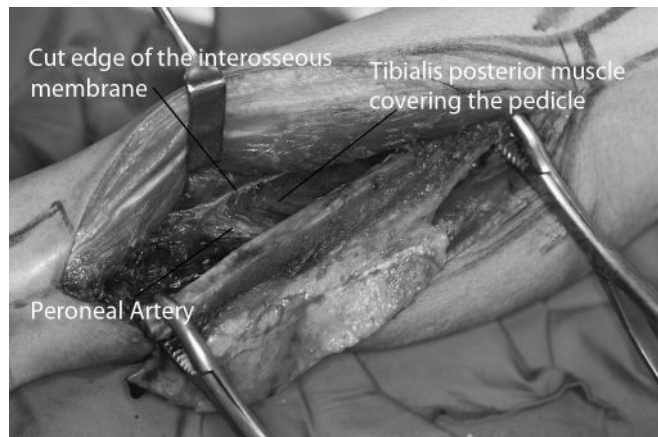
Figure 7. Step 3.

Figure 8. Once the fibula is osteotomized and the interosseous membrane is cut, lateral and outward traction will enable the surgeon to visualize the distal end of the peroneal artery. This is ligated and the tibialis posterior muscle and fascia covering the peroneal artery is unroofed from distally to proximally.

The posterior tibial artery and posterior tibial nerve is located medially in the plane of the peroneal pedicle. The posterior tibial artery is inspected to ensure its adequacy. Once this is determined, the distal end of the peroneal pedicle can be ligated and further lateral traction applied to the fibula bone. The remaining medial attachment to tibialis posterior and FHL muscles and branches supplying these structures are progressively ligated and cut in a distal to proximal fashion.
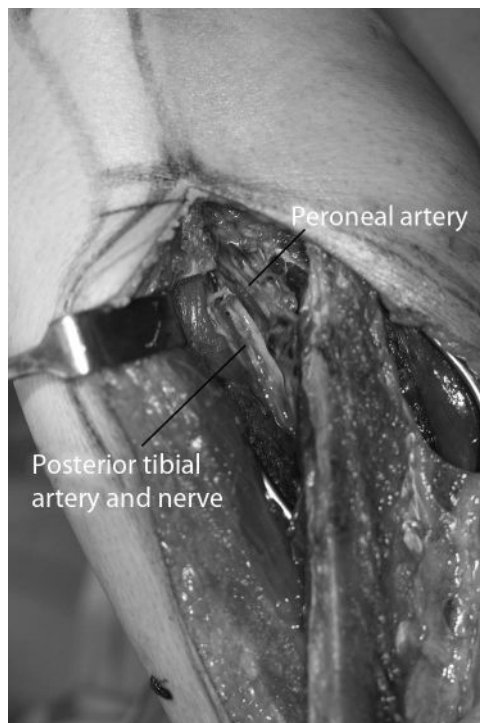

Figure 9. The peroneal pedicle, usually comprises on artery and two veins, should be traced to its takeoff from the tibioperoneal trunk to maximize pedicle length.

Proximally, the pedicle is traced to its bifurcation with the posterior tibial artery (Fig. 9). Some large branches supplying the surrounding muscles can be safely ligated up to the bifurcation of the tibioperoneal trunk. The tourniquet is then released, the viability of the flap is checked and hemostasis secured. The flap is allowed to reperfuse for at least 20 minutes before flap division (Fig. 10).

In closing the donor, re-establishing muscle attachment to the bone that has been stripped off during harvest is important to minimize donor site morbidity. The FHL is sutured to the interosseous membrane with 3 to 4 interrupted sutures. A suction drain is placed and the peroneus longus is then sutured to the soleus with 3 to 4 interrupted sutures. The proximal and distal incisions are then closed as much as possible to minimize the wound. The preserved cuff of deep fascia over the anterior aspect of the wound is pulled to cover the peroneus longus tendon as sutured to the muscle substance of the soleus muscle (Fig. 11). This covers the tendon with well-vascularized fascia improve skin graft take and prevents tendon exposure in the even of graft failure. The wound is the skin grafted and the leg immobilized for 5 days with a back slab.

