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Case Reports and Series

Healing Heel Ulcers in High-Risk Patients: Distally Based Peroneus Brevis Muscle Flap Case Series

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ABSTRACT

The purpose of this study was to demonstrate use of a distally based peroneus brevis muscle flap in high-risk patients with diabetes and peripheral vascular disease for limb salvage of nonhealing heel ulcerations. Seventeen patients were referred for a below-knee amputation because of nonhealing heel ulcerations and peripheral vascular disease. As a last resort, 17 distally based peroneus brevis muscle flaps were elevated in 17 patients with full-thickness heel ulcerations measuring an average defect size of 14.11 cm². All flaps were supplemented with concentrated bone marrow aspirate, negative pressure wound therapy, bilayer wound matrix, and static external fixation for an average time of 10.3 weeks. Split-thickness skin graft was delayed by an average of 17.5 days. All procedures were performed on patients diagnosed with diabetes, advanced peripheral arterial disease and a nonhealing heel ulcer present >1 year. All flaps survived at 1.5 years follow-up. The average time to healing was 10.3 weeks. No major amputations were performed to date. Partial tip necrosis occurred in 2 patients and healed uneventfully with local wound care. Distally based peroneus brevis muscle flaps in patients with diabetes and peripheral vascular disease offer a reliable alternative to limb salvage for full-thickness heel ulcerations measuring up to 7 × 6 cm. Combinatorial procedures are necessary to improve outcomes in high-risk patients whose alternative is a major amputation.

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Heel ulcers are challenging wounds for foot and ankle specialists. Even with the gold standard of off-loading with total contact casts, there is a high failure rate (up to 63.3%) with conservative approaches (1). Multiple options for wound coverage include free flaps, local fasciocutaneous flaps, and muscle rotational flaps, all with good success in healthy patients.

Diabetes has been erroneously thought of as a relative contraindication to flaps. More recently, Oh et al (2) have demonstrated success in 121 microsurgical free-tissue transfer with an overall limb salvage rate of 84.9%. The 5-year survival rate was 86.8% compared with patients with above-the-ankle amputation at 41.4% ($p < .001$) (2). However, free flaps require microsurgical expertise, specialized microscope, and long operating time. Additionally, many patients are not candidates for free flaps.

Other methods can be used, such as use of allografts, skin grafts, negative pressure wound therapy, calcanectomies, and propeller type flaps, to name a few. However, once these options have been exhausted, approaching the reconstructive ladder in a stepwise fashion from simple to more advanced was the next option. In this case, the distally

based peroneus muscle flap was chosen based on previous reports of success, relative ease of dissection, and low functional morbidity in sacrificing this muscle.

The distally based peroneus brevis muscle flap has been reported with success for small- to medium-sized defects of the distal leg and ankle; it is often preferable because of its reliability and ease of dissection and is economical (3–24). Pers and Medgyesi (3) established it as a workhorse flap for the lower leg. However, Hallock (25) reported that this is not ideal in patients with peripheral vascular disease, risking higher wound complication rates. Unfortunately, patients with diabetes and peripheral vascular disease have limited options, and many revert to a major amputation. We present a case series of successful muscle transfers in high-risk patients with diabetes and peripheral vascular disease who were referred for a below-knee amputation because of a nonhealing heel ulcer.

Review of the Literature

Barr et al (26) and Saydam et al (7) first reported the clinical use of distally based peroneus brevis muscle flap. Barr et al (26) reported 100% flap necrosis, which may be the reason it was discouraged early on. Several reports since then have shown successful use of this flap with better understanding of the anatomy, including a review by Ensaf et al (20) reporting on 192 cases, the

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Fig. 1. Preoperative heel ulceration will be sharply debrided until healthy viable tissue is visible.

largest study to date. The flap was first described as a type 2 muscle by Mathes and Nahai (27) classification but later was reclassified as a type 4 (9,28). The segmental nature of this muscle allows its use as either a proximally or distally based flap as long as the axial vessel remains intact during dissection (20,23).

