PERONEAL ARTERY PERFORATOR-BASED PROPELLER FLAP RECONSTRUCTION OF THE LATERAL DISTAL LOWER EXTREMITY AFTER TUMOR EXTIRPATION: CASE REPORT AND LITERATURE REVIEW

ARIEL N. RAD, M.D., NAVIN K. SINGH, M.D., and GEDGE D. ROSSON, M.D.*

Background: Soft tissue defects in the distal lower extremity present a formidable challenge due to the lack of reliable local flap options. Pedicled adipofasciocutaneous flaps provide the closest match to local tissues, but random pattern flaps are limited in reliability, size, reach, and arc-of-rotation. One hundred and eighty degree perforator-based propeller flaps are an innovative option because they provide robust axial perfusion to flaps with significantly greater surface area and ease of transposition versus that provided by their random pattern counterparts in these anatomic regions traditionally addressed with free tissue transfer. *Case:* We present a rare case of aggressive digital papillary carcinoma of the posteriolateral ankle and Achilles region. Wide local excision resulted in a defect with Achilles tendon exposure and denudation. A fasciocutaneous propeller flap based on a dominant peroneal artery perforator was raised and rotated 180° to resurface the wound, providing a gliding surface for Achilles tendon function. The reconstruction was successful with no complications, excellent contour, and esthetic appearance. *Conclusions:* Peroneal perforator-based propeller flaps in the ankle region are useful local options providing unparalleled form and function, with excellent surface area and mobility, for dynamic areas of the lower extremity, without sacrificing any major vessels or nerves. This technique adds to the reconstructive microsurgeon's armamentarium for complex coverage of the ankle region. © 2008 Wiley-Liss, Inc. Microsurgery 28:663–670, 2008.

The skin in the ankle and Achilles region is thin, pliable, sensate, and provides a gliding surface for the Achilles tendon. These properties are vital to the normal function of the ankle as a dynamic joint during ambulation. The challenge for the reconstructive surgeon is to match the original tissue properties if joint function and esthetic form are to be preserved. Free tissue transfer has been the traditional reconstructive modality in this region; however, microsurgical skill, specialized equipment, and resources required for these complex operations are not commonly available outside of tertiary care centers. Furthermore, tissue properties of some free flaps may not be ideal matches to the thin, supple fasciocutaneous tissue of the ankle region.

Muscle flaps are associated with a loss of function, albeit often imperceptibly, as well as with inadequate reach in the distal lower extremity.[1,2] Reconstruction with local fasciocutaneous flaps is an ideal option because it provides the closest match to lost tissue in terms of skin color, durability, volume, and pliability. Local random pattern flaps are unreliable because of limited flap dimensions, a wide pedicle base restricting flap mobility, and relatively poor tissue laxity. There is an upward of 25% flap necrosis in single-stage distal lower extremity reconstruction utilizing the most robust random pattern flaps.[3] Reverse sural artery or sural neurocutaneous flaps are often reported for these defects, but there is a lack of consensus in their technique, success rates, and applicability. Perforator-based flaps address these problems and allow superior movement of significantly larger fasciocutaneous flaps. Successful outcomes have been described in the axilla,[4] peri-olecranon,[5] forearm,[6] and lower extremity.[7,8] For the distal lower extremity, the design and use of true propeller flaps for small wounds less than 20 cm^2 based on the tibioperoneal system have been well described for wounds from trauma, osteomyelitis, and chronic small vessel disease.[9] However, large propeller flaps for wounds greater than 40 cm^2 following tumor extirpation have not been described.

With this case report, we seek to illustrate the coverage of a tumor extirpation defect at the lateral ankle joint with exposed, denuded Achilles tendon. Although microsurgical free tissue transfer and other pedicled fasciocutaneous flaps were entertained, we opted for the peroneal artery perforator-based 180° propeller flap.

CLINICAL CASE REPORT

Our patient is a 40-year-old male investment broker referred to us for definitive treatment of a left posterolateral ankle digital papillary adenocarcinoma. The patient had noticed an asymptomatic black growth measuring 1 inch in size and gradually increasing in size over several months. There was no ulceration, induration, or bleeding from the mass. He was otherwise healthy and a nonsmoker. His primary care physician excised the mass

Division of Plastic and Reconstructive Surgery, The Johns Hopkins University School of Medicine, Baltimore, MD

*Correspondence to: Gedge D. Rosson, M.D., Division of Plastic and Reconstructive Surgery, The Johns Hopkins University School of Medicine, Johns Hopkins Outpatient Center 8th Floor, McElderry 8161, 601 North Caroline Street, Baltimore, MD 21287. E-mail: gedge@jhmi.edu