MATERIALS AND METHODS

From June 2002 to May 2009, 52 consecutive fibula osteoseptocutaneous flaps were harvested using the three-step approach as described above. The mean age of the patients was 58 (range, 17–72). Forty-five of these patients were men
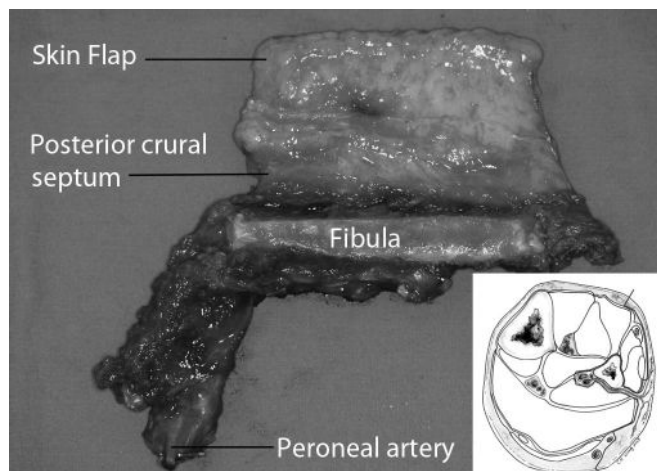
Figure 10. The fibula OSC flap harvested.

Figure 11. The preserved deep fascia is used to cover the tendon of the peroneus longus muscle. This layer of well-vascularized deep fascia provides a relatively immobile bed that is more favorable for skin graft take. In the event of skin graft loss, this layer also protects the underlying tendon from exposure.

and 7 were women. Of these, forty-nine were for head and neck defects and three for lower limb defects.

RESULTS

The flap success rates were 96% with two flap failures. The mean duration of the harvest was 84 minutes (range, 56–135). Septocutaneous vessels were identified in 50 cases (96%). In the two cases with absent septal vessels, the following was done: In one case, a musculocutaneous perforator from the peroneal artery traversing the soleus muscle was used to perfuse the skin island. In another, a lateral leg perforator flap was used as a second free flap as the musculocutaneous perforator originated from the posterior tibial artery. In all cases but one (49 of 50, 98%), the septocutaneous vessel within the posterior crural septum originated from the peroneal artery. In one exceptional case, the septocutaneous vessel arose from the posterior tibial artery (Fig. 12).
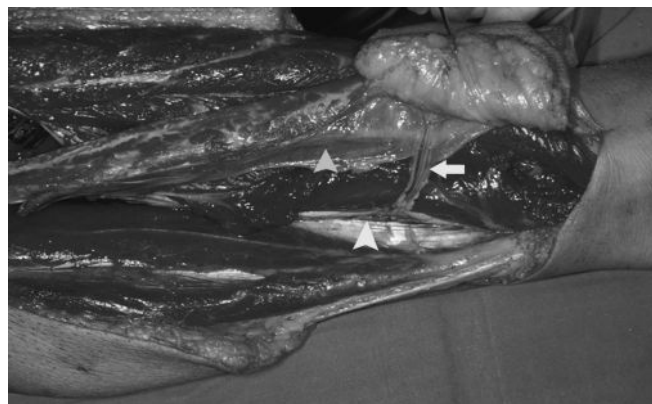

Figure 12. A rare anomaly in which the septocutaneous vessel (*arrow*) within the posterior crural septum runs past the peroneal artery (*top arrow head*) to originates from the posterior tibial artery (*bottom arrow head*). The bone and skin flaps need to be transferred as separate free flaps in this instance. The anatomic anomaly is fortunately exceedingly rare.

DISCUSSION

The three-step approach described here is a safe and reliable way of harvesting the fibula osteoseptocutaneous flap. The septum is first explored from anteriorly as access to the septum is most direct from this perspective and no potentially useful perforators come in the way of the dissection (step 1). In contrast, if one were to start from posteriorly, one or more musculocutaneous coming through the soleus muscle will come in the way of the dissection. Adequately, visualization of the posterior septum would necessitate cutting these perforators. However, it is not advisable to cut these vessels until the presence of septal vessels are confirmed as these musculocutaneous perforators could be used to supply the skin island in cases where the former is absent.[18] Therefore, once the presence of septocutaneous vessels is confirmed from anteriorly, all musculocutaneous perforators encountered when elevating the flap from posteriorly can be safely cut. Then, the septocutaneous vessel is traced to its origin. Concomitantly, the attachments of the FHL to the posterior crural septum, the posterior border of the fibula, and the posterior aspect of the peroneal artery are detached. This is the ideal place to detach the posterior aspect of the peroneal pedicle from the FHL as visualization of the muscle branches running posteriorly from the peroneal artery to supply the muscles is best and access for ligating them most direct (step 2). Once the posterior aspect of the peroneal pedicle is freed, the remaining of the dissection can then be completed expediently from the front (step 3).