Few reports indicate successful healing in patients with diabetes, and no reports have been found in the face of peripheral vascular disease as of this writing. Therefore, the author (E.R.-C.) found it necessary to apply a regenerative medicine approach to maximize healing

potential in difficult-to-heal wounds as described in detail previously (29). Regenerative medicine has numerous definitions, but generally speaking it includes techniques that allow the regeneration of lost tissues such as using bone marrow aspirate and platelet-rich plasma to promote angiogenesis of muscle as in our case series. These techniques are used when prior conservative measures have failed, such as local wound care and noninvasive offloading of heel wounds.

Peripheral vascular disease will increase wound complications, and use of muscle flaps has been discouraged in this population (25). However, with the increasing incidence of diabetes and concomitant rise in peripheral vascular disease, there is a need to perform rapid wound closure with the least morbid technique while achieving reliable results to prevent major amputations (30).

Surgical Technique

Surgical technique in muscle harvesting has been described in detail by others (23). All patients consented to a below-knee amputation owing to the absence of the dorsalis pedis and posterior tibial artery and were selected for the peroneus brevis muscle flap as a last attempt to salvage the limb if angiograms interpreted by the interventional radiologist had 1 distal runoff via the peroneal artery. Serial wound bed preparation was performed until it was clinically judged by the surgeon to be free of gross infection, necrotic tissue, or both (Fig. 1). No patients were suspected of having osteomyelitis and were not routinely on antibiotics; therefore, bone was not resected in any of these cases. No tourniquet was used throughout the procedure.

General anesthesia was administered, and the patient was positioned in a slight lateral decubitus position on the operating table. A linear incision was carried 1 cm behind the fibula from proximal to distal exposing the entire lateral compartment. Care was taken to retract the superficial peroneal nerve found consistently at the middle third of the fibula. The peroneus brevis muscle was carefully dissected free from the peroneus longus and then detached from its origin at the proximal fibula until the pivot point was reached, typically about 5 to 6 cm proximal to the distal fibula. Viability of this muscle relies on the peroneal artery being intact and can be identified with a handheld Doppler scanner throughout the dissection. Once the muscle was freed, it was observed for edge bleeding and then transposed to cover the full-thickness heel defect and sutured peripherally with absorbable suture (Figs. 2 and 3).

The addition of adjunctive therapies was systematically applied to all selected patients to maximize healing potential in this particular population because they had several comorbidities and were at high risk for major amputation. Each modality has been described in the following referenced literature.

Integra bovine collagen Bilayer Matrix Wound Dressing (Integra LifeSciences, Plainsboro, NJ) was applied on top of the muscle flap and



Fig. 2. Distally based peroneus brevis muscle being transposed to cover heel defect.



Fig. 3. The distally based peroneus brevis muscle is transferred onto the heel defect and tunneled.



Fig. 4. Bilayer skin substitute applied on the muscle flap and stapled peripherally.

secured with staples (Fig. 4). Concentrated bone marrow aspirate (cBMA) was injected into the implantation bed as described previously (29,32). Negative pressure wound therapy (using a vacuum-assisted closure [VAC] device; Kinetic Concepts, San Antonio, TX) was applied for 7 to 10 days at 75 mm Hg of pressure (22,31). For off-loading, a static external fixator was applied with 2 wires crossing the tibia at 60° and 2 opposing wires in the foot to bypass the calcaneal area (Fig. 5).

The silicone layer of the bovine collagen bilayer wound matrix was removed at 17.5 days (range 7 to 27 days), and a split-thickness skin graft (0.018") was applied over the bovine collagen bilayer wound matrix graft for definitive closure. External fixation was removed when wounds healed, averaging at 10.3 weeks (range 6 to 21 weeks) (Fig. 6). A second case example is shown in Figs. 7–9 for covering heel ulceration in the diabetic patient.