Received 5 April 2008; Accepted 23 July 2008

Published online 8 October 2008 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/micr.20557

Figure 1. Defect of posterior lateral ankle measuring 8 cm × 6 cm with denudation of Achilles tendon. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

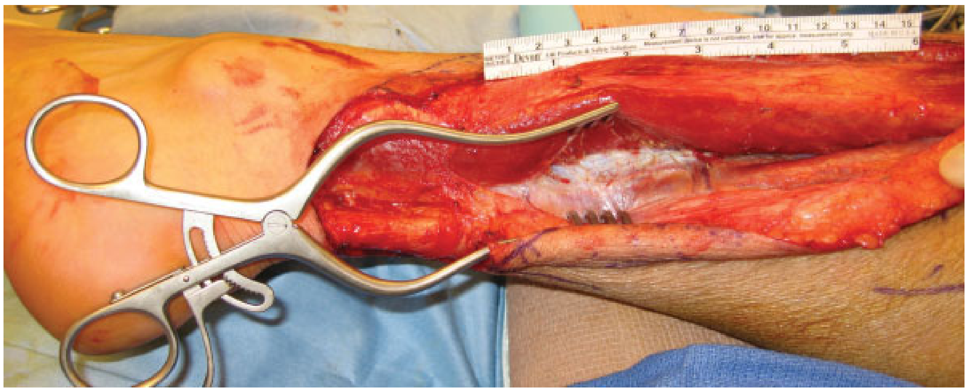

Figure 2. Anterior subfascial dissection until principle perforator is located. Note that the posterior incision is not yet made. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

in the office, and final pathology reported incompletely excised aggressive digital papillary adenocarcinoma. He was referred to one of our orthopedic oncology surgeons, who felt that wide resection with sentinel lymph node biopsy was indicated. Examination in clinic revealed a well healed transverse posterolateral ankle scar measuring 2.5 cm length, with normal posterior tibial and dorsalis pedis pulses. Because of the proximity to the Achilles tendon and potential exposure, we felt that coverage with a free flap may be needed.

He was taken to the operating room where sentinel lymph node biopsy and wide local excision were performed. The resection specimen included the sural nerve and Achilles tendon paratenon. The resultant defect measured 6 × 8 cm with exposed Achilles tendon with loss of paratenon (see Fig. 1). Primary closure was not possible, and we felt that a skin graft likely would not adhere and revascularize and certainly would not provide a stable gliding surface for preservation of Achilles tendon glide; therefore, free flap, reverse sural artery flap, and 180° propeller flap options were entertained. The use of Integra was considered, but it was felt to be unsuitable due to the patient's needs for quick healing and return to work after single stage surgery.

We chose the peroneal artery perforator-based 180° propeller flap, because this was a single-staged (i.e., non-delayed) operation, would provide an ideal tissue match, had minimal donor site morbidity, and seemed a simple and elegant solution. Using a Doppler probe, we identified a robust peroneal artery perforator 8 cm proximal to the superior edge of the wound and designed a flap extending 14 cm proximal to the perforator such that the most proximal aspect could be rotated to reach the most distal aspect of the wound (see Fig. 2). Thus, the flap itself measured 22 × 8 cm. The perforator was dissected using perforator flap dissection principles through some fibers of the flexor hallucis longus muscle around the fibula to its origin from the peroneal artery (see Fig. 3). The flap was then rotated 180° and inset without tension (Figs. 4 and 5). The proximal leg donor site overlying the soleus muscle required a small split thickness skin graft for closure, harvested from the ipsilateral proximal thigh. The patient was discharged home without complications on postoperative day 5.

His preoperative metastatic work-up, including CT scan of the chest, abdomen, and pelvis and PET scan, were all negative. Because final pathology from the wide resection specimen revealed widely negative margins

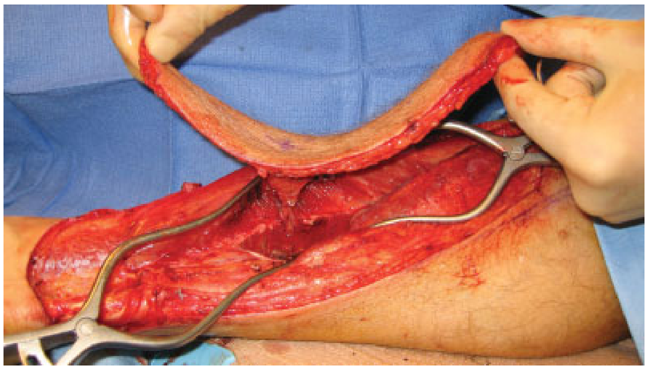

Figure 3. Dissected and elevated peroneal artery perforator-based propeller flap. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

