The Distally Based Superficial Sural Artery Flap—Clinical Experiences

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The distally based superficial sural artery flap is a veno-neurocutaneous pedicle flap based on reverse flow through the anastomosis between the median superficial sural artery and the lowermost perforator from the peroneal artery. We had thirteen cases experience in using this flap for reconstructing soft tissue defects over distal lower leg and ankle. Two partial and one total flap necrosis was noted and the other ten flaps survived well. Donor site complications included one partial loss of skin graft and one wound dehiscence. The average follow-up was 32 months. No patient complained of sensory disturbance in foot in the follow-up study. This flap has the advantages of reliable blood supply, easy and quick in elevation, no sacrifice of major arteries and minimal donor site morbidity. Disadvantages of this flap include: temporary hypesthesia at the lateral foot and unsightly donor site scar. Some technique refinements must be made to ensure maximal blood supply of the flap and decrease the incidence of complications. (J Plast Surg Asso R.O.C. 2002;11:231~238)

Key words: distally based superficial sural artery flap, neurocutaneous flap, veno-neurocutaneous flap

Introduction

Treatment of soft tissue defect in distal third of lower leg and ankle is difficult because of paucity of available local tissue. Reconstructive options used for this region includes: cross-leg flap, lateral calcaneal flap, dorsalis pedis island flap, various reverse-flow flap and free tissue transfers. Each has its own advantage and disadvantage. Cross-leg flap is cumbersome and needs two-stage operation and longer period of hospitalization. Although we can use many kinds of free flaps nowadays with they carry a high rate of success, the microsurgical free tissue transfer is still very time-consuming and technically challenging. The distally based superficial sural artery flap, first reported by Masquelet in 1992, is another good alternative and has been used widely for reconstructing soft tissue defect in distal leg and ankle. The flap can be elevated easily and safely, but it still has some disadvantages: flap congestion and partial flap failure due to inadequate venous return,
complete flap failure caused by torsion of artery or compression of vascular pedicle under subcutaneous tunnel, unsightly donor site scar, and limited size of the flap. We have used this flap in thirteen cases from Jul. 1995 through Jun. 1999. We will present our experiences in this paper.

Patients and Methods

We have treated 13 patients from Jul. 1994 through Jun. 1999 (Table 1.). All the flaps were fasciocutaneous. Age of the patients ranged between 8 and 67 years old. The sites of reconstructed soft tissue defect included: posterior heels (4 cases), medial malleolus (3 cases), lateral malleolus (2 cases), distal lower leg (3 cases) and middle third of leg (1 case). The size of the flap varied from 2x3 to 7x9 cm. The etiologies of the defect were: trauma (4 cases), pressure sore (3 cases), diabetic ulcer (2 cases), chronic ulcer (2 cases), contact burn (1 case) and necrotizing fasciitis (1 case). The average follow-up was 32 months (range, 2-6 years).

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (Years), Sex</th>
<th>Cause</th>
<th>Site of Skin Defect</th>
<th>Size of Flap (Cm)</th>
<th>Associated Problems</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63, M</td>
<td>Diabetic ulcer</td>
<td>Lateral malleolus</td>
<td>4x5</td>
<td>DM</td>
<td>Total necrosis of flap</td>
</tr>
<tr>
<td>2</td>
<td>63, M</td>
<td>Trauma</td>
<td>Posterior heel</td>
<td>2.5x6</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>8, M</td>
<td>Trauma</td>
<td>Posterior heel</td>
<td>2.5x3</td>
<td>Tibial and fibular fractures</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>43, M</td>
<td>Pressure sore</td>
<td>Posterior heel</td>
<td>3x5</td>
<td>Meningococcal sepsis</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>54, M</td>
<td>Chronic ulcer</td>
<td>Middle third of lower leg</td>
<td>2x3</td>
<td>Exposure of tibial bone</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>23, M</td>
<td>Contact burn</td>
<td>Medial malleolus</td>
<td>4x5</td>
<td>None</td>
<td>Venous insufficiency and distal flap necrosis</td>
</tr>
<tr>
<td>7</td>
<td>33, M</td>
<td>Trauma</td>
<td>Anterior aspect of distal lower leg</td>
<td>4x6</td>
<td>Tibial fracture</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>58, M</td>
<td>Pressure sore</td>
<td>Lateral malleolus</td>
<td>3x4</td>
<td>Spinal cord injury</td>
<td>Wound disruption of donor site</td>
</tr>
<tr>
<td>9</td>
<td>41, F</td>
<td>Trauma</td>
<td>Anteromedial aspect of distal lower leg</td>
<td>7x9</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>45, F</td>
<td>Pressure sore</td>
<td>Posterior heel</td>
<td>4x6</td>
<td>Spinal cord injury</td>
<td>Skin graft failure of donor site</td>
</tr>
<tr>
<td>11</td>
<td>65, M</td>
<td>Necrotizing fasciitis</td>
<td>Medial malleolus</td>
<td>4x7</td>
<td>Liver cirrhosis</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>58, M</td>
<td>Chronic ulcer</td>
<td>Anterior aspect of distal lower leg</td>
<td>5x8</td>
<td>Gout</td>
<td>None</td>
</tr>
<tr>
<td>13</td>
<td>67, F</td>
<td>Diabetic ulcer</td>
<td>Medial malleolus</td>
<td>4x4</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

