Background: The reversed sural artery flap is a well-described method for lower limb reconstruction. However, in the standard technique, the flap is usually not harvested from the proximal third of the leg. We conducted this study to evaluate the efficiency, safety, and success rate of the reversed sural flap harvested from the proximal third of the leg.

Methods: The authors harvested medium to very large sized flaps from or extended to the upper third of the calf in 28 patients to cover the defects in the distal tibia, ankle, heel, foot, and sole.

Results: With proximal extension of the flap, we would have a longer and larger flap with a safer pedicle. The majority of flaps resulted in a good coverage of defects. Only the distal 1cm of a large flap developed marginal necrosis in the distal border, which was treated with a secondary skin graft. Six flaps developed venous congestion. In seven other patients, minor complications such as hypertrophic scar in the donor site, rupture of sutures, and superficial epidermolysis occurred. In these 13 patients, the complications did not influence the final outcome.

Conclusion: Extension of reversed sural island flap to the proximal third of the leg was safe and reliable. It was efficiently used to treat patients with large and far wounds, from the distal leg to the distal foot and the sole with more versatility and easier reach to the recipient site.

Keywords: Lesser saphenous vein • perforator arteries • reverse island flap • sural artery • sural nerve

Introduction

Complex wounds and soft tissue defects in the distal third of the leg, ankle, and foot remain difficult problems to solve. Free tissue transfer could be the treatment of choice, but it requires a team approach, and accompanies long operative time, donor morbidity, and a risk of complete failure.

In 1992, Masquelet et al.1 described neuroskin island flaps and presented one case of a distally-based sural artery and nerve flap. Since then, many studies have been performed on anatomical and clinical aspects of this flap, which was commonly referred to as “reverse sural artery island flap” and has become an acceptable and routine technique for lower limb reconstruction.

To facilitate safe usage of this flap in difficult and special conditions, several modifications have been already made to the technique, such as delaying,2–4 exteriorizing the pedicle,5,6 a wider than usual pedicle,6 mobilizing the peroneal perforator in the intermuscular septum,7–9 supercharging,10 cross-leg sural flap,9,11,12 leaving a skin extension over the pedicle,13,14 and harvesting a midline cuff of the gastrocnemius muscle with the flap5,15. In the standard technique, the flap is usually not harvested from the proximal third of the leg due to the deep course of the sural nerve between the two heads of the gastrocnemius muscle.

In another approach, we applied a method similar to the conventional technique to harvest the reversed sural flap from the proximal third of the leg, without any of the above-mentioned modifications. This study was performed to evaluate the efficiency, safety, and success rate of...
the reversed sural flap harvested from the proximal third of the leg.

**Patients and Methods**

From 1998 through 2005, we treated 52 patients with ankle, heel, sole, distal leg, and foot defects with reversed sural artery flaps. In 28 of these patients, due to particular conditions, we harvested the flap from or extended to the proximal third of the leg.

Only this group of 28 patients was included in the present study. In these patients, three major special situations persuaded us to harvest the flap from a more proximal than usual site in the leg. In four patients, although the defects were in the ankle, heel, or distal leg, they were too large to be covered by a standard sural flap extracted from the middle third of the leg. In 20 patients, defects were in the foot, sole, or weightbearing heel; far away to reach by a sural flap from the middle third of the leg. Some of these wounds were very large as well. In the other four patients, the primary wound itself or a previous scar was near the lateral malleolus, so we could not rely on the lowermost perforator from the peroneal artery as the only blood supply to the flap pedicle, and we put the pivot point at 7 to 8 cm proximal to the lateral malleolus, to incorporate more perforators in the flap. Consequently, we had to shift the skin paddle to the proximal calf. Some of the patients had two or three of the above mentioned conditions, simultaneously.

A form was filled out for each patient to collect data on patient’s demographics, wound and defect properties including its cause, size, site, bone, tendon, or joint exposure, and associated problems such as diabetes, varicose veins, and smoking. Then, at the operating room and during four to 14 months of follow-up in the ward and outpatient clinic, the second part of the form was completed to record flap characteristics, including the size of the skin paddle, distance of the proximal border of the flap to the popliteal skin crease, pedicle length and width, site of any previous scar at the leg, pivot point distance from the lateral malleolus, and also any complications.