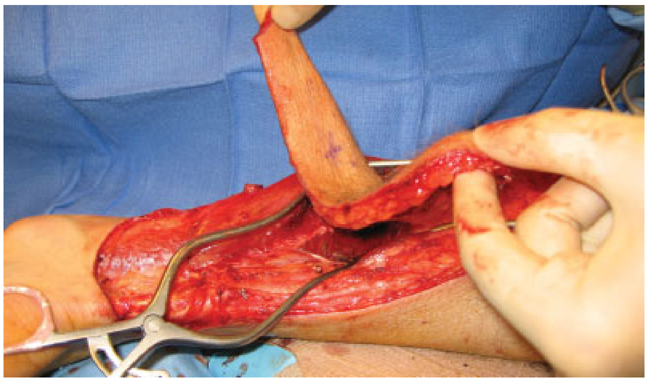

Figure 4. Flap partially rotated. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

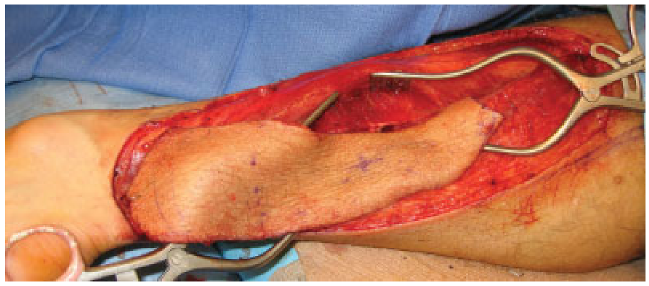

Figure 5. Flap rotated 180° and transposed into ankle defect. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Figure 6. Two-year postoperative follow-up demonstrating excellent contour, appearance, and stable wound coverage. We have not performed any revisions or touch-ups. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

coupled with a negative sentinel lymph node biopsy, his radiation oncologist felt that adjuvant radiation therapy would be unnecessary and recommended close clinical monitoring.

Follow-up 22 months from the time of reconstruction revealed no evidence of recurrent disease. Subjectively, he reports no pain or any other problems with the foot. On examination, his flap is soft and supple (see Fig. 6). He has some residual decreased sensation in the sural nerve distribution, as expected. There is full range of motion at the knee and ankle. He has been back to all his usual activities and participates in sports at his preoperative level. We have not performed, nor has he requested, any revisions or touch-ups.

DISCUSSION

Flap Options for the Ankle and Achilles Region

This is a rare case of digital papillary adenocarcinoma with a primary lesion arising from the posterior ankle soft tissue. Digital papillary adenocarcinoma, an aggressive and rare eccrine carcinoma that typically affects males, has a metastatic potential of 14%. These tumors have no benign counterpart.[10] Treatment has centered around sentinel lymph node biopsy for staging and surgical excision with wide margins. Recurrence rates approach 50% with simple excision, and thus radiation therapy is typically recommended.[11] Postoperative external beam radiation therapy to the tumor bed was a possibility; therefore, we chose an adipocutaneous flap for reconstruction because this may theoretically withstand tumoricidal radiation changes more robustly than a skin graft.[12] Important to preoperative reconstructive planning is the potential for exposure, with or without denudation, of vital structures such as bone, tendon, or blood vessels, the location of the defect over a static (i.e., between joints) or dynamic (over joints) anatomic region, cause of the defect (trauma, tumor extirpation, etc.), donor site morbidity, the tissue quality needed to optimally address these requirements, and the technical expertise and resources that are required.

Although free tissue transfer is the traditional solution to distal lower extremity reconstruction,[13] it is tedious and requires special resources. Aside from the complexity of free tissue transfer, tissue recruited from a distant site may not suit the thin, durable, and gliding surfaces needed for the ankle region. Flaps such as the ALT,[14,15] lateral arm,[16] and radial forearm[17] flaps are excellent options for resurfacing the ankle region in thin patients. However, as the ankle is not a region of significant adiposity, these flaps may not be ideal in the obese. Donor site morbidity with use of these free flaps is significant both functionally and esthetically. Furthermore, free tissue transfer sacrifices arterial inflow to the foot from the recipient artery if end-to-end anastomosis is used. Although this may not be critical to perfusion of the foot in the young healthy patient, this may prove crucial in the aged patient in whom the peroneal artery may provide retrograde perfusion through the posterior and anterior tibial artery systems. Free tissue transfer can be an excellent option if local tissue transfer with a pedicled or propeller flap is unsuccessful.

