Assessment of Flap Viability for Complex Transmetatarsal Amputation Using Indocyanine Green Fluorescent Angiography

A Case Study

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Despite advancements in the treatment of diabetic patients with "at-risk" limbs, minor and major amputations remain commonplace. The diabetic population is especially prone to surgical complications from lower extremity amputation because of comorbidities such as renal disease, hypertension, hyperlipidemia, microvascular and macrovascular disease, and peripheral neuropathy. Complication occurrence may result in increases in hospital stay duration, unplanned readmission rate, mortality rate, number of operations, and incidence of infection. Skin flap necrosis and wound healing delay secondary to inadequate perfusion of soft tissues continues to result in significant morbidity, mortality, and cost to individuals and the health-care system. Intraoperative indocyanine green fluorescent angiography for the assessment of tissue perfusion may be used to assess tissue perfusion in this patient population to minimize complications associated with amputations. This technology provides real-time functional assessment of the macrovascular and microvascular systems in addition to arterial and venous flow to and from the flap soft tissues. This case study explores the use of indocyanine green fluorescent angiography for the treatment of a diabetic patient with a large dorsal and plantar soft-tissue deficit and need for transmetatarsal amputation with non-traditional rotational flap coverage. The authors theorize that the use of indocyanine green may decrease postoperative complications and cost to the health-care system through fewer readmissions and fewer procedures. (J Am Podiatr Med Assoc 112(2), 2022)

Limb salvage in the high-risk patient population is a growing focus area because of its potential to reduce patient morbidity, mortality, and health-care cost.[1] The Functional Lower Extremity team at Wake Forest Baptist Medical Center is a multidisciplinary collaboration between vascular surgery, plastic and reconstructive surgery, podiatric surgery, orthopedic surgery, and wound care aimed at improving outcomes in this patient population.

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Among the most difficult patients with foot disease to treat are those with diabetes mellitus and nonhealing foot ulcers.[2,3] Microvascular and macrovascular disease and peripheral neuropathy frequently contribute to this wound type. Moreover, patient characteristics, such as smoking and obesity, have negative effects on local tissue perfusion. Because of these factors, diabetic foot amputations are common despite quality interdisciplinary care.

At our institution, soft-tissue perfusion is assessed with noninvasive vascular studies and clinical examination. Perioperative vascular laboratory studies typically include Doppler examinations, pulse waveform measurements, transcutaneous oximetry measurements, ankle-brachial indices, and toe-brachial indices to assess tissue perfusion. Standard intraoperative techniques to evaluate soft-tissue perfusion include inspection of the appearance of skin and subcutaneous tissues, dermal edge bleeding, capillary refill, skin

temperature, and turgor.[4] Although the standard of care, these clinical parameters lack sensitivity and specificity to identify inadequate tissue perfusion; therefore, new techniques to assess tissue perfusion/vascularity are warranted.[4]

Indocyanine green fluorescent angiography (ICGFA) produces real-time vascular images based on light stimulation of indocyanine green dye bound to plasma proteins in the blood. The dye is excreted through the biliary system. Once stimulated by light, the dye releases infrared energy, resulting in a fluorescent image of the tissue being studied. Tissue perfusion is identified based on imaged color change of the tissues containing the dye. This technology has been used in reconstructive surgery for functional assessment of the vascular systems, patency of microvascular anastomoses, and flap tissue perfusion.[5,6] The process of ICGFA is simple and uses minimal extra equipment, and dye administration is through a peripheral intravenous line. Further benefits of ICGFA include that it may be performed multiple times in a row and may be used perioperatively or intraoperatively. People with diabetes and renal disease (a common complication of diabetes) benefit from the hepatic excretion of the dye and the avoidance of nephrotoxic contrast agents.[4]

Case Study

A 52-year-old man with hypertension and type 2 diabetes mellitus with associated retinopathy, gastroparesis, peripheral neuropathy, and microvascular peripheral arterial disease presented to the emergency department with complaints of fever, nonproductive cough, nausea, vomiting, right lower extremity swelling, and right foot wound for 5 days. The patient was evaluated for respiratory infection (including coronavirus disease of 2019) and right diabetic foot wound infection. Podiatry evaluation identified multiple ulcers of the plantar aspect of the right foot metatarsophalangeal joint region that could be probed to bone and were associated with cellulitis, purulent drainage, and dorsal foot bogginess (Fig. 1). Vascular examination revealed palpable dorsalis pedis and posterior tibial arterial pulsation at the foot. Laboratory results identified a white blood cell count over 20×10^9/liter and elevated inflammatory markers. The patient was scheduled for emergent incision and drainage of his right foot wound with suspected necrotizing infection of the foot.