Patients and Methods

Data were collected from January 2014 to December 2016. Seventeen patients were referred for a below-knee amputation owing to a nonhealing heel ulcer and advanced peripheral vascular disease, confirmed by angiography and the treating vascular surgeon. Preoperative Doppler scans confirmed the absence of the dorsalis pedis and posterior tibial artery, but presence of the peroneal artery remained, which was detected 5 cm proximal and posterior to the distal fibula. These patients were then selected for limb salvage as a last resort if they had wounds that were relatively small to medium sized. All patients had type 2 diabetes mellitus, 6 also had hypertension, and 1 person admitted to smoking (Table). No patients had a contralateral or ipsilateral limb amputation.

Seventeen distally based peroneus brevis muscle flaps were elevated in 17 patients (10 males, 7 females) to cover full-thickness heel ulcers and exposed bone. Ulcer size was 2 to 7 cm in width (medial to lateral) and 3 to 6 cm in length (proximal to distal). The average surface area was 14.11 cm² (range 6 to 27), and time in the external fixation was 10.3 weeks (range 6 to 21). The average days to the split-thickness skin graft was 17.5 (range 7 to 27).

Results

Seventeen patients with type 2 diabetes underwent a distally based peroneus brevis muscle flap to cover heel defects in 17 patients (10 males, 7 females). The mean average patient age was 52 years (range 37 to 69). The follow-up period was 1.5 years.

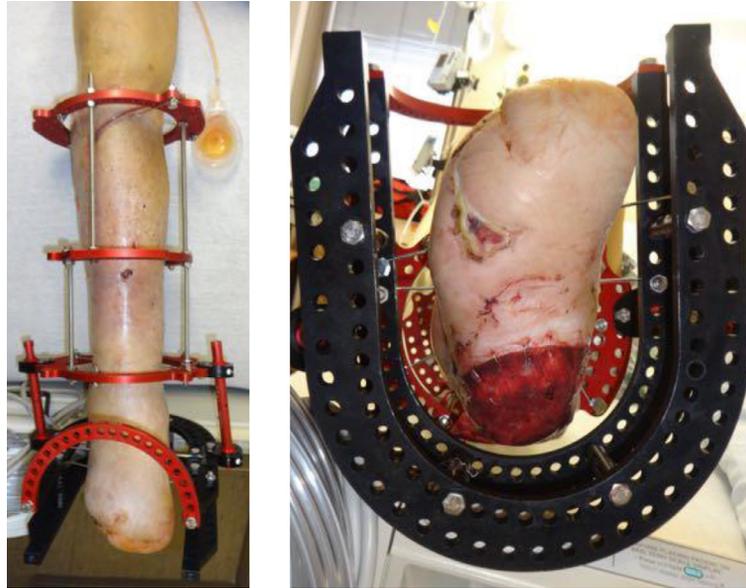


Fig. 5. Application of a static external fixator device.



Fig. 6. When the split-thickness skin graft is healed, the negative pressure wound therapy and external fixator are removed.

All heel ulcers were present >12 months. The surface area of the defect averaged 14.11 cm². Time to removal of the external fixation was also time of flap healing and averaged 10.3 weeks. Flap survival was 100% with 2 partial tip necroses that healed uneventfully with local wound care. Minor complications such as pin site irritation caused by wire loosening were easily resolved with a Russian tensioning technique in the office. No report of osteomyelitis or major amputation was observed. The split-thickness skin graft from the donor site of the calf healed uneventfully as well. Results were satisfactory to both patient and surgeon with durable coverage and maintenance of limb length.

Discussion

Heel ulcers are difficult to treat because of the challenge of off-loading this area. Even with total contact casts, a gold standard for plantar neuropathic ulcers, it has not been recommended for heel ulceration



Fig. 7. Another example of a heel ulceration in a 56-year-old male with osteomyelitis in the calcaneus, status-post sharp excisional debridement to prepare the wound bed.