Operative Procedure

The blood supply of this flap comes from the superficial sural artery that accompanying the sural nerve and also the arteries that accompanying the lesser saphenous vein. These arteries send branches to the skin of the posterior aspect of the leg and anastomose with septocutaneous perforators...
from the peroneal artery in the lower part of the tibiofibular space.

The flap can be raised anywhere over the posterior aspect of the leg, including the upper third. A skin island is marked according to the size of the recipient defect and the need of the pedicle length. The center of the flap is placed along the midline of the posterior leg (Fig. 1A and 2A). The pivot point is situated 5cm above the lateral malleolus (Fig. 2C), the location of anastomosis with the perforator from the peroneal artery, which will supply a reverse-flow flap.

Incision is made through the skin and deep fascia along the distal and lateral margins of the flap. The sural nerve, superficial sural artery and lesser saphenous vein are identified and divided at the distal end of flap. The deep fascia is sutured to the skin and included in the flap. The subcutaneous pedicle is exposed through a zigzag incision and elevated with a width of 4cm. The flap is then transferred to the defect through a subcutaneous tunnel. When the subcutaneous tunnel is tight, the skin bridge is incised and skin graft over the pedicle is performed (Fig. 2D). The flap donor site is closed directly when it is less than 3cm wide (Fig. 1C), otherwise a skin graft is applied (Fig. 2D).

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Fig 1. Patient 2. (A) Avulsion injury over posterior aspect of distal lower leg with exposure of Achilles tendon and flap design (B) Flap elevation (C) Final result

Fig 2. Patient 4. (A) Pressure sore over posterior heel and flap design (B) Flap elevation (C) Flap transfer (D) Final result and scar of the grafted donor site.
Results

Ten of the flaps healed completely (Fig. 1 and 2). One flap in a diabetic patient developed total skin necrosis. The wound was further debrided and split-thickness skin graft was used thereafter to achieve wound healing. This complication was thought to be arterial insufficiency due to diabetic angiopathy. Another two flaps sustained marked swelling and distal necrosis (Fig. 3), but the wounds eventually healed by secondary intention 3 weeks later. Tight compression of the pedicle within the subcutaneous tunnel accounted for this venous congestion. The donor sites of 5 smaller flaps (width < 3cm) were closed primarily. One of these wounds disrupted, but it healed by conservative treatment.

Skin grafts for the donor site defects was done in 8 patients. Partial loss of the skin graft occurred in one patient and further regraft was done to achieve wound healing. The other 7 grafts were well taken.

Long term follow-up of the patients revealed good contour of all the flaps. There was no need for any secondary debulking procedure. One flap in a patient with spinal cord injury developed recurrent pressure sore 6 months later. Split-thickness skin graft was done and covered the ulcer successfully. There was no more recurrence thereafter. The scars of the skin graft on the donor site, although noticeable (Fig. 2D), were acceptable to all the patients. No patients complained of sensory disturbance in foot in the follow-up study.

Discussion

Although the advent of the microsurgical technique and many newly designed muscle and fasciocutaneous flaps cured many difficult wounds all over the body. Soft tissue defects of the distal third of the leg, ankle and foot are still difficult to treat and remain a challenge to many reconstructive surgeons. The reasons consist of: (1) local tissues or pedicles were usually within the zone of injury, (2) lack of available nearby donor tissue for transposition, and (3) the nature of the underlying disease (e.g., diabetes mellitus and peripheral arterial occlusive disease), which often precludes the usage of many surgical procedures. Possible options for reconstruction in these regions include cross-leg flap, muscle flap, fasciocutaneous flap and free flap. Although the cross-leg flap is more reliable, the resultant contour deformity is objectionable both in donor and recipient sites. Local muscle flaps (e.g., soleus, peroneus brevis, and extensor hallucis longus), based on their proximal vascular pedicles, can occasionally be used for coverage of distal third leg.
defects. However, their size is relatively small. The transposition of the distally based muscle flaps (e.g., soleus, extensor digitorum longus, and extensor hallucis longus) is not reliable and had high failure rate because the minor pedicles may be within the zone of injury and have great variability in their location.