As dictated by Poisseuille's law, blood flow through an ideal vessel varies with the radius to the fourth power ($dV/dt \propto r^4$). This law explains why local random pattern flaps are poor options because blood flow is through the fine, low-flow capillary network. This varies with anatomic region—for instance, the face has a more rich and robust perfusion and thus is more "forgiving" with larger flaps, whereas the distal lower extremity is less so. However, with the advent of perforator techniques, pedicled perforator flaps are a superior option because they enjoy the same caliber pedicle as a free perforator flap but without the requirement for microsurgical anastomosis. To be fair, there is a theoretical decrease in blood flow due to the 180° twist, which depends on the length of the pedicle through which this twist is distributed. As the pedicle approaches zero length, the blood flow approaches zero; therefore, it makes intuitive sense that pedicle length should be maximized. The exact relationship of blood flow to flap perfusion and drainage has not yet been rigorously studied and warrants further investigation.

Propeller fasciocutaneous flaps are effective but underutilized alternatives for soft tissue reconstruction. Table 1 highlights several well illustrated series of peroneal perforator-based flaps, including propeller, standard pedicled, and free flaps.

Other examples cited in the literature include the reverse sural artery flap[27] and its lateral variant flap, the medial sural artery perforator flap,[28] the saphenous artery, and reversed flow saphenous island flaps.[29] Flap elevation requires a detailed knowledge of the main vessel's course and its possible anatomical variations and dissection around the vessel can be time-consuming. Unfortunately, the originally described reverse sural artery flap technique has a risk of partial or total flap necrosis as high as 25%. Therefore, a delay of the flap may also be necessary as reliability of a single-stage operation may not be consistent. A wide pedicle base is also necessary, but this often results in contour deformity and dog ear.[30]

The donor site created following transposition of this flap required a skin graft in this patient, however the surface area requiring skin grafting is able to accept a skin graft, unlike the original wound over the Achilles tendon. This is a procedure that can be performed predictably and reproducibly in a comparatively short period of time. Detailed knowledge of the distribution of perforator vessels in this area is not an absolute prerequisite to performing this procedure, because the vessels can be mapped reliably before surgery using Doppler ultrasound, much as any "free-style free flap."[31] Indeed, this technique expands the repertoire of reconstructive surgeons who may or may not be skilled in microsurgery. Although the procedure eliminates what might be perceived as the most intimidating portion of microsurgery—the microanastomoses, it still requires meticulous perforator flap technique, loupe magnification, and adherence to the principles of microvascular reconstruction.

Anatomy for Flap Design

The peroneal artery branches off the tibioperoneal trunk and courses along the medial aspect of the fibula in the deep compartment to supply the posterolateral lower leg, ankle, and heel. Perforating vessels branch from the peroneal artery at 3–5 cm intervals and course through or in close proximity to the posterolateral intermuscular septum before reaching the subdermal plexus of the posterolateral skin. They may be purely septal or course through the flexor hallucis muscle, the soleus muscle, or both.[32] These perforating vessels may be identified with handheld unidirectional Doppler,[1,33] color duplex imaging,[34] magnetic resonance angiography,[35] or, similar to DIEP flap perforators,[36,37] 3D CT scan angiography. Distally, the peroneal artery anastomoses with the posterior tibial artery via one to three transverse communicating branches deep to the Achilles tendon.[38] These branches are located about between 0 and 6 cm above the level of the ankle joint or just above the calcaneal insertion of the Achilles. Consequently, it is impossible by Doppler ultrasound to know whether the flow through the distal posterior tibial artery originates comes from the proximal posterior tibial artery or indirectly from the distal peroneal artery via the communicating branches. Conversely, it is also not possible to determine whether the flow through the peroneal artery originates from the peroneal artery proper or from the posterior tibial artery.[39] This fact becomes important in assessing the relative contribution of each major vessel to foot perfusion, particularly in the setting of peripheral vascular disease, and therefore the appropriateness of flaps based on these arterial systems. The perforator-based propeller flap technique mitigates the use of either the posterior tibial or the peroneal arteries proper, as these major vessels themselves are not

Table 1. Well-Described Clinical Series Utilizing a Peroneal-Artery Perforator for Basis of Flap Design

