CASE REPORT

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Reverse flow digital artery pedicle flap for closure of diabetic forefoot ulceration

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Digital artery pedicle flap is a useful surgical technique for coverage of plantar foot defects. For diabetic forefoot ulcers that are subject to recurrence despite consistent care, this flap can provide long-term durable closure. The authors provide a case report and overview of this innovative reconstructive procedure.

Keywords: *diabetic ulceration*; *diabetes mellitus*; *digital artery flap*; *amputation*; *forefoot flaps*

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Achieving durable closure of soft tissue defects at weight-bearing surfaces of the foot can be a challenge. In diabetic patients, a combination of peripheral neuropathy, microvascular disease, and abnormal mechanical stress can lead to plantar forefoot ulcers, which have high rates of recurrence (1–3). Local wound care and offloading may facilitate healing by secondary intention; however, long term, the resultant tissue may not be able to withstand the high pressures inflicted to the area during gait. Depending on the extent of tissue loss, simple primary closure of plantar forefoot wounds is not always possible. Use of adjacent or distant soft tissue of similar properties can provide better options to restore the specialized tissue of the forefoot. Although local random flaps are associated with low morbidity, their use in the forefoot is limited by excursion potential and the plantar structures can be compromised through extensive dissection (4). Pedicled island flaps, first described by Moberg for use in the foot, provide adequate coverage with similar tissue without disturbing the existing plantar anatomy (5). The digital artery pedicle flap, based on an isolated neurovascular pedicle, is a viable option for closure of plantar forefoot wounds. The authors describe successful treatment of a chronic diabetic foot ulcer, using a reverse flow digital artery pedicle flap and closure of the donor defect with a split-thickness skin graft (STSG) harvested from the ipsilateral foot.

Case report

A 50-year-old man presented to the authors' institution with a chronic plantar ulceration to the right foot. The patient reported that the wound had resulted from a large hyperkeratotic lesion that had opened nearly two years previously. The wound persisted with intermittent drainage despite professional local wound care. Worsening size, drainage, and pain caused the patient to seek further care in our emergency department. Although his past medical history included diabetes mellitus and hypertension, he admitted to non-compliance with his medications. His social history was significant for 30 pack-years of smoking and occasional alcohol use. Prior to his foot issues, he was an active individual working in construction.

The patient's vital signs were stable on presentation. Examination of the foot demonstrated palpable arterial pulses and brisk capillary refill to the digits; however, there was profound loss of protective sensation via Semmes-Weinstein 10-g monofilament testing. The partial-thickness ulceration located at the plantar aspect of the right first metatarsal head measured $2.2 \times 2.0 \times 0.5$ cm and had a granular base without purulence, probing to bone or cellulitis. Despite mild periwound edema, the remaining skin to the foot was supple and warm to touch. Range of motion to the joints and manual muscle testing of both lower extremities showed no deficits. A review of three standard radiographic views of the foot revealed only mild degenerative changes to the hallux proximal phalanx and first metatarsal head. Laboratory analysis including complete blood cell count, serum chemistry, erythrocyte sedimentation rate, and C-reactive protein were within normal limits. There was no clinical or radiographic evidence of osteomyelitis.

Based on the patient's history of uncontrolled diabetes and heavy smoking, non-invasive vascular testing was performed to evaluate perfusion to the right lower

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extremity. Results showed triphasic arterial waveforms, ankle-brachial index of 1.11, and toe-brachial index of 0.68, indicating no evidence of macrovascular occlusive disease. Owing to the chronicity of the wound and failure of previous conservative care, the authors decided that a digital artery pedicle flap could provide adequate coverage of the plantar wound.

After administration of a weight-based first-generation cephalosporin antibiotic and induction of general anesthesia, a pneumatic thigh tourniquet was secured to the right lower extremity. The procedure began with full-thickness excision of the ulceration to the subcutaneous level to remove all non-viable tissue. Deep soft tissue cultures were obtained, and the wound was irrigated with copious amounts of sterile saline. A sterile Doppler probe was utilized to identify the digital vascular pedicle at the lateral aspect of the hallux and this was marked with a surgical marker. The recipient wound was marked and the corresponding identical size and shape was marked at the donor site to incorporate the neurovascular pedicle. The thigh tourniquet was then inflated to 325 mmHg to enhance visualization, and the full thickness pedicle flap was raised under loupe magnification. A skin incision was made to connect the recipient wound bed and donor site. The pedicle flap was carefully mobilized and inset at the recipient site. The tourniquet was deflated and the flap was carefully secured in place using simple interrupted non-absorbable sutures. The communicating incision was also closed with simple interrupted non-absorbable sutures. The medial arch of the ipsilateral foot was subsequently prepared for harvesting of the STSG by local subcutaneous infiltration of 1% lidocaine with epinephrine. A 0.018-inch thick by 1-inch wide STSG was harvested using an electric powered dermatome and the graft was meshed in a 1:1.5 ratio. The graft was placed at the lateral aspect of the hallux to cover the donor site of the pedicle flap and secured with skin staples under minimal tension, followed by a small bolster dressing consisting of a sterile sponge and non-adherent gauze. Topical thrombin was applied to the skin graft donor site and this area was dressed with povidone-iodine soaked non-adherent gauze. The foot was then loosely dressed with gauze to allow access to the pedicle flap for close monitoring every 2 h while the patient was in the hospital (Fig. 1).

