Distally based perforator sural flaps for foot and ankle reconstruction

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Abstract
Distally based perforator sural flaps from the posterolateral or posteromedial lower leg aspect are initially a neurofasciocutaneous flap that can be transferred reversely to the foot and ankle region with no need to harvest and sacrifice the deep major artery. These flaps are supplied by a perforating artery issued from the deep peroneal artery or the posterior tibial artery, and the chain-linked adipofascial neurovascular axis around the sural/saphenous nerve. It is a versatile and reliable technique for soft-tissue reconstruction of the heel and ankle region with 180-degrees rotation. In this paper, we present its developing history, vascular basis, surgical techniques including flap design and elevation, flap variations in pedicle and component, surgical indications, and illustrative case reports with different perforating vessels as pivot points for foot and ankle coverage.

Key words: Fasciocutaneous flap; Distally based flap; Foot and ankle; Perforator flap; Neurocutaneous flap; Sural flap; Propeller flap

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Core tip: Distally based perforator sural flaps are perfused by a perforating artery issued from the deep peroneal or posterior tibial artery, and the longitudinal chain-linked adipofascial neurovascular axis around the sural/saphenous nerve. It is a versatile and reliable rapid procedure for soft-tissue reconstruction of the heel and ankle region with 180-degrees rotation. This paper presents the developing history, vascular basis, surgical techniques including flap design and elevation, flap variations in pedicle and component, surgical indications, and illustrative case reports with different perforating vessels as pivot points for foot and ankle coverage.
INTRODUCTION

Reconstruction of the foot and ankle wounds, especially when complicated with deep vital structures such as bone, joint, nerves or tendon are exposed, remains a challenging problem for the treating surgeon. The foot with the features of weight bearing requirement, the lack of intervening muscle between the skeleton and the skin, and the limited movement of the overlying skin, make the soft-tissue coverage even more difficult[1]. In general, there are several methods of surgical procedures, including vascular-pedicled loco-regional transposition and microsurgical free transfer of muscle or myocutaneous flaps, and fascial or fasciocutaneous flaps. Each procedure has its own merits and drawbacks on indications, technical requirement, flap size, range of vascular pedicle, and limitations of patient’s local and general conditions[2].

Besides free flaps with microsurgical vascular anastomosis, there are other options using pedicled vascular flaps from the ipsilateral uninjured lower leg with a distal-base, which had been developed and consequently modified in the past two decades[3]. Currently, those reverse-transferred flaps can be categorized into three patterns[4]: (1) The reverse-flow island flaps, such as the reversed anterior tibial artery flap, the posterior tibial artery flap, and the peroneal artery flap; (2) The distally perforator-based flaps, which avoid the sacrifice of the main deep arteries, such as the lateral and medial supra-malleolar flap; and (3) The distally based neuro-veno-fasciocutaneous flaps that are supplied by the chain-linked longitudinal directed vascular plexuses from a wide neuro-veno-adipofascial pedicle. These three loco-regional kinds of flaps can be elevated easily and substituted for microsurgical free flaps for foot and ankle reconstructions in some conditions.