Study author	Flap used	Vascular system	Patients	Mean age	Mean flap size (cm^2)	Anatomic region reconstructed	Indication	Complications
Touam[18]	Reverse distally-based perforator flap	Lateral supramaleollar artery from peroneal perforator	27	47	47 cm^2 (15–112)	Heel, ankle, forefoot	Trauma, infection, chronic wound	Five partial/total flap loss
Chang[19]	Modified distally-based peroneal artery perforator flap	Posterior supramalleolar perforator from peroneal artery	7	36	135 cm^2 (102–250)	Heel, ankle, Achilles	Trauma, electrical burn	None
Wolff[20]	Proximal leg perforator free flap, peroneal artery preserved	Proximal peroneal artery perforators	10	63	30 cm^2 (24–48)	Intraoral	Tumor	One total flap necrosis
Lee[21]	Distal leg adipofascial flap, peroneal artery preserved	Distal peroneal artery perforators	7	12	55 cm^2 (36–108)	Foot	Trauma, chronic scar contracture	None
Zhang[22]	Distally-based sural neurofasciocutaneous perforator flap	Posterior supramalleolar perforator from peroneal artery	21	33	80 cm^2 (12–216)	Malleolus, heel	Trauma, pressure ulcers	None
Voche[23]	Reverse distally-based perforator flap	Lateral supramaleollar artery, peroneal perforator	41	35	51 cm^2 (9–135)	Heel, ankle, forefoot	Trauma, infection, chronic wound	Three partial flap necrosis
Kawamura[24]	Mid and distal leg perforator free flap, peroneal artery preserved	Distal peroneal artery perforators	5	37	Not given (10–36)	Great toe, hand, leg, arm, jaw	Tumor and trauma	One total flap necrosis
Kawamura[24]	Proximal leg perforator free flap, peroneal artery preserved	Proximal soleus peroneal artery perforators	18	41	Not given (15–135)	Great toe, hand, leg, arm, jaw	Tumor and trauma	Five venous thrombosis, but all survived
Chai[25]	Distally-based sural neurfasciocutaneous perforator flap	Posterior supramalleolar perforator from peroneal artery	15	34	176 cm^2 (48–323)	Heel, ankle, forefoot	Trauma and electrical burn	Two patients with marginal necrosis
Jakubietz[9]	Distally-based perforator "propeller" flap	Distal perforators, peroneal and posterior tibial arteries	8	61	15 cm^2 (9–20)	Ankle, Achilles	Trauma and electrical burn	One partial flap loss, two epidermolysis
Chang[26]	Retromalleolar perforator-based flap	Most distal peroneal artery perforators	5	41	45 cm^2 (18–60)	Heel	Trauma, melanoma, pressure ulcer	One minor dehiscence

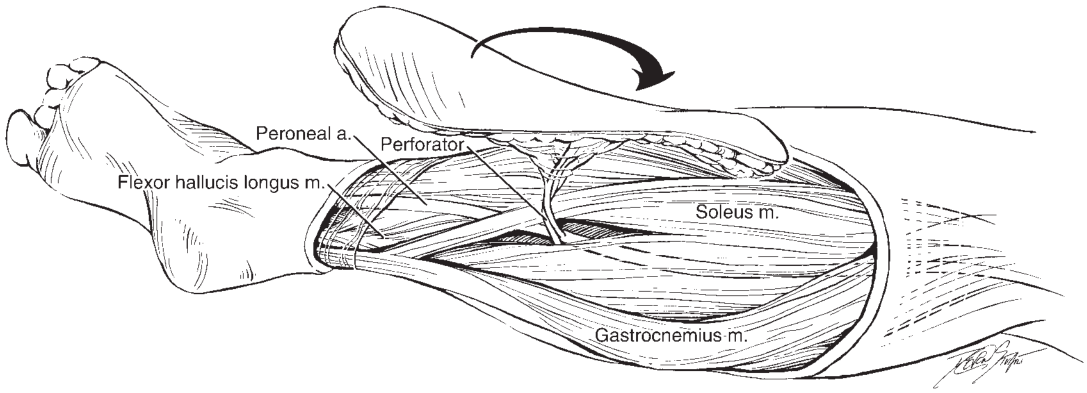

Figure 7. Illustration of the peroneal artery perforator-based 180° propeller flap demonstrating pertinent anatomy, including relative locations of the flexor hallucis longus and soleus muscles. This flap has already been 'spun' such that the longer proximal leg tissue is now facing distally and overlies the lateral ankle and distal leg. (© 2008 Devon Stuart, used with permission).

dissected or divided. Whichever main vessel is giving primary flow to the perforator will remain intact.