Fig. 8. Removal of a static external fixation device once the bilayer skin substitute overlying the distally based peroneus muscle transfer is integrated.

owing to the high failure rate 63.63% (1) and redistribution of pressure added to the heel (33).

Results from this study argue against Hallock (25) that patients with peripheral vascular insufficiency are not good candidates because of its high complication rates. We observed 100% partial or complete flap viability, and 2 patients had distal tip necrosis that healed without additional surgery time. What is different in our study is that the combined approach to optimize flap viability with cBMA, bovine collagen bilayer wound matrix, use of a VAC device, external fixation, and delaying time to definitive wound closure is necessary in more high-risk patients. We are in agreement that if the pedicle to the flap is not audible by Doppler scanning, then another procedure should be considered.

The limitation to this study is that the patient selection for this type of combinatorial approach is specific to a particular patient

type. For our study, patients were referred for a below-knee amputation and were evaluated for a limb salvage approach, understanding that they might still undergo major amputation with their comorbidities. Another limitation to our study is inherent in the nonrandomized design, and the relative contribution of each modality remains to be determined. Given the time-sensitive nature of amputation prevention, complex wounds demand an integrative approach in orthoplastic techniques to limb preservation. One may need to consider the financial burden related to limb salvage operations versus the cost savings of amputations in the long run, including loss of income and loss of independence. It would be worthwhile for future investigations to evaluate cost-benefit analysis of each combinatorial modality while still maintaining a relatively high success rate of limb salvage. This study demonstrated 100% success of flap survival with the combined approach.

Difficulties and risks involved in performing this procedure are similar to any other muscle flap harvesting. In particular, the peroneus brevis muscle can easily be damaged at the origin, which is often buried under the peroneus longus muscle. Damage while dissecting at the muscle insertion consequently can limit the distal reach, which is most needed for covering foot defects. Careful dissection, good hemostasis control, and use of intraoperative Doppler scanning and vascular clips to test viability of the muscle while perforators are sequentially clamped ascertains the success of this muscle flap. Additionally, standard wound care principles of off-loading the pressure point must be used to protect the flap during healing. After reconstructive surgery to treat heel wounds, the calcaneal gait must also be managed with the patient either using a wheelchair if they are unable to walk and only using the limb to transfer or using a patellar tendon brace to reduce pressure on the heel.

In conclusion, the distally based peroneus brevis muscle is reliable in closing heel defects of up to 14.11 cm² in size for high-risk patients facing a major amputation, including diabetic patients with advanced peripheral vascular disease. To heal difficult wounds, multiple strategies are necessary to ensure limb salvage success, and this report supports the use of cBMA, bovine collagen bilayer wound matrix, VAC therapy, static external fixation, and delaying of split-thickness skin graft applications.



Fig. 9. After the bilayer skin substitute promotes base granulation, a split-thickness skin graft is applied, healing the heel wound completely.

Table
Patient demographics, wound sizes, and outcomes (N = 17)

Patient No.	Sex	Age	Comorbidities	Heel Ulcer Size (medial->lateral, proximal->distal) (cm)	Surface Area (cm ²)	Time in Ex-Fix (wk)	Time to STSG (d)	Outcome
1	F	52	DM2	3 × 4	12	11	22	Healed
2	F	47	DM2	4.5 × 6	27	17	27	Healed
3	M	64	DM2, HTN	2 × 3	6	21	14	Partial tip necrosis
4	F	68	DM2, HTN	6 × 4	24	10	18	Healed
5	M	44	DM2	5 × 3	15	13	13	Healed
6	M	46	DM2, HTN	4 × 4	16	8	17	Healed
7	F	53	DM2	7 × 3	21	10	22	Healed
8	F	54	DM2	6 × 3	18	9	27	Partial tip necrosis
9	M	67	DM2	3 × 4	12	6	8	Healed
10	M	60	DM2, HTN	2 × 3	6	12	9	Healed
11	M	39	DM2	3 × 3	9	7	11	Healed
12	F	49	DM2	4 × 4	16	6	15	Healed
13	M	37	DM2, HTN	5 × 3	15	7	37	Healed
14	M	53	DM2	2 × 3	6	7	17	Healed
15	F	34	DM2, HTN	3 × 3	9	11	7	Healed
16	M	45	DM2, smoker	4 × 4	16	9	11	Healed
17	M	69	DM2	4 × 3	12	11	22	Healed
Avg:		52		All full thickness to bone	14.11	10.3	17.5	