HISTORIC PERSPECTIVE

The concept of fasciocutaneous flaps was first introduced by Ponten et al[5] in 1981 for lower leg soft-tissue reconstruction. The first distally based lateral sural fasciocutaneous flap was described by Donski et al[6] in 1983 for Achilles tendon coverage. The flap was supplied by a septocutaneous vessel issued from the peroneal artery that located in the postero-lateral septum of the lower leg and about 10cm above the lateral malleolus. In 1986 Amarante et al[7] reported a similar medial sural flap supplied by a perforator from the posterior tibial artery that located in the postero-medial septum of the lower leg. In 1988 Masquelet et al[8] introduced the lateral supramalleolar flap that perfused by the anterior perforator of the peroneal artery located at 5 cm above the lateral malleolus. In 1992 Masquelet et al[9] proposed the concept of neurocutaneous flap, and described the distally based sural neurocutaneous flap for reconstructing the distal third leg, foot and ankle defects. This flap is nourished by the lower-most septocutaneous perforator from the peroneal vessel, usually located 5 cm (4-7 cm) above the lateral malleolus as demonstrated by Hasegawa et al[10] in 1994, and the longitudinally disposed chain-linked adipofascial plexuses as well as the neuro-vascular axis around the sensitive sural nerve. In 1996 Chang[11] pointed out that in essence, neurocutaneous flaps in the limbs was a specific example of fasciocutaneous flaps, as it was basically fasciocutaneous in flap component but strengthened in blood supply by longitudinally disposed perineural vascular plexus. These flaps also called neurofasciocutaneous flaps[11]. In 1999 Nakajima et al[12] notified the accompanying vessels of the lesser saphenous vein and sural nerve, and proposed the term of veno-fasciocutaneous flap and neurovenofasciocutaneous flap. In 2003 Chang et al[13,14] demonstrated in experimental studies that cutaneous large superficial veins in distally-based flaps played a negative role and suggested ligate these big cutaneous veins (great/lesser saphenous vein) to prevent flap ingress. In 2004, Chang et al[15] converted the flap pedicle from wide adipofascial to septum perforator, making it easy for 180-degrees rotation. In 2007 Chang et al[16] described a new vascular basis of the sural neurocutaneous flap, which is supplied by the lateral retromalleolar perforator of the peroneal artery usually located 1 cm above lateral malleolus. To reduce the postoperative flap congestion, Chang et al[17] further modified a technique in 2014 with perforator-plus-adipofascial pedicle for sural propeller flaps.

VASCULAR ANATOMIC CONSIDERATIONS

The fasciocutaneous vascularization of the lower leg is mainly provided by septocutaneous perforators, sometimes supplemented by musculocutaneous perforators and strengthened by the neuro-veno-cutaneous plexuses[18,19].

Vascular anatomic studies have shown that there are 2 longitudinal rows of perforators in the distal sural region. The medial row was issued from the posterior tibial artery, located between the tibia and the Achilles tendon. The lateral row was originated from the peroneal artery, located between the fibula and the Achilles tendon. As a general rule, perforators can be found above the medial or lateral malleolar tip approximately at (1) 2 cm (which is termed the retro-malleolar space perforator); (2) 5 cm (which is termed the distal-most septocutaneous perforator); and (3) 10 cm (the middle septocutaneous perforator), respectively (Figure 1). These perforators form a three-dimensional vascular architecture. There are prominent longitudinal axially of the vasculature in different tissue layers, including fascial, paraneural and perivenous vascular plexuses[20-22].

Anatomic study also showed the possibility to
harvest muscles with the sural flap. The gastrocnemius muscle-tendon junction was located at the midpoint (1/2) of the lower leg. The sural nerve was found passing through the deep fascia from the inter-gastrocnemius muscle groove to the superficially subcutaneous tissue at the junction of upper-middle third (1/3). Therefore, a midline "groove muscle cuff" around the inter gastrocnemius nerve "mesentery" would be included to form a fasciomyocutaneous flap to cure osteomyelitis and/or filling dead space\cite{26,27}. There was a 4 cm overlapping length (range 3 to 5 cm) between the lateral gastrocnemius muscle belly and the deep fascia foramen where the sural nerve went from the subfascial to the suprafascial. In its suprafascial route, the sural neurovascular axis gave off at least 1 branch, i.e., the musculo-fascio-cutaneous perforator, reversely to the lateral gastrocnemius muscle, and usually 2 branches, reversely to the medial muscle. The diameter of these perforators was smaller than 0.5 mm (range 0.2 to 0.5 mm)\cite{28}. These findings provide the anatomic basis for harvesting distally based sural neuro-fasciomyocutaneous flap with the distal portion of gastrocnemius muscle. The vascular supply for the attached gastrocnemius muscle fragment beneath the deep fascia, was assumed reversely from the superficial neuroadipofascial vascular axis, which was perfused by the distal perforator of the peroneal artery\cite{28}.

