Use of the Soleus Musculocutaneous Perforator for Skin Paddle Salvage of the Fibula Osteoseptocutaneous Flap: Anatomical Study and Clinical Confirmation

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Background: The skin paddle of the fibula osteoseptocutaneous flap is reliably vascularized by septocutaneous perforators from the peroneal artery. However, in 5 to 10 percent of lower limbs, these perforators are absent. This anatomical study evaluated use of the soleus musculocutaneous perforator for skin paddle salvage in such situations.

Methods: Latex injection studies were performed on 20 cadaveric lower limbs. The presence, prevalence, and location of the musculocutaneous perforators in the distal leg were documented. The perforators were traced proximally to determine their origins.

Results: Of the 20 cadaveric limbs, one or more musculocutaneous perforators of at least 0.5 mm in diameter were noted in 18 specimens (90 percent). They were located within 6 cm of the junction of the middle and lower thirds of the fibula. The soleus musculocutaneous perforators originated in the peroneal artery in 10 specimens (50 percent), the posterior tibial artery in seven (35 percent), and the tibioperoneal trunk in one (5 percent). This information was successfully used to salvage the skin paddle in two of our clinical cases.

Conclusions: Use of the soleus musculocutaneous perforator depends on its origin. When it arises from the peroneal artery, a single set of anastomoses is all that is necessary for flap revascularization, with the skin paddle serving as a monitor for the bone flap. When it originates from the posterior tibial artery or tibioperoneal trunk, a second set of anastomoses is needed and the skin paddle cannot monitor the bone flap. The authors propose that one or two soleus musculocutaneous perforators be preserved during harvest until existence of the septocutaneous perforator is confirmed. (*Plast. Reconstr. Surg.* 120: 1576, 2007.)

The fibula osteoseptocutaneous flap with a distal skin island is a well-established design for oromandibular reconstruction. Wei et al. demonstrated that a skin island centered over the distal leg at the junction of the middle and distal thirds of the fibula is reliably supplied by the peroneal septocutaneous vessels passing within the posterior crural septum.[1] Later, Jones et al. confirmed unequivocally that a skin flap can be reliably harvested with the fibula based purely on the septocutaneous perforator, without the need to incorporate portions of the soleus or flexor hallucis longus muscles.[2,3]

Occasionally, however, such septocutaneous perforators are absent. In the senior author's (F.-C.W.) personal experience of over 1100 fibula osteocutaneous flaps, 3 percent ($n = 30$) had no septocutaneous perforator. Faced with such a situation, the surgeon may choose one of the following surgical options. First, rely on the septum's intrinsic circulation to vascularize the skin flap.[1] This is unreliable and may result in partial or complete flap loss.[4] Second, abandon the skin

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flap and substitute it with a second flap from another site. This option is safe but adds to the duration and morbidity of surgery. Third, salvage the skin island by preserving the soleus musculocutaneous perforators to the flap. Such perforators are traced by intramuscular dissection to their origins and the skin paddle raised as a perforator-type flap.[1,4–6] The purpose of our anatomical study is to elucidate the anatomy of the soleus musculocutaneous perforators in the distal leg. This information will be valuable to the surgeon attempting to salvage a fibula flap skin paddle.

MATERIALS AND METHODS

Anatomical Study and Specimen Preparation

Injection studies were carried out in 20 cadaveric lower limbs (10 cadavers). The femoral artery was cannulated and injected with 10% buffered formalin followed by pigmented latex to delineate the arterial system of the leg. The limbs were then allowed to cure overnight by refrigerating at 4°C. The latex coagulated in the presence of the formalin; thus, the arterial tree was preserved for further study. Each specimen was dissected to obtain the following information: (1) the prevalence of the soleus musculocutaneous perforator in the distal leg, (2) its position in relation to the junction of the middle and lower thirds of the fibula where septal perforators reside, and (3) the origin of the soleus musculocutaneous perforator.