Operative Technique of Propeller Flap

Perforator vessels are mapped using a handheld Doppler ultrasound probe ideally before induction of general anesthesia. This is to avoid the associated drop in perfusion blood pressure, which can confound identification of dominant perforators by Doppler. Alternatively, continuous epidural space anesthesia may be used in patients at high risk for complications from general anesthesia. Flap design and orientations are marked on the skin around the sited perforators, ensuring adequate flap length proximally should the most proximal perforator be selected. A tourniquet is inflated around the thigh without prior exsanguination. This ensures that the perforator vessels remain fully dilated that aids in their identification.

A longitudinal incision is made along the anterior edge of the flap. Using loupe magnification, the dissection proceeds posteriorly in either a suprafacial or subfascial plane and local perforators are identified and protected. During this dissection, the proximal margin of the flap should be left intact until the final choice of perforator to use has been made (a more proximal perforator will require a longer flap). The ideal perforator is selected based on vessel caliber and the most distal position possible. The posterior incision is then made, and the flap completely undermined while protecting the isolated perforators. Assessment of flap perfusion and venous drainage based on the chosen vessel can be made with temporary atraumatic occlusion of deselected perforators with Acland clamps after the tourniquet is released. If flap color and capillary refill suggest adequate perfusion and venous drainage over time, secondary perforators are deselected, ligated, and divided. Inadequate flap circulation or venous congestion warrants inclusion of nearby perforator(s) or flap delay. Thus it is critical to leave one or more skin bridges intact (preferably the proximal and distal margins) should the decision to delay the flap become necessary during periodic evaluation of flap perfusion. If commitment to a single perforator is appropriate, the proximal and distal skin bridges are divided last.

Retrograde intramuscular or intraseptal dissection of the principal perforator toward the peroneal artery maximizes pedicle (perforator) length (see Fig. 7). This distributes the 180° rotation over a greater pedicle length to minimize tension and twist on the pedicle (perforator) and allows greater reach. During flap inset, undue tension on or twisting of the vessels is avoided, and the flap is secured with 3-0 and 4-0 absorbable sutures. A drain is placed subcutaneously and is removed after 24–48 hours. A posterior foot-drop plaster splint is applied and strict elevation of the flap is enforced for ~1–2 weeks postoperatively.

The only series of true propeller flaps based on anterograde flow from the peroneal artery are those presented by Jakubietz et al.,[9] Chang et al.,[19] and Chai et al.[25] Chang et al. describe a variation of the technique whereby the propeller flap is neurotized by identifying and coapting the proximal cut end of the sural nerve saphenous or superficial peroneal nerves in an end-to-end fashion. Chai et al. describe large fasciocutaneous flaps, the largest being 31 × 13 cm (403 cm^2), to resurface massive plantar and heel wounds. They cite the fact that constant vascular anastomoses between the superficial sural artery and the septocutaneous peroneal artery perforator form arterial plexuses around the sural nerve that are able to support a large flap without the need for additional venous drainage (such as via anastomosis of the lesser saphenous vein to the peroneal vein). As the fascial plexuses allow venous egress from the flap, Chai et al. warn against the detachment of the fascia from the overlying skin and subcutaneous fat in order to avoid venous congestion and resultant flap necrosis.

This method of flap elevation differs from those presented by the other authors listed in Table 1. The decision to preserve or ligate the vascular connections between the distal peroneal and anterior tibial arteries allows the surgeon the freedom to choose anterograde flow or retrograde flow to the flap. This decision is based on how much pedicle length is required to resurface the wound. Specifically, Touam et al. demonstrate this principle by ligating the septocutaneous peroneal artery perforator and anterolateral malleolar branch of the anterior tibial artery, thus changing flap perfusion to retrograde flow from the anterior tibial system. This allows great reach of the flap to most distal locations in the foot. The technique is appropriate for wounds distal to the lateral malleolus, as trauma in the region of the dorsalis pedis artery will obviate retrograde flap perfusion through this conduit. Voche et al. expound on their experience with the lateral supramalleolar flap in 41 patients. Here, perfusion to the flap is retrograde through the tarsi arteries by ligating the distal peroneal perforator, anterolateral malleolar branch of the anterior tibial artery, the tarsal lateral artery, and the dorsal arch vessels.[23] This gives superior pedicle length to resurface distant foot wounds.

Other peroneal perforator-based flaps include the series of seven patients reported by Lee et al. who utilized a lateral supramalleolar adipofascial flap turned over to resurface dorsal foot wounds. The advantage here is the avoidance of bulk that would otherwise result from a fasciocutaneous flap as well as providing a gliding surface for extensor tendons of the foot.[21]

Free tissue transfer utilizing a lateral lower leg flap based on the peroneal perforators has been described for reconstruction of remote wounds of the head and neck[20] and hand and elbow.[24] These flaps have adequate pedicle length of 4–6 cm and spare the sacrifice of a major leg vessel.

