

A Perioperative Approach to Increase Limb Salvage When Treating Foot Ulcers in Patients With Diabetes

Raelina S. Howell, MD; Theresa Criscitelli, EdD, RN, CNOR; Jon S. Woods, MD; Brian M. Gillette, PhD; Harold Brem, MD, FACS; Scott Gorenstein, MD, FACEP

ABSTRACT

Foot ulceration in patients with diabetes increases the risk of lower extremity amputation. Major amputations produce substantial adverse consequences, increase length of hospital stay, diminish quality of life, and increase mortality. In this article, we describe approaches that decrease amputations and improve the quality of life for patients with diabetes and foot ulcers. We highlight the role of the perioperative nurse, who is essential to providing optimal patient care in the perioperative period. Perioperative care of patients with diabetes involves providing optimal surveillance for a break in the skin of the foot, screening for neuropathy, following guidelines for foot ulcer infections, preparing for pathophysiology-based debridement, using adjuvant therapies, and offloading the patient's affected foot. Nurses should understand the disease process and pathophysiology and how to use these approaches in the perioperative setting to assist in curtailing the morbidity and mortality associated with foot ulcers in patients with diabetes.

Key words: *diabetic foot ulcer, limb salvage, lower extremity amputation, hyperbaric oxygen therapy, surgical debridement.*

In 2015, the worldwide prevalence of diabetes was estimated to be 8.8% with a projected prevalence of 10.4% by the year 2040.¹ Foot ulceration is common, with ulcers affecting up to 34% of patients with diabetes in their lifetimes.² Foot ulcers precede approximately 85% of nontraumatic amputations in persons with diabetes,³ with a 15- to 20-fold increased risk of amputation compared with people without diabetes.⁴ A variety of causal pathways (eg, involvement of bone, obesity) have been identified in patients who require amputation.^{4,5} Foot ulcers act as portals of entry for systemic infections that can have particularly deleterious effects on patients with diabetes, whose impaired immunity substantially increases their risk for infection.⁶ Diabetes-related limb amputations are associated with an increased risk of additional amputation and a reported five-year mortality rate ranging from 53% to 100%.⁷

Most clinical trials involving patients with diabetes target the neuropathic plantar foot ulcer, which classically appears as a callus surrounding an area of granulation tissue on the plantar aspect of the foot. For the purposes of this article, we define a foot ulcer in a patient with diabetes as any nontraumatic skin break below the malleoli in a person with diabetes. This definition encompasses toe, heel, dorsal, and plantar foot ulcers. Despite the heterogeneity of foot ulcers in patients with diabetes that can lead to amputation, we suggest that a potential for healing exists in every new ulcer that has adequate vascular supply and is treated in a timely manner. In this article, we present perioperative approaches that may greatly accelerate healing while reducing morbidities and amputation rates among patients with diabetes and foot ulcers.

PREOPERATIVE NURSING CARE

The preoperative assessment of a patient receiving wound care is essential to determine if there are any factors that can contribute to risk of injury in the intraoperative and postoperative settings. Patients often receive insulin perioperatively while simultaneously maintaining NPO status, which increases the risk of perioperative hypoglycemia.⁸ Perioperative nurses are a crucial line of defense when reviewing preoperative laboratory results and can alert providers to abnormal findings. The preoperative period is also an ideal time to coordinate a care plan for the patient. Preventive care for skin breakdown, screening for neuropathy, and managing infection are a few specific elements that are essential when taking care of a patient with a foot ulcer and diabetes.

Optimal Surveillance for a Skin Break on the Foot

Proper preventive care can influence the emergence and recurrence of foot ulcers in patients with diabetes.² Preventing foot ulcers begins with a comprehensive foot examination, including assessing risk factors, inspecting the foot, and neurologic and vascular testing.⁹ Perioperative nurses assess patients before, during, and after surgical procedures and may identify a foot ulcer that could have gone unidentified by the patient or the patient's family. During the preoperative assessment, the perioperative nurse should elicit specific information from the patient including the presence of previous ulcerations or amputations, tobacco use, renal or retinal complications secondary to diabetes, and prior vascular surgery (eg, angioplasty).¹⁰ Perioperative clinicians also should determine whether the patient is experiencing any current symptoms that are associated with increased risk of foot ulceration, such as claudication, rest pain, numbness, or tingling.¹⁰

The American Diabetes Association's (ADA's) guidelines for foot care recommend that a qualified health care professional perform a yearly comprehensive foot examination for all patients with diabetes and a comprehensive foot examination at each visit for patients with known insensate feet, foot deformities, or a history of foot ulceration.¹¹ The ADA also recommends that patients with diabetes perform daily self-checks of their feet.¹¹ Perioperative clinicians can inform surgical patients who have diabetes of these ADA recommendations. Also, recommending a follow-up appointment with a diabetes educator can be helpful. The comprehensive physical examination should

be performed in a well-lit room and begin with the removal of the patient's socks and shoes. The clinician should examine the patient's shoes and question the patient regarding proper sizing because ill-fitting or overly worn footwear may lead to ulceration.¹² The clinician should then inspect the feet, including interdigital spaces, with attention to skin color, perspiration, erythema, infection, skin breaks, callus, blistering, nail abnormalities, deformity, and muscle wasting.¹³ Perioperative nurses maintain a vital role in identifying any potentially damaging footwear that the patient may wear during preoperative check-in and assessment and work with other health care providers to ensure correction.