For reconstruction of the heel and ankle, superficial muscle group of the sole (e.g., flexor digitorum brevis, abductor hallucis, and abductor digiti minimi) can sometimes be used. There are also a lot of various fasciocutaneous flaps (e.g., dorsalis pedis flap, lateral calcaneal flap, instep flap, reverse anterior tibial artery flap, and reverse peroneal artery flap) available for coverage. Generally speaking, we prefer to use microsurgical free tissue transfer in these regions because the success rate of free flap is high (around 90%) nowadays. The disadvantages of microsurgery include requirement of well-trained microvascular surgeons and team, complex equipment and lengthy surgical procedure. Patients with poor medical status also are not candidates for free flap surgery. In fact, an ideal flap should be reliable, easy to raise, not sacrifice a major artery and nerve, and not dependent on microsurgery.

In 1992, Masquelet and colleagues introduced the concept of neurocutaneous flaps and reported a flap based on reverse flow through the anastomosis between the median superficial sural artery and a perforator from the peroneal artery. Hasegawa refined this technique and first published the “distally based superficial sural artery flap” in 1994. It has been suggested that the pivot point should be at least 5 cm above the lateral malleolus to keep the anastomosis with the peroneal artery, although some said 3 cm is adequate. The pedicle width should be no less than 2 cm and should include the vessels, nerve, and saphenous vein. To increase the vascularity of the flap, inclusion of the deep fascia was also suggested. The advantages of this flap include a reliable vascular pedicle, easy and quick procedure, long rotation arc, and avoidance of microvascular anastomosis. It can replace the microvascular free flaps used for the distal leg, ankle and heel in some selected patients.

The blood supply of this flap was claimed to be reliable, but there is still 12.5% to 30% incidence of venous congestion, superficial necrosis, partial loss or even total necrosis of flap. Venous congestion does occur as the character of this reverse flow flap. Venous drainage in the reverse flow flap is believed to bypass the venous valves through micro-venous and macrovenous connections. The venae comitantes around the superficial sural artery were thought to be insufficient in number to bypass the valves. To improve the flap viability and avoid complication, there are some technique refinements we like to emphasize. We advocate the width of the subcutaneous fascia pedicle should be at least 4 cm, instead of 2 cm, to prevent flap congestion and partial flap failure caused by inadequate venous return. When transferring the flap, care should be taken to avoid torsion of artery or compression of vascular pedicle under subcutaneous tunnel. If in doubt, the subcutaneous tunnel should be opened to release tension and then the wound closed with a skin graft. Some authors recommend T-shaped modification with skin extension over the neurovascular pedicle, or teardrop configuration of the flap to prevent this compression.

The blood supply of the distally based superficial sural artery flap comes from the accompanying artery of the sural nerve, which is known as the median superficial sural artery. This artery and the sural nerve course below the deep fascia in the upper third of the leg, regularly giving off small branches to the nerve, and giving off small branches to the skin only in the lower two third of the leg, where it courses above the deep fascia. These branches are called neuro-cutaneous arteries or neurocutaneous perforators. In the past, it was thought that flap design was safe only if it was taken from the lower two third of the posterior leg along the suprafascial course of the superficial sural
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artery,\textsuperscript{1,2,6,8,9,11} Flap failure can occur when the flap is extended to the proximal third of the calf\textsuperscript{6,9,11}; The portion of the flap that exceeds the suprafascial portion (i.e., in the lower two thirds of the leg) of the nerve behaves like a random extension, and thus its reliability is unsure\textsuperscript{6}.

But, according to the study of Nakajima et al, the accompanying artery of the sural nerve (the median superficial sural artery) had few perforators to the skin\textsuperscript{3} in the upper half of the leg. The lesser saphenous vein had independent accompanying arteries with perforators, called venocutaneous perforators, to the skin along the entire length of the vein\textsuperscript{3}. Therefore, the blood supply of skin of the upper half of the leg came from the two accompanying arteries of the lesser saphenous vein and lower half of the leg from the accompanying artery proper to the lesser saphenous vein and median superficial artery\textsuperscript{3}. Actually, the distally based neuroskin flap using the accompanying artery of the sural nerve described by Masquelet et al. was, in reality, a veno-neurocutaneous flap rather than a neurocutaneous flap. Flap including the proximal third of posterior leg, perfused by venocutaneous perforators from two accompanying arteries of the lesser saphenous vein will survived well\textsuperscript{3,7,12}.