CONCLUSIONS

Together, these techniques of peroneal perforator-based flaps provide the microvascular surgeon with a vast repertoire of options in resurfacing complex wounds. These options should be considered in the patient subpopulation with isolated wounds of the distal lower extremity. Usage of local tissue, such as with the propeller flap in this clinical case example, demonstrates many advantages over free tissue transfer, including decreased operating time, donor site morbidity, superior esthetic outcomes, and functional gliding surfaces for these dynamic areas of the leg in a single stage.

Specifically, peroneal perforator-based “propeller” flaps in the ankle region are useful local options providing unparalleled form and function, with excellent surface area and mobility, for dynamic areas of the lower extremity, without sacrificing any major vessels or nerves. This technique adds to the reconstructive microsurgeon’s armamentarium for complex coverage of the ankle region. We encourage other groups to utilize this technique and report larger series.

REFERENCES

1. Quaba O, Quaba A. Pedicled perforator flaps for the lower limb. Semin Plast Surg 2006;20:103–111.
2. Kamath BJ, Joshua TV, Pramod S. Perforator based flap coverage from the anterior and lateral compartment of the leg for medium sized traumatic pretibial soft tissue defects–A simple solution for a complex problem. J Plast Reconstr Aesthet Surg 2006;59:515–520.
3. Almeida MF, da Costa PR, Okawa RY. Reverse-flow island sural flap. Plast Reconstr Surg 2002;109:583–591.
4. Geh JL, Niranjan NS. Perforator-based fasciocutaneous island flaps for the reconstruction of axillary defects following excision of hidradenitis suppurativa. Br J Plast Surg 2002;55:124–128.
5. Davalbhakta AV, Niranjan NS. Fasciocutaneous flaps based on fascial feeding vessels for defects in the periolecranon area. Br J Plast Surg 1999;52:60–63.
6. Yii NW, Niranjan NS. Fascial flaps based on perforators for reconstruction of defects in the distal forearm. Br J Plast Surg 1999;52:534–540.
7. Lees V, Townsend PL. Use of a pedicled fascial flap based on septocutaneous perforators of the posterior tibial artery for repair of distal lower limb defects. Br J Plast Surg 1992;45:141–145.
8. Venkataramakrishnan V, Mohan D, Villafane O. Perforator based V-Y advancement flaps in the leg. Br J Plast Surg 1998;51:431–435.
9. Jakubietz RG, Jakubietz MG, Gruenert JG, Kloss DF. The 180-degree perforator-based propeller flap for soft tissue coverage of the distal, lower extremity: A new method to achieve reliable coverage of the distal lower extremity with a local, fasciocutaneous perforator flap. Ann Plast Surg 2007;59:667–671.
10. Duke WH, Sherrod TT, Lupton GP. Aggressive digital papillary adenocarcinoma (aggressive digital papillary adenoma and adenocarcinoma revisited). Am J Surg Pathol 2000;24:775–784.
11. Malafa MP, McKesey P, Stone S, Dudley-Walker S, Cockerell CJ. Sentinel node biopsy for staging of aggressive digital papillary adenocarcinoma. Dermatol Surg 2000;26:580–583.
12. Sumi Y, Ueda M, Kaneda T, Oka T, Torii S, Sakuma S. Postoperative irradiation after reconstructive surgery: Comparative study of radiosensitivity between free-skin grafts and skin flaps. Plast Reconstr Surg 1984;74:385–392.
13. Levin LS. Foot and ankle soft-tissue deficiencies: Who needs a flap? Am J Orthop 2006;35:11–19.
14. Kuo YR, Kuo MH, Chou WC, Liu YT, Lutz BS, Jeng SF. One-stage reconstruction of soft tissue and achilles tendon defects using a composite free anterolateral thigh flap with vascularized fascia lata: Clinical experience and functional assessment. Ann Plast Surg 2003;50:149–155.
15. Rodriguez ED, Rosson GD, Bluebond-Langner R, Bochicchio G, Grant MP, Singh NK, Silverman RP, Scalea TM. The utility of the anterolateral thigh donor site in reconstructing the United States trauma patient. J Trauma 2007;62:892–897.
16. Ulusal BG, Lin YT, Ulusal AE, Lin CH, Yen JT. Reconstruction of foot defects with free lateral arm fasciocutaneous flaps: Analysis of fifty patients. Microsurgery 2005;25:581–588.
17. Musharafieh R, Atiyeh B, Macari G, Haidar R. Radial forearm fasciocutaneous free-tissue transfer in ankle and foot reconstruction: Review of 17 cases. J Reconstr Microsurg 2001;17:147–150.
18. Touam C, Rostoucher P, Bhatia A, Oberlin C. Comparative study of two series of distally based fasciocutaneous flaps for coverage of the lower one-fourth of the leg, the ankle, and the foot. Plast Reconstr Surg 2001;107:383–392.
19. 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.
20. Wolff KD, Holzle F, Nolte D. Perforator flaps from the lateral lower leg for intraoral reconstruction. Plast Reconstr Surg 2004;113:107–113.