The patient was discharged from the hospital 2 days later with instructions for strict non-weight bearing to the right foot with crutches, and a 2-week course of culture-specific oral antibiotics. One week after surgery, the flap was intact and well perfused at the first postoperative visit in the authors' outpatient clinic. At postoperative week 3, the pedicle flap remained viable and the bolster dressing to the lateral hallux was removed, revealing the incorporated skin graft. All sutures to the foot were removed at this visit as well. At postoperative week 9, all surgical sites were completely healed and the patient was advanced to full weight bearing in extra depth shoes with custom trilaminar insoles. The patient's foot remained well-healed and showed no evidence of skin breakdown or other complications during his most recent outpatient visit at 26 weeks postoperatively.

Discussion

Among diabetic patients, complications of foot ulcers represent a leading cause of hospitalization and amputation (6). Several conservative and surgical techniques exist to provide closure of diabetic forefoot wounds, yet failure to restore the area with durable tissue can lead to wound recurrence and risk of infection. The plantar aspect of the forefoot, particularly the submetatarsal areas, is comprised of a thick layer of keratinized epithelium and multiple fibrous septae that firmly anchor the skin to underlying structures (7). The composition of the digital artery pedicle flap closely resembles the plantar soft tissue at the forefoot, making it ideal for coverage of these defects. A multidisciplinary approach to patient treatment is important for favorable outcomes in the diabetic population (8). Appropriate medical management of comorbidities, eradication of infection, and vascular assessment to determine distal arterial patency should be undertaken prior to any reconstructive foot procedures.

Digital artery pedicle flaps first gained popularity in reconstructive surgery of the hand (9). Modifications of the flap have been used for salvage of the foot, particularly at the digits and other forefoot areas (10–12). Pallua et al. reviewed the use of reversed island flaps in 12 diabetic patients; however, their study was restricted to dorsalis pedis flaps and medial plantar artery flaps (13). Dutch et al. reported on the digital artery pedicle flap for forefoot wounds in 12 patients, but not all were diabetic (4). Roukis and Zgonis described modifications of the great toe fibular flap for soft tissue and bone reconstruction in the diabetic foot (12). Demirtas et al. used the homodigital reverse flow island flap for coverage of four diabetic great toe ulcers with good results (14).

In this case report, the pedicle flap is based on the lateral plantar digital artery and includes the digital nerve when it is harvested (15). Meticulous, atraumatic dissection is critical to maintaining flap viability. Coverage of the donor site can be achieved through a STSG or syndactilization to an adjacent toe (4). In this case report, the authors harvested a STSG from the medial arch of the foot rather than from the more traditionally used leg or thigh sites. The consistency and appearance of the skin at this part of the foot closely replicates the skin at the lateral aspect of the digit, leading to a more functional and aesthetically pleasing result (16). Possible complications

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Fig. 1. Intra-operative picture of the right plantar forefoot wound (A) followed by a full thickness ulceration excision and a reverse flow digital artery pedicle flap for closure (B). Intra-operative picture showing the viability of the pedicle flap and harvesting of the STSG (C) for the donor site at the lateral aspect of the hallux (D). Clinical pictures showing the healed pedicle flap (E) and donor sites (F) at 9 weeks postoperatively. Long-term clinical outcomes at 26 weeks postoperatively (G, H).

of digital artery pedicle flaps include incomplete flap take, delayed healing, dehiscence, flap necrosis, venous congestion, hematoma, and infection (12, 14, 17). Careful monitoring of the flap every 1 to 2 h during the patient's hospital stay can allow for prevention and/or early treatment of complications. Strict non-weight-bearing and loose sterile dressings to the flap facilitate incorporation and prevent ischemia. Medical leeches have been reported in treating cases of venous congestion (4). Donor site morbidity is usually minimal, but depends on how the area is surgically addressed. The patient in this case report experienced an uneventful postoperative course. By the sixth postoperative month, he had only minimal scar formation to the surgical sites, full mobility of the foot with return to normal activity, and no ulcer recurrence.

In carefully selected patients, the authors strongly recommend the reverse flow digital artery pedicle flap as an alternative treatment for recalcitrant diabetic forefoot wounds. This flap allows for restoration of the highly specialized soft tissue at the plantar forefoot. A successful functional outcome can allow the patient to withstand shearing forces encountered during ambulation, even in the setting of peripheral neuropathy, thereby reducing the risk of reulceration and/or amputation.

Conflict of interest and funding

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