**Surgical technique**

With the patient in prone position, a skin island was marked along the axis of the sural nerve and

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**Figure 1.** Dissection of a large flap. A) The sural nerve and artery, and lesser saphenous vein are ligated 1–2 cm proximal to the proximal border of the flap at the popliteal fossa. B) Extraction of all elements and tissues in the mesentery like structure connected to the flap. At the end, nothing remains between the two heads of the gastrocnemius. C) The lateral sural nerve is included in wide flaps. D) More than one perforator can be incorporated in the pedicle.
lesser saphenous vein in the middle of the posterior aspect of the leg. This can only be in the proximal third of the leg or proximal and middle thirds depending on the size and site of the defect. Furthermore, a line was marked from a point halfway between the Achilles tendon and the lateral malleolus extending to the midline between the two heads of the gastrocnemius. This line roughly marks the course of the pedicle. The dissection was started at the proximal border of the skin island. The sural nerve and artery and lesser saphenous vein were identified and ligated 1 to 2 cm proximal to the proximal border of the skin paddle between the two heads of the gastrocnemius, at or close to the popliteal fossa (Figure 1A). The sural nerve and artery are located deeper between the two heads of the gastrocnemius, while the lesser saphenous vein is always superficial (Figure 2). An important tip here is to expose and release the sural pedicle meticulously by pushing the two heads of the gastrocnemius muscle aside gently, and keeping intact the tiny perforators and accompanying vascular plexus, which are located in the loose fibro-adipo-areolar tissue between the two heads of the gastrocnemius. In fact we extracted all the elements and tissues in the mesentery-like structure while keeping them connected to the flap and at the end, nothing remained between the two heads of the gastrocnemius (Figure 1B). In wide flaps, the lateral sural nerve, if present, and its accompanying artery were also included in the flap (Figures 1C and 2). The skin was elevated along with the fascia. It is advisable to suture the fascia to the skin when elevating it from the muscles. The longer pedicle achieved in this modification let us stop the dissection 5 to 8 cm from the lateral malleolus, and keep more than one peroneal perforators incorporated in the flap (Figure 1D). In the majority of cases, we transposed the flap by tunneling into the recipient defect. In the rest, we incised the skin and repaired it over the pedicle. Except in small flaps, we were not able to directly close the donor site, and applied a skin graft.

Results

The studied patients consisted of 21 men and seven women with a mean age of 25 (range:six to 54) years. Twenty-one of them had been injured in motor accidents; three by mine explosion, three had burns, and one had frostbite.

Defect sizes ranged from 6×4 to 20×10 cm. They were located on the heel, sole, dorsum of the foot, ankle, and distal tibia. None of the patients had diabetes or varicose veins. Seven were smokers (Table 1). In 25 patients, at least one of the bones, joints, or tendons was exposed. Three other patients had chronic unstable scars due to previous burns and skin grafts.

The size of skin islands ranged from 7×5 to
Extraction of reverse sural artery flap from the proximal third of the leg

21×12 cm. The proximal borders of the flaps were 1.5 to 4 cm from the popliteal skin crease. The pedicles were 7 – 17 cm in length and 2 – 3 cm in width. The pivot point was 5 – 8 cm away from the lateral malleolus (Table 2). In two patients, the defect was very close to the lateral malleolus; in two others, there were previous scars over it.

The patients were followed for four to 14 months. None of the flaps failed completely. Nonetheless, in one patient we faced partial loss of the distal 1 cm of a large flap, which was consequently treated by a small skin graft. Six flaps (21%) developed venous congestion which recovered within two weeks. Other minor complications included rupture of suture line in two (7%), superficial epidermolysis in two (7%), and hypertrophic scars at the donor site in three (11%) patients. However, none of these complications affected the final outcome of the flap (Table 3).