In each specimen, a skin paddle measuring 20 × 8 cm was elevated and centered over the junction of the middle and distal thirds of the fibula. Using a posterior approach, the skin flap was elevated subfascially toward the posterior crural septum. All soleus perforators greater than 0.5 mm in diameter in the vicinity were preserved. The septocutaneous vessels in the posterior crural septum were also identified. Their relative locations and diameters were documented. Intramuscular dissections of the soleus perforators were then performed to trace these vessels to the artery of origin. The pedicle length and perforator diameter at the artery of origin were documented. All dissections were recorded by photography.

RESULTS

Eighteen lower limb specimens (90 percent) were found to have at least one large musculocutaneous perforator coming through the soleus muscle to supply a skin paddle over the lateral aspect of the distal leg. Our findings are summarized in Table 1. Most of the dominant musculocutaneous perforator was located within 2 cm of the junction of the middle and distal thirds of the fibula, with the farthest being within 6 cm from this reference point (Fig. 1). The diameter of the musculocutaneous perforators ranged from 0.8 to 1.5 mm (mean, 1.1 mm) at the deep fascia level. When traced to its origin at the major vessels, its diameter ranged from 1.2 to 2.2 mm (mean, 1.6 mm). The pedicle length of the musculocutaneous perforators ranged from 4 to 25 cm (mean, 12.5 cm). In the 20 lower limbs dissected, the septocutaneous perforator was absent in one specimen (5 percent).

The musculocutaneous perforators supplying the fibula flap's distal skin paddle were noted to originate from three sites (Table 1). In 10 specimens (50 percent), they arose from the peroneal artery. In seven specimens (35 percent), the vessel originated from the posterior tibial artery, and in one specimen (5 percent), it arose from the tibioperoneal trunk. The musculocutaneous perforator was absent in two specimens (10 percent). We classified the vascular pattern of the soleus musculocutaneous perforators into two types based on their origin; namely, convergent and divergent (Fig. 2). A convergent system is defined as one in which the perforator arises from the peroneal artery and thus the fibula osteocutaneous flap can be raised as a single composite unit comprising bone and skin subunits (50 percent). A divergent system is one in which the perforator originates from an artery other than the peroneal artery. These can be either the posterior tibial artery (35 percent) or tibioperoneal trunk (5 percent). A divergent system would mean that the skin and the bone portions would have to be raised as separate flaps.

Surgical Technique

Based on our anatomical findings, we propose a slight modification of the technique of harvesting the fibula osteoseptocutaneous flap, which is to preserve one or two soleus musculocutaneous perforators until the septocutaneous perforator is clearly seen. In the standard fashion, the axis of the skin flap is centered over the posterior border of the fibula, at the junction of the middle and lower thirds of the bone.[1,7] Preoperative Doppler assessment is used to mark the location of the skin perforators. The skin flap is incised along its posterior margin and deepened down to muscle. It is elevated in the subfascial plane toward the posterior crural septum. When approaching the posterior crural septum from posteriorly, one or more

Table 1. Summary of Cadaveric Dissection Findings

Cadaver	SC Perforator	Soleus MC Perforator	Diameter of Soleus MC Perforators at the Deep Fascia Level (mm)	Diameter of Soleus MC Perforators at the Origin of Perforator (mm)	Length of the MC Perforator (cm)	Distance from Junction of Middle and Lower Thirds of the Fibula (cm)	Source of Soleus MC Perforator		
							Peroneal	Posterior Tibia	Tibioperoneal Trunk
1	+	+	1.0	1.2	11	+3	+		
2	+	+	1.2	1.2	15	+5			+
3	+	−							
4	+	+	1.0	1.4	12	+4.5	+		
5	+	+	1.2	1.2	20	−1		+	
6	+	+	1.2	1.4	15	−6.5		+	
7	+	+	0.8	1.4	25	−6		+	
8	+	−							
9	+	+	1.5	2.2	12	+2	+		
10	+	+	1.2	2.0	8	−1	+		
11	+	+	0.8	1.5	4	+2	+		
12	+	+	0.8	1.5	8	+2	+		
13	+	+	1.2	2.2	12	+5		+	
14	+	+	1.2	2.0	12	−1		+	
15	+	+	1.2	1.6	5	+5.5	+		
16	+	+	1.0	1.2	14.5	−1.5		+	
17	+	+	0.8	1.6	12	+4	+		
18	+	+	1.0	1.6	16	+1	+		
19	−	+	1.2	1.2	14	+1		+	
20	+	+	1.2	1.8	12	−2	+		
Mean			1.1	1.6	12.5				
Prevalence							50%	35%	5%

SC, septocutaneous; MC, musculocutaneous.