Abbreviations: Avg, average; DM2, type 2 diabetes mellitus; Ex-Fix, external fixation; F, female; HTN, hypertension; M, male; STSG, split-thickness skin graft.

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References

- Ali R, Qureshi A, Yagoob MY, Shakil M. Total contact cast for neuropathic diabetic foot ulcers. *J Coll Physicians Surg Pak* 2008;18:695–698.
- Oh TS, Lee HS, Hong JP. Diabetic foot reconstruction using free flaps increases 5-year-survival rate. *Plast Reconstr Aesthet Surg* 2013;66:243–250.
- Pers M, Medgyesi S. Pedicle muscle flaps and their applications in the surgery of repair. *Br J Plast Surg* 1973;26:313–321.
- Neale HW, Stern PJ, Kreilein JG, Gregory RO, Webster KL. Complications of muscle-flap transposition for traumatic defects of the leg. *Plast Reconstr Surg* 1983;72:512–517.
- Eyssel M, Dresing K. The peroneus brevis muscle flap-plasty. A simple procedure for covering fibular soft tissue defects after osteosynthesis. *Unfallchirurg* 1989;92:85–91.
- Eren S, Ghofrani A, Reifenrath M. The distally pedicled peroneus brevis muscle flap: a new flap for the lower leg. *Plast Reconstr Surg* 2001;107:1443–1448.
- Saydam M, Yilmaz S, Seven E. Distal peroneus brevis muscle flap. *Plast Reconstr Surg* 2002;110:351.
- Hallock GG. Lower extremity muscle perforator flaps for lower extremity reconstruction. *Plast Reconstr Surg* 2004;114:1123–1130.
- Yang YL, Lin TM, Lee SS, Chang KP, Lai CS. The distally pedicled peroneus brevis muscle flap anatomic studies and clinical applications. *J Foot Ankle Surg* 2005;44:259–264.
- Koski EA, Kuokkanen HO, Tukiainen EJ. Distally-based peroneus brevis muscle flap: a successful way of reconstruction lateral soft tissue defects of the ankle. *Scand J Plast Reconstr Surg Hand Surg* 2005;39:299–301.
- Fansa H, Frerichs O, Schneider W. Distally pedicled peroneus brevis muscle flap for defect coverage on the lower leg. *Unfallchirurg* 2006;109:453–456.
- Bach AD, Leffler M, Kneser U, Kopp J, Horch RE. The versatility of the distally based peroneus brevis muscle flap in reconstructive surgery of the foot and lower leg. *Ann Plast Surg* 2007;58:398–404.
- Lorenzetti F, Lazzero D, Bonini L, Giannotti G, Piolanti N, Lisanti M, Pantaloni M. Distally based peroneus brevis muscle flap in reconstructive surgery of the lower leg: postoperative ankle function and stability evaluation. *J Plast Reconstr Aesthet Surg* 2010;63:1523–1533.
- Kneser U, Brockmann S, Leffler M, Haerberle L, Beier JP, Dragu A, Unglaub F, Back A, Horch RE. Comparison between distally based peroneus brevis and sural flaps for reconstruction of foot, ankle and distal lower leg: an analysis of donor-site morbidity and clinical outcome. *J Plast Reconstr Aesthet Surg* 2011;64:656–662.
- Ng YH, Chong KW, Tan GM, Rao M. Distally pedicled peroneus brevis muscle flap: a versatile lower leg and foot flap. *Singapore Med J* 2010;51:339–342.