Most authors will emphasize the importance to include the deep fascia with the flap. This concept can be misleading to the new beginners who do not know the surgical anatomy exactly. When a flap is located in the upper half of the posterior leg, the flap pedicle may be still in its subfascial course. If an inexperienced surgeon try to raise this flap using the deep fascia as a dissection plane in a manner like raising a fasciocutaneous flap, he may inadvertently leave the pedicle underneath the flap and thus jeopardize the blood supply.

Some authors used this flap in patients with peripheral vascular disease or diabetic atherosclerosis\textsuperscript{5,6,9,13}; but preoperative evaluation of the anastomosis between the lowermost perforator of peroneal artery and the flap pedicle, with Doppler or even angiography, is mandatory to ensure the reliable vascular supply. Also, some used this flap in patients with acute or severe trauma\textsuperscript{5,6,12}; preoperative confirmation of the perforator is suggested likewise. We agreed with Jeng’s opinion to exclude usage of the flap in patients with extensive calf trauma and dysvascular problems\textsuperscript{7}. Primary closure of the donor site is possible when the flap’s width is less than 3cm. The scar is linear and acceptable. But, whenever tension exists, skin graft of the wound should be done and the scar will be obvious. If a linear scar is preferred, the fascial flap is recommended.

Some authors reported sparing the sural nerve during elevation of the flap\textsuperscript{4,8,14}, but it is risky for the blood supply and it seems not necessary\textsuperscript{6,11}. The sensory impairment of raising this flap with the sural nerve is minimal. All our patients showed great improvement of sensation with time. One year after surgery, no patients complained of significant alteration in foot sensibility\textsuperscript{5,6}.

This flap is a fasciocutaneous flap. Although insensate because neural anastomosis was not performed, the flap durability is good. It can be used for soft tissue coverage in the distal third of leg, posterior heel and plantar heel. There was no pressure sore or recurrent ulceration, even in reconstruction of the weight-bearing areas of plantar heel\textsuperscript{3,6,9}. If a neurosensorial flap is necessary, the lateral sural cutaneous nerve can be transferred with the flap and coapted to a recipient nerve in the defect to be reconstructed\textsuperscript{4,8}. In reconstructing plantar heel, the medial plantar flap is a first choice because it offers the most similar tissue of the sole. Free innervated fasciocutaneous flap or free muscle flap with skin graft are other alternatives. Because of lack of bulk and septa between the skin and fascia, the fasciocutaneous flaps are less resistant to pressure and shearing forces. Although muscle flaps covered with skin grafts is more durable, ulceration may still occur\textsuperscript{15}. The most important reason for recurrent breakdowns are abnormally high pressure points and
there is no correlation between sensibility of free and distant flaps and the durability of the soft tissue reconstruction.16

**Conclusion**

In summary, ten of our thirteen distally based superficial sural artery flaps healed without any complications. The flap has the following advantages: reliable blood supply, elevation is easy and quick, long pedicle, no sacrifice of major arteries and low morbidity of the donor site. There are two main disadvantages of this flap: temporary hypesthesia at the lateral aspect of the foot and unsightly donor site scar when it is covered with a skin graft. This flap can be used for reconstruction of the distal third of leg, ankle and heel and substituted for microsurgical free flaps in selected cases. Some technique refinements must be made to ensure maximal blood supply of the flap and decrease the incidence of complications.

**References**

遠端性表淺腓腸動脈皮瓣的臨床經驗

李俊達  徐宗伯  鄭立福  王健興  黃介琦  簡守信  陳明庭

遠端性表淺腓腸動脈皮瓣是一種帶血管內的靜脈神經皮膚性的皮瓣，它逆流的基礎是
經由正中表淺腓腸動脈和腓骨動脈來的最下面的穿透枝之間的吻合。我們有十三病例經驗
用這塊皮瓣來重建小腿遠端和足踝的軟組織缺損。有兩例部份及一例全部皮瓣壞死，其餘
十例皮瓣存活良好。供皮區的併發症包括一例部份皮膚移植喪失及一例傷口裂開，沒有病
人抱怨腳部的感覺異常。這個皮瓣的優點有：穩定的血流供應，皮瓣的拆卸容易而迅速，
不犢牲主要的動脈和極低的供皮區的罹病率。為了要確保皮瓣有最大的血流供應以及減少
併發症的發生，手術技術要做一些改良。