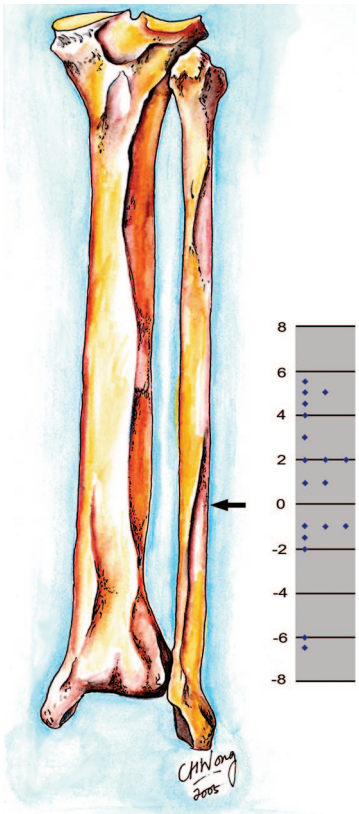

Fig. 1. The distances of the largest soleus musculocutaneous perforators from the junction of the middle and distal thirds of the fibula (*arrow*) noted in 18 cadaveric specimens (numerical scale on the *right*, in centimeters).

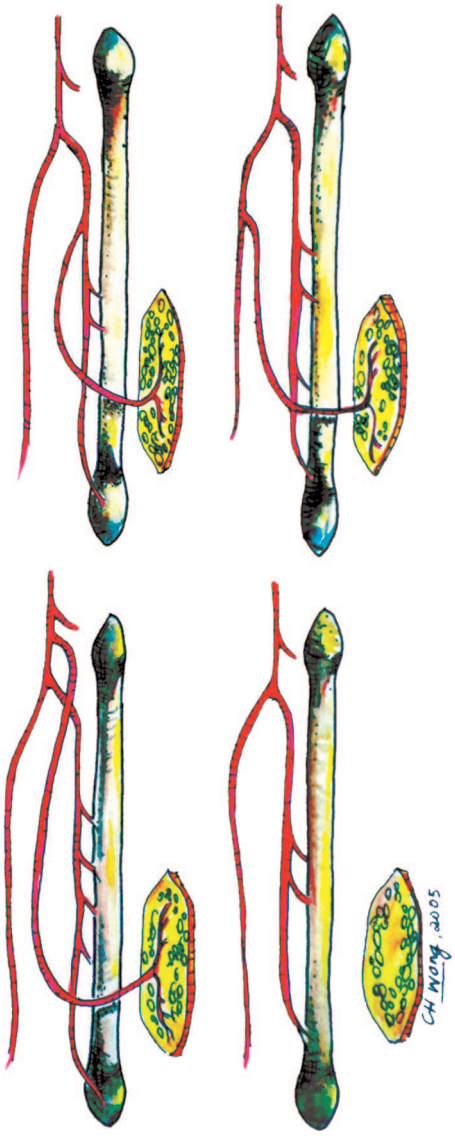

Fig. 2. Schematic representations of the origin of the soleus musculocutaneous perforator that can be used for skin paddle salvage (viewed from the posterior aspect of the lower limb). A convergent system can be raised as a composite flap (*above*, *left*), whereas divergent systems (*above*, *right* and *below*, *left*) have to be raised as separate flaps. (*Above*, *left*) A convergent system with a musculocutaneous perforator originating from the peroneal artery. (*Above*, *right*) A divergent system with a musculocutaneous perforator originating from the posterior tibial artery. (*Below*, *left*) A divergent system with a musculocutaneous perforator originating from the tibioperoneal trunk. (*Below*, *right*) No musculocutaneous perforator.