Figure 1. Dorsal and plantar appearance of foot at initial presentation.

Over the course of 6 days, three debridement procedures in the surgical suite were performed. Full-thickness excision to the level of deep fascia and bone (at the distal metatarsal level) was performed. Initial cultures identified a multiorganism infection with *Streptococcus*, *Staphylococcus*, and *Enterococcus* species treated with culture-directed antibiotics. Once no further infected or devitalized tissue was encountered (Fig. 2), the patient was a candidate for transmetatarsal amputation for limb salvage. The transmetatarsal amputation (TMA) osteotomies were carried out in the standard fashion. In addition, the third metatarsal was resected to the level of the tarsometatarsal joint, allowing cerclage suture placement around the second and fourth metatarsal remnants, minimizing wound dead space and decreasing the distance between plantar wound edges. Because of the atypical configuration of the remnant soft tissues, the plastic and reconstructive surgery service was called to the operating suite to aid with soft-tissue coverage of the TMA. Medial and lateral soft-tissue flaps were designed to cover the metatarsal remnants. Specifically, the medial flap, measuring approximately 13 × 8 cm, consisted of a great toe fillet

Figure 2. Dorsal and plantar appearance of foot after serial irrigation and debridement.

flap in continuity with portions of dorsal and instep glabrous skin and subcutaneous tissues. Similarly, the lateral flap, which measured 8 × 9 cm, consisted of a fifth toe fillet flap in continuity with portions of glabrous skin and dorsal foot skin. Because of the "spare parts approach" to covering the patient's atypical TMA, ICGFA was used to assess flap perfusion and guide resection of poorly perfused flap components. A small strip of the medial flap that was identified to have poor perfusion on ICGFA was resected back to healthy bleeding flap edge (Fig. 3). The medial fasciocutaneous flap was advanced and rotated caudally to fill the wound dead space located at the anterior plantar aspect of the wound. The lateral fasciocutaneous flap was advanced and cranially rotated to close the remainder of the plantar wound and cover the metatarsal remnants. Because of the exposure of the extensor tendon mechanism and to facilitate its gliding with ambulation, a dermal substitute was used for preparation of the dorsal wound for future definitive skin coverage (Fig. 3).

The patient was readmitted 2 weeks after hospital discharge because of hyperglycemia, emesis, dehydration, and acute kidney injury. The patient improved with fluid resuscitation, and during this hospital stay, the patient was returned to the operating suite for debridement of partial dehiscence of the plantar wound and split-thickness skin grafting of the integrated dermal substitute of the dorsal foot. Split-thickness skin grafts of 0.010-inch thickness were harvested and applied in the usual fashion

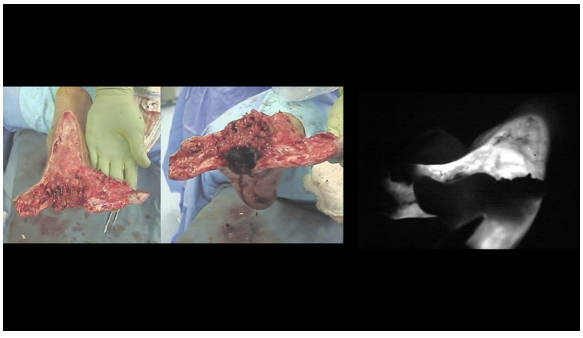

Figure 3. A, Dorsal view of transmetatarsal amputation with medial and lateral fasciocutaneous flaps. B, Plantar view of transmetatarsal amputation with medial and lateral fasciocutaneous flaps. C, Transmetatarsal amputation with confirmation of flap perfusion by means of indocyanine green fluorescence angiography. The distal extent of the medial flap was determined to be poorly perfused and was excised.

Figure 4. A and B, Dorsal and plantar images of the foot 1 day after transmetatarsal amputation. C and D, Dorsal and plantar images of the foot 10 weeks after transmetatarsal amputation.

using a wound vacuum-assisted closure device as a skin graft bolster. Saline-moistened packing was instituted for the plantar wound. The patient was followed in our wound center, and his plantar wound has healed, he has full active and passive range of motion of the right ankle, and he has begun ambulating on the salvaged extremity (Fig. 4).