Venous drainage in distally based flaps is usually a special concern in hemodynamic physiology because the venous blood of the flap must reversely return to its distal pedicle against venous valves. Venous problems are one of the major reasons for flap complications and failures. Chang et al\cite{13,14,29,30} proposed that the lesser saphenous vein in distally based sural flap have no positive role for venous drainage, but conduct the venous blood from the foot to ingress the flap to cause venous overloaded, which is hazardous for flap survival. Large superficial veins should be interrupted and ligated distal to the pivot point of the flap to prevent flap congestion and swelling. Other methods to relieve venous load include venous anastomosis by microsurgical technique and leech therapy.

**Surgical Technique**

**Flap design**

In designing a surgical flap, five key points should be considered: (1) pivot point, the flap is rotated around this point, which is usually the axial vascular perforator issued from the deep main vascular stem; (2) axial line, the flap is designed along this line, which is the direction of vascularization of the flap; (3) flap area, which is the size of the flap according to the defect; (4) dissection plane, which is the surface that the flap was elevated; and (5) rotation arc, which indicates the most distal point that the flap can reach by rotation.

A longitudinal line roughly represents the course of the posterior tibial artery (or peroneal artery) is drawn from the mid-point of popliteal fossa to the mid-point between Achilles tendon and medial malleolus (or lateral malleolus) in the leg. This also represents the course of the posterior branch of the saphenous nerve in the postero-medial aspect, or the superficial sural nerve and the lesser saphenous vein in the posterolateral aspect of the lower leg, respectively. All distal-based perforator flaps are centered on either of these two lines. The required skin paddle is then outlined reversely on the lower leg, according to location and the size of the tissue defect.

**Flap elevation**

Under continuous epidural anesthesia or intratracheal intubational general anesthesia, the patient was placed in the prone (for heel coverage), supine (for medial ankle coverage), or lateral position (for lateral ankle coverage). A thigh pneumatic tourniquet was used and the leg was exanguinated by elevation and hand compression for 1-2 min. This maneuver allows emptying of most of the blood from the leg but retains enough in the perforating vessels to allowing for easier identification during operative exploration. After debridement of the defect, a sharp long exploratory incision (5-7 cm in length) along its posterior margin (Achilles side), is firstly made, straightly down to the deep fascia from the wound to the distal part of the flap. Temporary anchoring stitches should be used to secure the deep fascia with the skin paddle. Then the flap is elevated forward from the sub-fascial level (the surgical plane) to the septum to search the perforator. After a proper perforator is identified, the flap design is re-evaluated and adjusted, according to the exact location of the perforator. If the perforator showed nice (for example, 1 mm in diameter, at least 2 cm in length, and closer companion of the perforating artery and partner veins, and observed pulsation after pneumatic release), we recommended skeletonize the perforating vessels to achieve free-restrict rotation. If
are located in flap dimension. The flap was rotated 180 degrees to reach the recipient foot or heel and inset with tension-free. No venous anastomosis was performed for super-drainage. The sural nerves in the flaps were harvested more proximally to get extra 2 to 3 cm, and coated the proximal cut end of sural nerve to a recipient nerve (saphenous nerve or superficial peroneal nerve) in end-to-side fashion or calcaneal branch from the medial plantar nerve in side-to-side fashion to restore the flap sensation. The donor areas can be covered by split-thickness skin grafts, or directly closed provided its width is less than 5 cm.

For foot and calcaneus coverage, an anterior supportive plaster of Paris or splint was used postoperatively for immobilization for 2 wk. After plaster was removed, the patients started an active and passive physical rehabilitation program to get maximum range of ankle motion.

**FLAP VARIATIONS**

Many different modifications of the sural flaps have been made based on its vascular pedicle and flap components\(^{[31,32]}\). Table 1 summarizes those different types of flap variations.