soleus musculocutaneous perforators may come in the way of the dissection, and it is at this stage that the technique is modified to preserve these perforators until the septal perforator is clearly seen. If present, the musculocutaneous perforators are ligated and flap elevation proceeds as usual; if absent, the course of the musculocutaneous perforator is dissected out for skin paddle salvage. In such situations, the surgeon should be cognizant of the variability of the musculocutaneous perforator's origin and be prepared for a second set of microvascular anastomoses. As a routine, one should raise only one border first, check for perforators, and then, if necessary, recenter the skin paddle based on the location of the new musculocutaneous perforator location. Occasionally, no soleus perforator is seen in the distal leg. In such situations, the incision is extended up the leg to look for more proximal perforators. Once identified, the skin paddle is relocated accordingly.

Some surgeons prefer to approach the posterior crural septum from the anterior aspect of the planned skin island. A similar approach can be adopted to deal with cases with absent septocutaneous perforators when an initial anterior incision has been made. In such cases, a parallel posterior skin incision would have to be made to locate

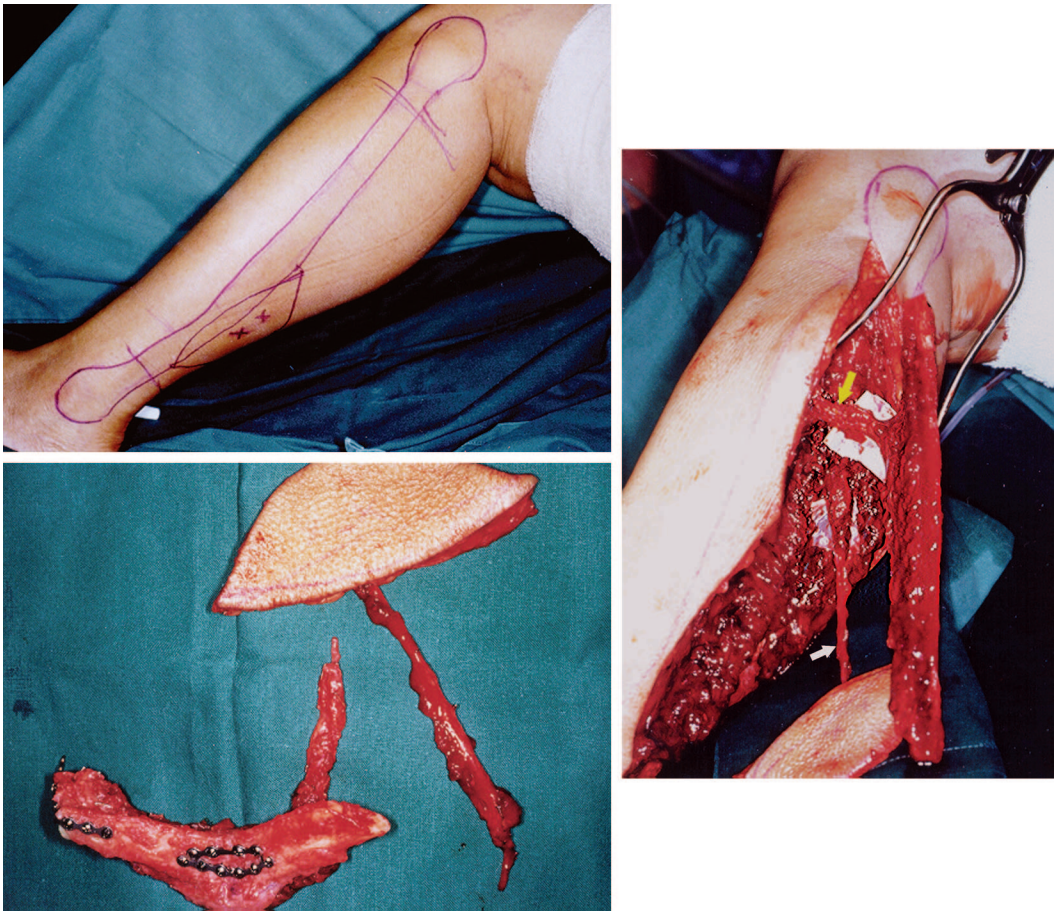

Fig. 3. (*Above, left*) Skin markings for the fibula osteocutaneous flap with a distally sited skin island. Preoperative Doppler assessment detected two good-quality sounding skin perforators. (*Right*) No septocutaneous perforator was seen in the posterior crural septum intraoperatively. Instead, a significantly sized musculocutaneous perforator was noted. This was traced intramuscularly for a distance of 12 cm up to its origin at the tibioperoneal trunk (*white arrow*, soleus musculocutaneous perforator; *yellow arrow*, peroneal artery). (*Below, left*) A skin paddle was raised as a perforator flap and revascularized as a second free flap.

soleus musculocutaneous perforators, as these are located posterior to the posterior crural septum. Having confirmed the presence and location of these perforators, the skin is then islanded and intramuscular dissection proceeds in the usual fashion.

CASE REPORTS