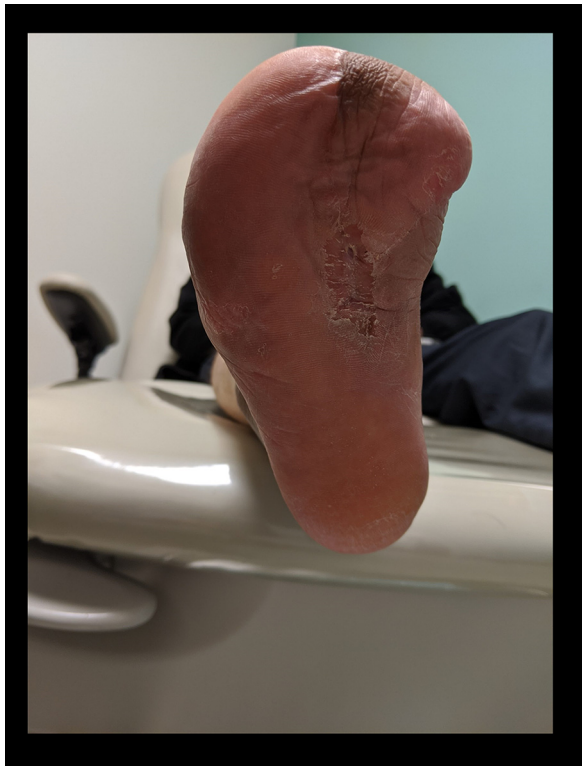

Figure 5 Healed plantar forefoot 15 weeks after transmetatarsal amputation.

Discussion

This case demonstrates a common clinical scenario encountered by many health-care practitioners involved in the care of the diabetic patient. From the podiatric standpoint, we present this case to highlight the benefits of a multidisciplinary approach to the management of this common clinical scenario in addition to the use of novel technique that may improve patient outcomes.

The traditional incision for a TMA is a fishmouth incision with plantar and dorsal flaps. In the case described, large dorsal and plantar soft-tissue defects did not allow for traditional TMA flap design. Using nontraditional skin flaps (with adequate perfusion confirmed by intraoperative fluorescent angiography) in combination with cerclage technique for decreasing foot width and, in turn, wound dead space, the metatarsal remnants were covered by fasciocutaneous flaps that included glabrous skin resurfacing of weightbearing surfaces.

Despite advances in extremity reperfusion capabilities, assessment of downstream smaller vessel status and their soft-tissue perfusion remains a challenge. This may manifest as the high rate of TMA stump complications, resulting in the need for revision surgery and more proximal amputations. A recent review of TMA cases at a single institution reported a 91% postoperative complication rate for TMAs, and 56 percent of TMA patients required revision to a more proximal level. This was, in part, attributed to poor perfusion of remnant soft tissues used for the TMA.[7] The clinical utility of ICGFA as a real-time intraoperative objective tool has been demonstrated in small sample sizes of prevascularization and postrevascularization procedures in diabetic patients.[8] As there is significant patient morbidity and financial burden associated with TMA, further investigation is warranted into novel approaches to decrease postoperative wound complications caused by inadequate soft-tissue perfusion.

Our complication of a plantar incision dehiscence seen in Figure 4D is thought by the authors to be attributable to tension on the plantar skin edges rather than failure of flap perfusion. Li et al[9] discussed that vascularization of distal portions of transferred tissues represents the most critical factor in the success of reconstructive surgery.

The use of ICGFA and a knowledge of vascular anatomy to predict flap healing may decrease patient burden of disease secondary to microvascular compromise.[10,11] Although there is significant literature about the use, efficacy, and safety of ICGFA in the breast and plastic surgery literature, little research has been performed regarding its use in the diabetic lower extremity.

Although there have been preliminary studies in the lower extremity regarding the use of ICGFA in wound healing and flap surgery, the available literature describing the clinical utility of ICGFA for intraoperative perfusion assessment of amputation flaps is limited.[9,11,12] This article contributes to a growing body of evidence supporting more frequent use of ICGFA in the treatment of diabetic foot ulcers and infections. Future research includes determination of whether routine use of ICGFA in diabetic foot infections and ulcerations decreases postoperative wound healing complication rates and whether ICGFA can be a cost-effective treatment modality in this patient population.

Conclusions

Wound healing complications are common in TMA and represent a significant cause of morbidity. This case study demonstrates the use of intraoperative ICGFA for assessment of tissue perfusion and subsequent viability in diabetic limb salvage. Our experience suggests that continued research into ICGFA is warranted in limb-threatening soft-tissue infections or ulcerations of the diabetic foot.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

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