**SURGICAL INDICATIONS**

The distally based sural fasciocutaneous flaps can generally be rotated to cover any soft-tissue defect of
the foot and ankle region, usually small to medium-sized defect (about 10 cm in length). In practice, it usually restricts to the middle of the foot.

Distally based adipofascial flap can be transferred by turn-over mode to provide thin and subtle coverage for exposed tendons and bone on the dorsum of the foot. The adipofascial flap is then covered with skin graft primarily or secondarily.

Distally based fasciomyocutaneous flap can provide a bulk and high metabolic viable muscle component for repairs of the soft tissue defects complicated with osteomyelitis, deep dead space and for plantar heel pad reconstruction, which need thickness.

**CASE PRESENTATIONS**

**Case 1: Fasciocutaneous island flap**
A 60-year-old paraplegic male suffered a pressure ulcer over the lateral malleolus of his left leg for 6 mo. After debridement, the wound was measured 4 cm × 3 cm in size with bone exposure. A distally based fasciocutaneous island flap from the lateral sural region was used to solve the problem. The skin paddle measured 5 cm × 4 cm in size, supplied by a 3 cm wide and 4 cm long adipofascial pedicle. The flap was rotated to the defect and inset with tension free. The donor site was closed directly. The flap survived completely, and the wound was cured successfully (Figure 2).

**Case 2: Turnover adipofascial flap**
A 62-year-old woman suffered calcaneus fracture of her right foot. After open reduction and plate fixation through lateral extended L-shaped incision, the wound became infected. One-year later, she was referred to us with chronic calcaneal osteomyelitis and a skin sinus. The problem was solved in three stages. In the first stage, the implant was removed and complete

![Image](image-url)
debridement was performed, followed with a vacuum-sealing-drainage (VSD) for 1 wk. In the second stage, as the wound was clean, an adipofascial turnover flap was designed on the posterolateral aspect of the lower leg to eradicate the dead space. The flap was based on the lateral retromalleolar perforators, the pivot point was located 2 cm above the lateral malleolus, and the flap measured 13 cm × 5 cm. The flap was turned over 180-degrees to fill the cavity of the calcaneus. In the third stage, the adipofascial flap was covered with split-skin grafts, and the subtalar joint was fused with 2 screws. The patient was followed up 3 mo. The wound was cured successfully, and she was able to walk independently (Figure 3).

Case 3: Perforator-plus fasciocutaneous flap
A 52-year-old man suffered an open pilon fracture of his right leg. After open reduction and internal fixation, the medial wound developed a delayed infection 3 mo later. The wound was first debridement and supplemented with VSD management. One week later, a distally based medial sural fasciocutaneous flap was designed to cover the defect. The flap was pivoted on the septocutaneous perforator located 10 cm above the medial malleolus, with a quarter of adipofascial to protect the perforator. The skin island measured 5 cm × 3 cm with a narrow skin bridge over the adipofascial pedicle. The flap was rotated 180-degrees to reach the recipient site, and inset with tension-free. The donor site was closed directly. Both the flap and donor site healed without complications (Figure 4).

Case 4: Perforator skeletonized propeller fasciocutaneous flap
A 60-year-old female suffered an open pilon fracture of her left leg. After plate fixation, the skin over the plate

![Figure 4 Perforator-plus fasciocutaneous flap for medial malleolar coverage. A: Delayed wound infection after open pilon fracture; B: First stage management, debridement and vacuum-sealing-drainage; C: Perforator-plus fasciocutaneous flap harvest from the posteromedial sural region; D: Flap transfer and inset; E: Complete flap survival in two weeks.]
was necrotized, leaving a 5 cm × 4 cm wound with plate exposure. A medial sural island fasciocutaneous flap, nourished by a posterior tibial artery perforator (Φ1.0 mm with 2 partner veins) located 9 cm above the medial malleolus. The flap was designed as propeller flap, with large blade 10 cm × 4 cm, and small blade 4 cm × 2 cm. The flap was rotated 180-degrees to reach the wound. Both the donor and recipient sites were sutured primarily. Postoperatively, the flap showed venous congestion and swelling. This was managed with multiple small incisions over the flap to let blood out. The flap survived completely after two weeks (Figure 5).