### Table 1. Wound sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Heel</th>
<th>Sole</th>
<th>Foot</th>
<th>Ankle</th>
<th>Distal Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases</td>
<td>11</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 2. Flap characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin paddle size (cm)</td>
<td>7×5 to 21×12</td>
</tr>
<tr>
<td>Pedicle length (cm)</td>
<td>7 to 17</td>
</tr>
<tr>
<td>Pedicle width (cm)</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Distance from popliteal crease (cm)</td>
<td>1.5 to 4</td>
</tr>
<tr>
<td>Pivot point distance from lateral malleolus (cm)</td>
<td>5 to 8</td>
</tr>
</tbody>
</table>

Discussion

Soft tissue defects of the distal third of the leg, ankle, heel, and foot are difficult to reconstruct. The reversed distally-based superficial sural artery flap is one of the recently-introduced and well-described therapeutic possibilities. Several studies showed that this type of flap is reliable and can be used for coverage of defects in the lower leg, heel, ankle, and foot.8,14,22 - 25

During harvesting the standard flaps, sometimes we extended our dissection to the proximal third of the calf to find the pedicle elements a few centimeters proximal to the skin paddle. Here, we always saw tiny vessels around the sural artery and nerve, where they were passing under the deep fascia between gastrocnemius heads, and also around the lesser saphenous vein, which was always superficial to the fascia over gastrocnemius heads. These miniature vessels lie in a delicate fibro-adipo-areolar tissue between the two heads of the gastrocnemius muscle and make a mesentery-like structure connected to the deep fascia. This is particularly clear at the distal juncture of gastrocnemius heads. Reviewing papers on sural flaps, we found that this idea had previously been mentioned by Nakajima et al.18,19 Holier et al.,9 and Ayyapan and Chadha20.

In 1998, to cover a large defect in the sole of a young soldier injured by mine explosion, we decided to harvest a sural flap from the proximal third of the leg. We did our best not to touch delicate vessels in the gastrocnemius juncture, the saphenous vein, and to completely incorporate the mesentery-like structure including the sural nerve and artery, tiny vascular network, and small perforators in the pedicle. Fortunately, the flap survived without any complications. Since then, we have harvested the reversed sural flap from the proximal third of the leg in 28 patients successfully (Figures 3 and 4).

As mentioned by Masquelet et al.,1 most authors reported successful flaps proximal are not in favor of or argue very cautiously about harvesting this type of flap from the proximal third of the leg. They reason that the flap circulation mainly depends on the median sural artery and that this artery has direct cutaneous branches only in its superficial portion (i.e., in the lower two thirds of the leg), hence, the proximal extension of the flap has been considered a random type flap and its survival is not predictable.7,8,13,14,22,23,25–27

A group of authors presented modifications to secure extension of the fasciocutaneous island to the proximal leg. Such modifications included delaying,2–4 a wider than usual pedicle,6 supercharging,10 and harvesting a midline cuff of the gastrocnemius muscle with the flap.15 – 17 Others tried to solve this problem without proximal extension of the flap; such modifications included exteriorizing the pedicle,5,6 mobilizing the peroneal perforator in the intermuscular septum,8,13,14 and cross-leg sural flap.9,11,12 There are a few authors third of the calf, using the same principles of the

### Table 3. Complications.

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete failure</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Marginal necrosis</td>
<td>1 (3.6%)</td>
</tr>
<tr>
<td>Venous congestion</td>
<td>6 (21.4%)</td>
</tr>
<tr>
<td>Suture rupture</td>
<td>2 (7.1%)</td>
</tr>
<tr>
<td>Superficial epidermolysis</td>
<td>2 (7.1%)</td>
</tr>
<tr>
<td>Hypertrophic scar at donor site</td>
<td>3 (10.7%)</td>
</tr>
</tbody>
</table>

182 Archives of Iranian Medicine, Volume 11, Number 2, March 2008
standard procedure.\textsuperscript{9,18,20,24,28} During our practice, we faced a number of special conditions urging us to extend the sural flap to the proximal third of the leg. Otherwise, we would have to tackle the problems associated with other options such as free flaps. The first condition was a large defect which required a long skin paddle beyond the middle third of the leg to be covered. The second condition was a far to reach defect in the weightbearing heel, sole, and dorsum of the foot that could be covered only if we were able to provide a sufficiently long pedicle, so the skin island had to be shifted toward the proximal calf. Finally, in some cases, the wound itself or a previous scar was close to the lateral malleolus, so it was preferable not to depend only on the lower most perforator. In such patients, we considered a pivot point more proximal than usual to incorporate proximal perforators in the flap as well. As a result, the flap had to be harvested from a more proximal site.