Our practice of preserving the soleus musculocutaneous perforator was useful in two clinical cases. This technique was used successfully to salvage the skin paddle for intraoral lining.

Case 1

A 61-year-old woman underwent resection of a retromolar trigone squamous cell carcinoma that included excision of the left hemimandible and ipsilateral neck nodes. To reconstruct the defect, the ipsilateral fibula with a 12 × 5-cm skin paddle centered over the junction of the middle and lower thirds of the fibula was used. Preoperative Doppler assessment identified two vessels supplying the skin paddle (Fig. 3, *above, left*), but during flap harvest, no peroneal septocutaneous perforator was seen. Instead a musculocutaneous perforator arising from the soleus muscle was noted. This was traced intramuscularly for a distance of 12 cm up to its origin at the tibioperoneal trunk (Fig. 3, *right*). Because the soleus perforator did not originate from the peroneal artery, the skin paddle was raised as a perforator flap and revascularized as a second free flap (Fig. 3, *below, left*). Both flaps healed well and she was able to commence radiotherapy postoperatively. She was well at 3-year follow-up (Fig. 4).

Case 2

A 60-year-old man underwent right hemimandibulectomy for squamous cell carcinoma. Reconstruction with a fibula osteoseptocutaneous flap was planned and preoperative Doppler assessment noted the presence of skin perforators over the planned skin paddle. Intraoperatively, no septocutaneous perforator was seen in the posterior crural septum. Instead, a 1.2-mm-diameter musculocutaneous perforator was noted coming through the soleus muscle. Intramuscular

Fig. 4. The patient at 3-year follow-up, with complete survival of both the bone and skin flap.

dissection was performed and the perforator and its venae comitantes were found to originate from the peroneal vessels (Fig. 5). Because it was a convergent system, the skin was kept attached to the bone and the entire flap was raised as a composite (Fig. 6). Only one set of microvascular anastomoses was required. Postoperative recovery was uneventful, with complete survival of the skin paddle.

Fig. 6. This convergent system was raised and transferred as a single composite flap with one set of microvascular anastomoses.