DISCUSSION
Coverage of soft-tissue defects of the foot is a challenging procedure in trauma and reconstructive surgery. The options lie in vascular pedicled flaps and microsurgical free flaps.

Since the introduction of fasciocutaneous, neurocutaneous, and perforator flaps in the lower leg, the vascularization of the calf and sural region has been extensively investigated. Anatomic studies have shown that the superficial sural artery from the popliteal, the septocutaneous perforators from posterior tibial artery (medial side) and peroneal artery (lateral side), and myocutaneous perforators from gastrocnemius and soleus, form a three-dimensional vascular architecture with prominent longitudinal orientation in the posterior lower leg\textsuperscript{[28]}. There are 4 to 5 axial communications between this longitudinal neuro-veno-adipofascial plexus and the posterolateral/posteromedial septocutaneous perforators issued from the peroneal artery/posterior tibial artery, respectively. The distal perforators, in particular, can be used effectively for coverage of defects of the heel, malleolus, Achilles tendon, and distal third of the tibia\textsuperscript{[33]}.

Island flap pedicled with a single perforator, also called pedicled perforator flap, island perforator flap, local perforator flap, or perforator pedicled propeller flap, has the greatest freedom of rotation, which can reach up to 180 degrees\textsuperscript{[34]}. In recent years, there was a great increasing use of perforator-based propeller flaps in limb reconstruction, especially for the lower leg and foot, with a distal rotation\textsuperscript{[35,36]}. These flaps combine the advantages of pedicled local flaps (good color and texture match), pedicled regional flaps (up to 180 degrees arc of rotation), pedicled distant flap (larger flap size and vascular reliable), and without microsurgical vascular anastomosis. Furthermore, for most small to medium-sized defects (< 10 cm in length), it allows linear closure with direct suture of the donor site.

The distally based sural island flaps is a useful and versatile reconstructive option in patients with soft-tissue defects of the foot. The advantages include: (1) the ability to be transferred from a proximal donor site to

**Figure 5** Perforator pedicled propeller flap for pilon wound coverage. A: Plate exposure in a 60-year-old woman with open pilon fracture; B: Posterior tibial artery perforator pedicled fasciocutaneous flap was raised, the perforator was skeletonized; C: The flap was propelled 180-degrees to the recipient site; D: Flap survival, with minor superficial marginal necrosis.
sacrifice the deep major artery. vascular plexus, which is no need to harvest and (3) the one-stage rapid procedure, which requires no distal recipient; (2) the avoidance of foot dependence; (4) it is supplied by a perforating artery and the chain-linked adipofascial vascular plexus, which is no need to harvest and sacrifice the deep major artery.

REFERENCES

1. Cho EH, Garcia R, Pien I, Thomas S, Levin LS, Hollenbeck ST. An algorithmic approach for managing orthopaedic surgical wounds of the foot and ankle. *Clin Orthop Relat Res* 2014; 472: 1921-1929 [PMID: 24577615 DOI: 10.1007/s11999-014-3536-7]

2. Ong YS, Levin LS. Lower limb salvage in trauma. *Plast Reconstr Surg* 2010; 125: 582-588 [PMID: 20124844 DOI: 10.1097/PRS.0b013e3181e2edd1]

3. Hallock GG. Distally based flaps for skin coverage of the foot and ankle. *Foot Ankle Int* 1996; 17: 343-348 [PMID: 8791082]