21. Lee YH, Rah SK, Choi SJ, Chung MS, Baek GH. Distally based lateral supramalleolar adipofascial flap for reconstruction of the dorsum of the foot and ankle. Plast Reconstr Surg 2004;114:1478–1485.
22. Zhang FH, Chang SM, Lin SQ, Song YP, Zheng HP, Lineaweaver WC, Zhang F. Modified distally based sural neuro-veno-fasciocutaneous flap: Anatomical study and clinical applications. Microsurgery 2005;25:543–550.
23. Voche P, Merle M, Stussi JD. The lateral supramalleolar flap: Experience with 41 flaps. Ann Plast Surg 2005;54:49–54.
24. Kawamura K, Yajima H, Kobata Y, Shigematsu K, Takakura Y. Clinical applications of free soleus and peroneal perforator flaps. Plast Reconstr Surg 2005;115:114–119.
25. 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.
26. Chang SM, Zhang F, Xu DC, Yu GR, Hou CL, Lineaweaver WC. Lateral retromalleolar perforator-based flap: Anatomical study and preliminary clinical report for heel coverage. Plast Reconstr Surg 2007;120:697–704.
27. Satoh K, Fukuya F, Matsui A, Onizuka T. Lower leg reconstruction using a sural fasciocutaneous flap. Ann Plast Surg 1989;23:97–103.
28. Lin SD, Lai CS, Chiu YT, Lin TM, Chou CK. Adipofascial flap of the lower leg based on the saphenous artery. Br J Plast Surg 1996;49:390–395.
29. Cavadas PC. Reversed saphenous neurocutaneous island flap: Clinical experience. Plast Reconstr Surg 1997;99:1940–1946.
30. Foran MP, Schreiber J, Christy MR, Goldberg NH, Silverman RP. The modified reverse sural artery flap lower extremity reconstruction. J Trauma 2008;64:139–143.
31. Wei FC, Mardini S. Free-style free flaps. Plast Reconstr Surg 2004;114:910–916.
32. Wolff K-D. Peroneal artery perforator flap. In: Blondeel PN, Morris SF, Hallock GG, Neligan PC, editors. Perforator Flaps: Anatomy, Technique, & Clinical Applications, Vol. 2. St. Louis: QMP Publishing; 2006. pp 707–717.
33. Hallock GG, Wei F-C, Mardini S, Kimura N. Reconstruction of the lower extremity. In: Blondeel PN, Morris SF, Hallock GG, Neligan PC, editors. Perforator Flaps: Anatomy, Technique, & Clinical Applications, Vol. 2. St. Louis: QMP Publishing; 2006. pp 915–933.
34. Hallock GG. Evaluation of fasciocutaneous perforators using color duplex imaging. Plast Reconstr Surg 1994;94:644–651.
35. Fukaya E, Grossman RF, Saloner D, Leon P, Nozaki M, Mathes SJ. Magnetic resonance angiography for free fibula flap transfer. J Reconstr Microsurg 2007;23:205–211.
36. Masia J, Clavero JA, Larranaga JR, Alomar X, Pons G, Serret P. Multidetector-row computed tomography in the planning of abdominal perforator flaps. J Plast Reconstr Aesthet Surg 2006;59: 594–599.
37. Rosson GD, Williams CG, Fishman EK, Singh NK. 3D CT angiography of abdominal wall vascular perforators to plan DIEAP flaps. Microsurgery 2007;27:641–646.
38. Attinger CE, Evans KK, Bulan E, Blume P, Cooper P. Angiosomes of the foot and ankle and clinical implications for limb salvage: Reconstruction, incisions, and revascularization. Plast Reconstr Surg 2006;117(Suppl 7):261S–293S.
39. Attinger C, Cooper P, Blume P, Bulan E. The safest surgical incisions and amputations applying the angiosome principles and using the Doppler to assess the arterial-arterial connections of the foot and ankle. Foot Ankle Clin 2001;6:745–799.