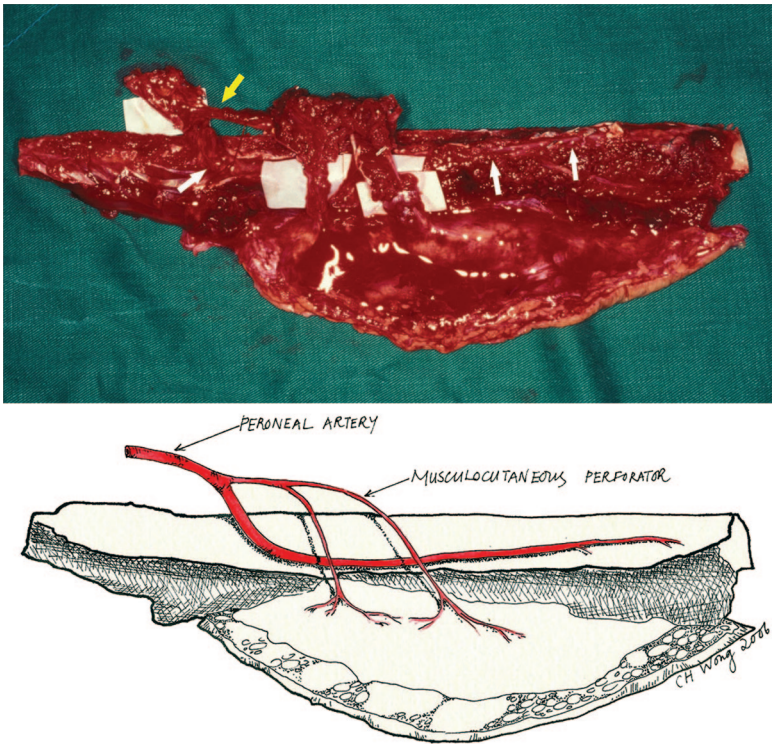

Fig. 5. Intraoperatively, no septocutaneous perforator was seen in the posterior crural septum. Intramuscular dissection of a soleus musculocutaneous perforator was performed and it was found to originate from the peroneal artery (*white arrows*, peroneal artery; *yellow arrow*, soleus musculocutaneous perforator joining the peroneal artery).

DISCUSSION

Recent attention has focused on the anatomical variations of the fibula osteoseptocutaneous flap.[2–6] This anatomical study concentrates on the anatomy of the soleus musculocutaneous perforator and its clinical application for vascularization of the distal lateral leg skin paddle. The septocutaneous perforator in the distal lower limb may be absent in 5 to 10 percent of cases.[2,3,8] In these instances, most authors would recommend intramuscular dissection to elucidate the course of the soleus musculocutaneous perforator supplying the skin flap.[4–6]

The origin of the musculocutaneous perforator, although not well described, is nonetheless important because it affects the course of surgery. The findings of our study were that this was convergent or divergent from the source artery of the fibula flap (i.e., the peroneal artery) in 50 and 40 percent of cases, respectively (Fig. 7). A convergent system is favorable because both the skin paddle and the fibula are vascularized by the same source artery and vein, obviating the need for a second set of microvascular anastomoses. Furthermore, the skin island serves as a monitor for the bone flap. In a divergent system, using the soleus musculocutaneous perforator to salvage the skin paddle would necessitate a second set of microvascular anastomoses, and the skin flap cannot function as a monitor because it is independent of the fibula flap. When a divergent vascular pattern is encountered, the skin paddle may be separated from the fibula by incising the posterior crural septum. By so doing, ischemic time is minimized for one of the flaps, because they have independent vascular supplies and one flap can remain attached while the other is being revascularized at the recipient site. More importantly, separating the flaps affords more freedom in inset of the skin paddle and the selection of optimal location at which to perform the microvascular anastomosis without being restricted by the fibula. In cases where there is a lack of donor vessels in the head and neck region, the distal end of the peroneal vessel can also serve as the recipient vessel in a piggyback manner as previously described.[7] When the skin paddle is harvested as a perforator flap, care should be taken not to damage the posterior tibial artery or tibioperoneal trunk to avoid foot ischemia. From a technical standpoint, the diameter of the pedicle is expected to be smaller (mean diameter, 1.6 mm), its length more variable (range, 4 to 25 cm), and the vessels (particularly the vein) more flimsy. These technical challenges, however, can be overcome by using perforator flap techniques.[9]