4. Parrett BM, Talbot SG, Pribaz JJ, Lee BT. A review of local and regional flaps for distal leg reconstruction. *J Reconstr Microsurg* 2009; 25: 445-455 [PMID: 19593730 DOI: 10.1055/s-0029-1223847]

5. Ponten B. The fasciocutaneous flap: its use in soft tissue defects of the lower leg. *Br J Plast Surg* 1981; 34: 215-220 [PMID: 7236984]

6. Donski PK, Fogdestam I. Distally based fasciocutaneous flap from the sural region. A preliminary report. *Scand J Plast Reconstr Surg* 1983; 17: 191-196 [PMID: 6673085]

7. Amaranth P, Costa H, Reis J, Soares R. A new distally based fasciocutaneous flap of the leg. *Br J Plast Surg* 1986; 39: 338-340 [PMID: 3730679]

8. Masquelet AC, Beveridge J, Romana C, Gerber C. The lateral supramalleolar flap. *Plast Reconstr Surg* 1988; 81: 74-81 [PMID: 2892218]

9. Masquelet AC, Romana MC, Wolf G. Skin island flaps supplied by the vascular axis of the sensitive superficial nerves: anatomic study and clinical experience in the leg. *Plast Reconstr Surg* 1989; 82: 1115-1121 [PMID: 1584872]

10. Hasegawa M, Torii S, Katoh H, Esaki S. The distally based superficial sural artery flap. *Plast Reconstr Surg* 1994; 93: 1012-1020 [PMID: 8134458]

11. Chang SM. The pedicle of neurocutaneous island flaps. *Plast Reconstr Surg* 1996; 98: 374-376 [PMID: 8764735]

12. Nakajima H, Imanishi N, Fukuzumi S, Minabe T, Fukui Y, Miyasaka T, Kodama T, Aiso S, Fujino T. Accompanying arteries of the lesser saphenous vein and sural nerve: anatomic study and its clinical applications. *Plast Reconstr Surg* 1999; 103: 104-120 [PMID: 9915170]

13. Chang SM, Gu YD, Li JF. Comparison of different managements of large superficial veins in distally based fasciocutaneous flaps with a veno-neuro-adipofascial pedicle: an experimental study using a rabbit model. *Microsurgery* 2003; 23: 555-560 [PMID: 14705071]

14. Chang SM, Gu YD, Li JF. The role of the large superficial vein in survival of proximally based versus distally based sural veno-neuro-fasciocutaneous flaps in a rabbit model. *Plast Reconstr Surg* 2005; 115: 213-218 [PMID: 15622253]

15. Chang SM, Zhang F, Yu GR, Hou CL, Gu YD. Modified distally based peroneal artery perforator flap for reconstruction of foot and ankle. *Microsurgery* 2004; 24: 430-436 [PMID: 15378572]

16. Chang SM, Zhang F, Xu DC, Yu GR, Hou CL, Linaweaver WC. Lateral retromalleolar perforator-based flap: anatomical study and preliminary clinical report for heel coverage. *Plast Reconstr Surg* 2007; 120: 697-704 [PMID: 17700121]

17. Chang SM, Wang X, Huang YG, Zhu ZX, Tao YL, Zhang YQ. Distally based perforator propeller sural flap for foot and ankle reconstruction: a modified flap dissection technique. *Ann Plast Surg* 2014; 72: 340-345 [PMID: 23277108 DOI: 10.1097/SAP0b013e3182610f81]

18. Carriquiry C, Aparecida Costa M, Vasconez LO. An anatomic study of the septocutaneous vessels of the leg. *Plast Reconstr Surg* 1985; 76: 354-363 [PMID: 3898166]

19. Le Huec JC, Midy D, Chauveau D, Calneux N, Colonseth B, Bovet JL. Anatomical basis of the sural fascio-cutanous cutaneous flap: surgical applications. *Surg Radiol Anat* 1988; 10: 5-13 [PMID: 3131898]

20. Cormack GG, Lamberty BGG. The arterial anatomy of skin flaps. *Plast Reconstr Surg* 1998; 102: 599-616; discussion 617-618 [PMID: 9727424]