Some authors have advocated routine preoperative imaging studies by angiogram, computed tomography angiogram, or magnetic resonance angiography.[19] The anterior tibial artery is commonly the dominant vessel supplying the foot via the dorsalis pedis artery with smaller contributions from the posterior tibial artery. Hypoplasia and aplasia involving the anterior tibial artery and/or posterior tibial artery may occur with the peroneal artery taking over the blood
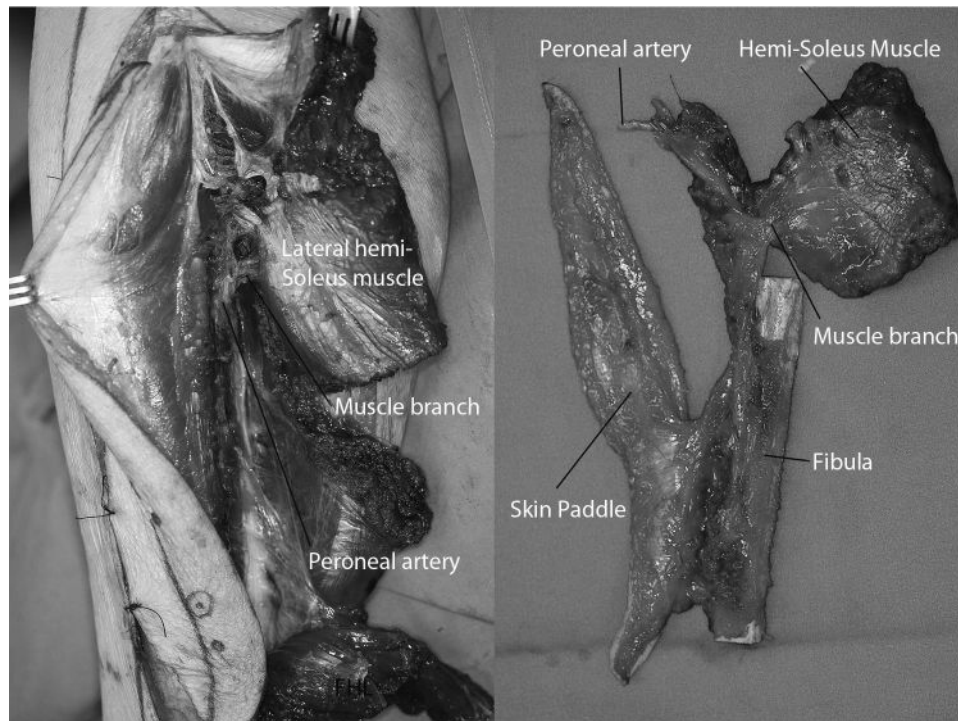
Figure 13. The three-step approach exposes the entire posterior aspect of the peroneal artery in step 2. *Left*: This gives excellent visualization of the pedicle from posteriorly and presents the opportunity to include the lateral hemisoleus with the fibula OSC flap. *Right*: This creates a peroneal artery-based chimeric flap consisting of bone, skin, and muscle components known as the FOCHS flap (fibula OSC flap incorporating the hemisoleus muscle), this chimeric flap can easily be harvested with slight modifications of the three-step approach.

supply to the foot. The degree of reliance on the peroneal artery for the foot blood supply varies, depending on whether it is mild or severe hypoplasia.[20–24] Rarely, the peroneal artery exists as the sole supply to the foot. This is known as peroneal arterial magna. Because the peroneal artery is harvested with the fibula, the foot would be at risk in such cases. If detected preoperatively, the presence of such anomalies would be a relative contraindication to fibula flap harvest. However, routine imaging is time consuming and costly. Lutz et al.[25] evaluated the use of preoperative angiogram in 120 donor legs and 111 contralateral legs before harvesting the fibula flap. Angiographic anomalies were noted in only 3% of patients. Of this, only one patient (<1%) had the intended harvest site changed to the contralateral leg based on preoperative angiogram findings. Peroneal arterial magna was noted in two cases (0.9%). Intraoperatively, however, all three vessels were noted to be of good sizes, and the angiogram findings were attributed to arterial spasm during the procedure. Vessel spasm is a well-documented cause of false positive with angiograms, and the true incidence of peroneal arterial magna is probably lower than the 0.2% reported by Kim et al.[22] We, therefore, are of the opinion that routine preoperative angiogram of the donor leg is not justified as the incidence of arterial anomalies that preclude the harvest of the fibula is extremely low. Imaging is, however, recommended for patients with nonpalpable or nonaudible pulses on hand-held Doppler assessment of the dorsalis pedis or