In our study, of 28 patients, we harvested flaps well beyond the middle third of the calf to manage special problems mentioned before. The proximal border of the flap was only 1.5 to 4 cm away from the popliteal skin crease. We followed the same

**Figure 3 (A, B, and C).** A 22-year-old man injured by mine explosion. Bones were exposed at the right sole, too far to be covered with a standard sural flap. Therefore, the flap was harvested from the proximal third of the leg. The flap survived completely without any complications.

**Figure 4 (A and B).** A 23-year-old woman, with an old frostbite injury and ulceration. To cover this large and distant wound at the left heel and sole, a large reversed sural flap was harvested. It was extended to 3 cm of the popliteal skin crease. The flap survived uneventfully.
principles as the standard technique and completed the procedure in one session. The main consideration during the procedure was keeping the vascular plexus around the sural nerve, sural artery, and lesser saphenous vein in the loose fibro-adipoareolar tissue between the two heads of the gastrocnemius muscle intact and connected to the fasciocutaneous island. This was named a mesentery-like structure by Ayyappan and Chadha. 20

The most significant finding in our study was the lack of complete necrosis of the flap; only one case of partial loss of distal 1 cm of a large flap was encountered. Since many of our patients were young, most of them had traumatic motor accidents and no major comorbid problems except smoking. Nonetheless, this can still be considered a favorable result compared with other series reported earlier using the standard reverse sural flap from the lower two third of the leg which had a rate of 5 to 36% of major ischemic events, i.e., complete or partial necrosis. 5,14,22,25,29–31

We believe that the low rate of ischemic events can be explained firstly by the easier reach of the flap to the recipient defect resulting in less tension, and secondly by more perforators from the peroneal artery that were incorporated in the flap pedicle owing to a more proximal pivot point which can be selected in this method.

The saphenous vein is always superficial, and a vascular network connects it to the fascia and skin. This can play a major role in the survival of the extended flap to the proximal third of the leg. 5,18 Accompanying arteries of the lesser saphenous vein and sural artery, their relationship in the lower two thirds and proximal third of the leg, and their independent role in survival of flaps were discussed in detail by Nakajima et al. 18 Imanishi et al. 32 later explained the role of concomitant veins of accompanying arteries of the lesser saphenous vein in venous drainage of distally based sural flaps, despite the presence of venous valves. Respecting the major role of the lesser saphenous vein, in fact, these authors preferred to use the name of distally based lesser saphenous-sural veno-neuro adipofascial pedicle fasciocutaneous flap. 18,19,32 We also noticed some tiny vascular connections from the sural artery itself to the fasciocutaneous island in the proximal third of the leg, which can be called miniature perforators. Ayyappan and Chadha 20 mentioned these perforators as well. So, we consider the proximal extension of a reverse sural flap as an axial flap and not a random one. Actually, if these delicate vessels are not respected and the proximal part of the sural nerve and artery, and the lesser saphenous vein are incautiously detached from the fasciocutaneous paddle, the proximal part of the flap will be converted to a completely random one and a major ischemic event should be expected.

Shaw et al. 33 described the use of island posterior calf fasciocutaneous flaps to cover knee defects. This flap is proximally based on the sural nerve, accompanying artery and lesser saphenous vein, and is harvested from the posterior calf in the middle and proximal thirds. They have reported one flap ischemia among 10 patients they studied. Their report showed that the proximal posterior calf skin is supplied and drained, at least partially though sufficiently, by arteries and veins incorporated in the sural flap which are similar in proximally and distally based flaps. This also supports the idea of extending distally based reverse sural flaps to the upper third of the leg.

In our experience, extension of reversed sural island flaps to the proximal third of the leg was safe and reliable, and the results of medium sized flaps to very large ones were quite acceptable. These promising results persuaded us to refine our techniques in harvesting the sural flap, and at the moment, we usually take the flap from a more proximal site even without any specific indication. This gives us more versatility and tensionless reach to the recipient defect.

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