21. Taylor GI, Pan WR. Angiosomes of the leg: anatomic study and clinical implications. *Plast Reconstr Surg* 1998; 101: 2013-2015 [PMID: 9623867]

22. Chang SM, Hou CL. Integument flaps incorporating the nutrifying arteries of cutaneous nerves and/or cutaneous veins. *Plast Reconstr Surg* 1999; 104: 1210-1212 [PMID: 10654780]

23. Tang M, Mao Y, Almutairi K, Morris SF. Three-dimensional analysis of perforators of the lower leg. *Plast Reconstr Surg* 2009; 123: 1729-1738 [PMID: 19483572 DOI: 10.1097/PRS.0b013e3181a3f736]

24. Al-Qattan MM. A modified technique for harvesting the reverse sural artery flap from the upper part of the leg: inclusion of a gastrocnemius muscle “cuff” around the sural pedicle. *Ann Plast Surg* 2001; 47: 269-274, discussion 274-278 [PMID: 11562031]

25. Al-Qattan MM. The reverse sural artery fasciocutaneous flap can help small lower-limb defects: the use of the gastrocnemius muscle cuff as a plug for small bony defects following debridement of infected necrotic bone. *Ann Plast Surg* 2007; 59: 307-310 [PMID: 17721212]

26. Chang SM, Zhang K, Li HF, Huang YG, Zhou JQ, Yuan F, Yu GR. Distally based sural fasciocutaneous flap: anatomic study and modified technique for complicated wounds of the lower third leg and weight bearing heel. *Microsurgery* 2009; 29: 205-213 [PMID: 19031395 DOI: 10.1002/micr.20595]

27. Chang SM, Chen ZW. Can superficial veins reverse flow through valves in distally based fasciocutaneous flaps? *Plast Reconstr Surg* 1991; 87: 995-996 [PMID: 20175151]

28. Chang SM, Hou CL. Role of large superficial veins in distally based flaps of the extremities. *Plast Reconstr Surg* 2000; 106: 230-231 [PMID: 10883652]

29. Follmar KE, Baccarani SP, Baumeister SP, Levin LS, Erdmann D. The distally based saphenous flap. *Plast Reconstr Surg* 2007; 119: 138e-148e [PMID: 17440334]

30. Schmidt K, Jakubietz M, Djalek S, Harenberg PS, Zeplin PH, Jakubietz R. The distally based adipofascial sural artery flap: faster, safer, and easier? A long-term comparison of the fasciocutaneous and adipofascial method in a multimorbid patient population. *Plast Reconstr Surg* 2012; 130: 360-368 [PMID: 22495207 DOI: 10.1097/PRS.0b013e3182589e0e]

31. Chai Y, Zeng B, Zhang F, Kang Q, Yang Q. Experience with the distally based sural neurofasciocutaneous flap supplied by the terminal perforator of peroneal vessels for ankle and foot reconstruction. *Ann Plast Surg* 2007; 59: 526-531 [PMID: 17992146]

32. Chang SM, Tao YL, Zhang YQ. The distally perforator-pedicled propeller flap. *Plast Reconstr Surg* 2011; 128: 575e-577e; author reply 577e [PMID: 22030531 DOI: 10.1097/PRS.0b013e31822b86ad]

33. Wong CH, Tan BK. Maximizing the reliability and safety of the distally based sural artery flap. *J Reconstr Microsurg* 2008; 24: 589-594 [PMID: 18024066 DOI: 10.1055/s-0028-1090604]

34. Tsai J, Liao HT, Wang PF, Chen CT, Lin CH. Increasing the
Chang SM et al. Distally based perforator sural flaps for traumatic foot and ankle reconstruction: patient selection and surgical refinement. *Microsurgery* 2013; 33: 342-349 [PMID: 23653382 DOI: 10.1002/micr.22099]

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