- Lorenzetti F, Agostini T, Pantaloni M, Lazzero D. The versatility of the distally based peroneus brevis muscle flap. *Plast Reconstr Surg* 2011;127:1751–1752.
- Bajantri B, Bharathi R, Ramkumar S, Lathief L, Dhane S, Sabapathy SR. Experience with peroneus brevis muscle flaps for reconstruction of distal leg and ankle defects. *Indian J Plast Surg* 2013;46:48–54.
- Rodriguez-Collazo ER, Bibbo C, Mechell RJ, Arendt A. The reverse peroneus brevis muscle flap for ankle wound coverage. *J Foot Ankle Surg* 2013;52:543–546.
- Hu XH, Du WL, Chen Z, Wang C, Shen YM. The application of distally pedicled peroneus brevis muscle flaps and retrograde neurocutaneous accompanying artery flaps for treatment of bon and soft-tissue 3-dimentional defects of the lower leg and foot. *Int J Low Extrem Wounds* 2013;12:53–62.
- Ensat F, Hladik M, Larcher L, Mattiassich G, Wechselberger G. The distally based peroneus brevis muscle flap-clinical series and review of the literature. *Microsurgery* 2014;34:203–208.
- Abd-Al Moktader MA. Open-book splitting of a distally based peroneus brevis muscle flap to cover large leg and ankle defects. *Plast Reconstr Surg Glob Open* 2016;3:e572.
- Erne H, Schmauss D, Schmauss V, Ehrl D. Postoperative negative pressure therapy significantly reduces flap complications in distally based peroneus brevis flaps: experiences from 74 cases. *Injury* 2016;47:1288–1292.
- Masadeh S, Bibbo C. Distally based peroneus brevis flap: a reliable and versatile flap to cover the lateral foot and ankle. *Curr Orthop Pract* 2016;27:499–507.
- Schmidt I. The distally pedicled peroneus brevis muscle and fasciocutaneous sural artery flap for reconstruction of the distal third of lower leg. *Int J Case Per Images* 2017;8:17–21.
- Hallock GG. Complications of 100 consecutive local fasciocutaneous flaps. *Plast Reconstr Surg* 1991;88:264–268.
- Barr ST, Rowley JM, O'Neill PJ, Barillo DJ, Paulsen SM. How reliable is the distally based peroneus brevis muscle flap? *Plast Reconstr Surg* 2002;110:360–362.
- Mathes SJ, Nahai F. *Reconstructive Surgery: Principles, Anatomy, and Technique*. Churchill Livingstone, New York; 1997.
- Taylor GI, Pan WR. Angiosomes of the leg: anatomic study and clinical implications. *Plast Reconstr Surg* 1998;102:599–616.
- Rodriguez-Collazo ER, Rathbone CR, Barnes B. A retrospective look at integrating a novel regenerative medicine approach in plastic limb reconstruction. *Plast Reconstr Surg Glob Open* 2017;5:e1214.
- World Health Organization. Diabetes: Key Facts. Available at: <http://www.who.int/mediacentre/factsheets/fs312/en/>. Accessed May 22, 2017.
- Park CA, Defranzo AJ, Marks MW. Outpatient reconstruction using integra* and subatmospheric pressure. *Ann Plast Surg* 2009;62:164–169.
- Lacci KM, Dardik A. Platelet-rich plasma: support for its use in wound care. *Yale J Biol Med* 2010;83:1–9.
- Shaw JE, Hsi W, Ulbrecht JS, Norkitis A, Becker MD, Cavanagh PR. The mechanism of plantar unloading in total contact casts: implications for design and clinical use. *Foot Ankle Int* 1997;18:809–817.