posterior tibial pulses or patients with significant previous trauma to the leg.[25] Intraoperatively, it is important to directly inspect both the anterior tibial and posterior tibial vessels.

It was initially thought that the skin based solely on the septal vessel is unreliable with reported of losses of up to 67%.[12] It was then recommended an osteocutaneous flap be harvested by inclusion of a 1 cm cuff of soleus and FHL muscles.[11,12] It was assumed that such design would include either or both the septocutaneous vessels and musculocutaneous perforators to the skin component. However, such design is not always successful, and occasionally, the skin component is lost.[15] There are several reasons for this. Firstly, the septocutaneous vessel may not always be present, and when present, its location in the distal leg is variable. Blind harvest without first clearly seeing the vessel may result inadvertently in its exclusion. Secondly, it was often erroneously assumed that the musculocutaneous perforator always originates from the peroneal artery and therefore captured by inclusion of a generous cuff of soleus and FHL muscles. This may not always be the case as musculocutaneous perforators may originate from the posterior tibial artery in a significant proportion of lower limbs.[18,26] Therefore, techniques that rely of inclusion of a cuff of soleus and FHL muscles would invariably cut musculocutaneous perforators arising from the posterior tibial artery not matter how generous the cuff of muscle included. Such techniques should therefore be abandoned.

A lateral leg skin of up to 24 × 10 cm² can reliably be supplied by the septocutaneous vessel.[3] A large study by Schusterman et al. found that septocutaneous vessels were absent from the posterior crural septum in 20% of their cadaveric specimens. This grossly overestimated the incidence of absent septal vessels. In our series, septal vessel was noted to be absent in 4% of cases. The key in successfully locating and including the septal vessels is in designing the skin island. We routinely design the skin island to span the entire length of the bone, keeping both ends tapered. Unwanted portions of the skin island can be de-epithelialized and buried or discarded. The septal vessel is most commonly located at the junction of the middle and distal third of the fibula. Its location, however, is variable and the most sizable septal vessel may be located more proximally. Designing a long skin island, therefore, gives greater versatility and enables the surgeon to capture all septal vessels. This gives a more robust flap and even allow for multiple skin islands. In situations where there is a true absence of septal vessels, dissection then proceeds from the posterior incision. Musculocutaneous perforators coming through the soleus muscle becomes crucial in such cases to supply the skin component. One or more musculocutaneous perforators are usually present. These are mobilized by intramuscular dissection to their origins. In our previous study, musculocutaneous perforators originate from the peroneal artery, posterior tibial artery, and tibioperoneal trunk in 50%, 35%, and 5%, respectively.[18] In cases where the musculocutaneous perforator originates form the peroneal artery (50%), the bone and skin components can be transferred as a single unit based on the peroneal vessel. In all other cases, the bone and the skin components would have to be transferred as separate free flaps, significantly increasing the complexity of the surgery. This situation is fortunately a rare occurrence.

Very rarely, the septal vessel may take origin from the posterior tibial artery.[27–29] In our approach, therefore, the entire course of this vessel is delineated early in the dissection (step 2) to ensure that the septocutaneous vessel originate from the peroneal artery before proceeding further. The entire length of the peroneal artery is then exposed from posteriorly. This also has the distinct advantage of allowing the surgeon to clearly visualize all muscle branches arising from the peroneal vessel early on in the harvest. This naturally presents an opportunity to include muscle with the flap. In particular, the entire lateral hemisoleus can reliably be included based on constant muscle branch from the peroneal artery, yielding a peroneal artery-based chimeric flap that has separate bone, skin, and muscle components (Fig. 13). This is a further advantage of harvesting the flap as described above. Such chimeric-type design based on independent vessel to each component affords greater versatility when insetting the flap and assures greater vascularity of the muscle harvested.[8]

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