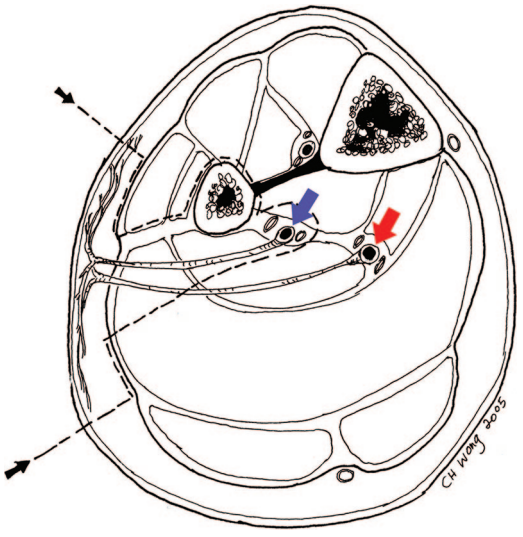

Fig. 7. It was previously assumed that the musculocutaneous vessel in the distal lateral leg originated from the peroneal artery. To preserve these musculocutaneous perforators, inclusion of a 1-cm cuff of both the deep and superficial posterior musculature, including the soleus and flexor hallucis longus muscles, has been recommended by some authors to capture the musculocutaneous perforators supplying the skin component. This is effective only for a convergent perforator (*blue arrow*). However, in patients with a divergent perforator (*red arrow*), taking a cuff of muscle, no matter how generous, will invariably cut the perforator, as it originates from a different artery.

It was previously assumed that the soleus musculocutaneous vessels in the distal lateral leg originated solely from the peroneal artery. Thus, some authors have advocated including a 1-cm cuff of the soleus and flexor hallucis longus muscles to ensure skin viability.[8,10,11] Despite doing so, the incidence of skin flap loss has remained considerable, with an incidence approaching 10 percent.[8,12–15] This is not surprising, as incorporating a cuff of muscle, however generous, would not preserve the vascularity of the skin component if it were supplied by a different source artery.[4,8,16] With the advent of the perforator flap era,[17–24] such a practice is increasingly considered imprecise, as perforator dissection expertise is available to make skin paddle salvage safe and reliable.[9,25]

Several authors have reported success using an approach similar to ours for skin paddle salvage in the absence of significantly sized septocutaneous perforators. Weber and Pederson[6] successfully salvaged two cases where the perforator did not stem from the peroneal artery. Yakoo et al.[5] reported an unusual fibula flap in which the musculocutaneous perforator when traced intramuscularly was

found to have an arterial origin from the posterior tibial artery and a venous origin from the peroneal vein. This osteocutaneous flap was successfully revascularized with two arterial anastomoses and a single venous anastomosis. These clinical experiences illustrate the usefulness of raising the distal lateral leg skin as a perforator flap in salvage situations.

The spectrum and prevalence of variant trifurcation arterial anatomy have been well documented by radiologic studies.[26,27] Of relevance to the harvest of the fibula flap are the various degrees of hypoplasia or aplasia of the anterior tibial and posterior tibial arterial systems. In such arterial anomalies, the peronea arteria magna takes over the blood supply of the foot.[28] Rarely, in a variant known as peroneal arterial magna, the peroneal artery exists as the sole supply to the foot. Because the peroneal artery is procured with the fibula, the foot would be at risk in such situations. If detected preoperatively (by conventional, computed tomographic, or magnetic resonance angiography), the presence of such anomalies would be a relative contraindication to the fibula flap harvest. The contralateral leg or a different donor site should be chosen. Therefore, increasingly, preoperative angiographic evaluation has been recommended for fibula flap harvest. However, Lutz et al. have shown that routine preoperative angiography of the donor leg is not justified, as intraoperative evaluation by direct visualization of the anterior and posterior tibial arteries would be a sufficient safeguard. They prospectively evaluated the use of preoperative angiography on 120 lower limbs.[29] Of these, 119 fibula flaps were subsequently harvested without any adverse sequelae to the leg. They recommended preoperative angiography only for patients with nonpalpable foot pulses or previous trauma to the leg.[29] Newer modalities such as multidetector row computed tomographic angiography capable of delineating skin perforators are increasingly available.[30] When using this technique for preoperative evaluation, potentially useful information that could be derived includes the arterial anatomy of the lower limb, distal leg skin perforators, and their origins. This may improve donor-site selection and preoperative planning.

CONCLUSIONS

The skin component of the fibula osteoseptocutaneous flap is often reliably supplied by septocutaneous perforators running within the posterior crural septum from the peroneal artery. Occasionally, these perforators may be absent. In such situations, the skin paddle can still be reliably harvested by using musculocutaneous perforators supplying the skin through the soleus muscle. However, the origins of these vessels are more variable and may necessitate the raising of two separate free flaps to accomplish the reconstruction.

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DISCLOSURE

The authors did not receive any funding for this work and declare no conflict of interest in this present work.

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