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Screening for Neuropathy

A foot ulcer in a patient with diabetes is the result of multiple factors, and perioperative nurses may identify these factors before or during a surgical procedure. Neuropathy is the most common contributing factor; other factors include peripheral arterial disease, age, and previous ulceration.¹⁴ Whereas individual risk factors alone (eg, neuropathy, peripheral artery disease, age) rarely cause ulceration, it is the combination of two or more factors that typically leads to ulcer formation.¹⁴ Neuropathy also complicates the decreased tissue oxygen saturation in the skin of the patient's foot.¹⁵

The symptoms of sensory neuropathy exist on a spectrum of severity; up to 50% of patients may be asymptomatic, but are at great risk of injury to their insensate feet.¹⁶ Clinicians can diagnose peripheral neuropathy by a simple clinical assessment of large fiber function (eg, loss of perception of vibration using a 128-Hz tuning fork) and small fiber function (eg, light-touch sensation) in the feet, along with an assessment of ankle reflexes.¹⁷ Simple tests of sensory function are also useful, such as pressure perception using a Semmes-Weinstein monofilament.¹⁷ The Semmes-Weinstein test involves the perception of pressure when a 10-g filament buckles against the skin of the foot.¹⁷ Biothesiometry is a semiquantitative method for determining vibration

perception in which a clinician increases the amplitude of a vibrating probe until the patient can sense the vibration. This method is useful, but is not as widely used or cost effective as the Semmes-Weinstein 10-g monofilament or the tuning fork, which are both considered to be simple, accurate, and easily learned.¹⁸ It is important for perioperative clinicians to be cognizant of the patient's neuropathy, proper footwear, and need for education in the perioperative setting. The optimal time to educate the patient may be when the patient's friends or family members are present and also attuned to perioperative instructions.

Managing Infection

The patient with a neuropathic foot ulcer often does not feel pain or tenderness, and the inflammatory response may be decreased, making infection difficult to detect.¹⁹ Efforts to identify systemic impaired physiology are hampered because of the chronicity of the wound and by the fact that neither an elevated white count nor fever may be present in a patient with a deep foot infection.¹⁹ Signs of infection are often postponed because of the delayed inflammatory response associated with neuropathy.¹⁹ If a wound is not healing or if drainage or cellulitis is present, we recommend deep sterile culture during debridement in the office or OR setting.

It is common for an ulcer in a patient with diabetes to harbor multiple types of microorganisms.²⁰ Based on current treatment guidelines, clinicians should use broad-spectrum antibiotics initially for severe foot infections.²¹ Definitive antibiotic therapy is based on the results of culture and sensitivity testing on an appropriately obtained wound specimen and the clinical response to empiric antibiotics.²¹ Clinicians can use parenteral therapy for severe and some moderate infections with a change to oral agents upon systemic improvement and available culture results. Antibiotic therapy should continue until the infection resolves.²¹

Because of the high incidence of osteomyelitis in patients with diabetes,²² clinicians should consider its presence when examining patients. In addition to a baseline radiograph, clinicians can diagnose a patient with osteomyelitis by performing bone palpation followed by microbiologic, histologic, and advanced radiographic (eg, magnetic resonance imaging, bone scan) confirmation. Tissue evaluation by histology and culture remains the gold standard.²² Clinical experience suggests that a bone probe can help exclude osteomyelitis, although it cannot replace

magnetic resonance imaging as the best noninvasive method for identifying occult osteomyelitis.^{23,24} Nuclear medicine scans may be equally diagnostic, but seldom provide additional information about bone architecture or localization.²⁵

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Osteomyelitis complicated by Charcot neuroarthropathy may necessitate leukocyte scanning or bone biopsy to differentiate between the two conditions. Bone scans have sensitivity between 80% to 100%, but specificity between 0% to 79%.²⁶ Leukocyte scanning is more effective than bone scans in the diagnosis of osteomyelitis, with a sensitivity between 74% and 86% and specificity between 68% and 85%.²⁷ Combined, the two scans are helpful in excluding bone infection in the presence of Charcot foot.²⁸ Clinicians need to complete all of these baseline tests before surgery to understand the extent of the disease process better and to be able to perform the best surgical intervention to achieve optimum outcomes.

INTRAOPERATIVE NURSING CARE

Perioperative nurses are crucial to the success of the intraoperative experience. Optimally, the perioperative nurse can ascertain that the patient is comfortable, can tolerate the position, and can ambulate postoperatively. The perioperative team must determine the optimal patient positioning for a debridement procedure. Nurses play a critical role in ensuring that they protect the patient's pressure points for the duration of the procedure and in maintaining the patient's normothermia with sheets, warming blankets, and forced-air warming.

Debridement

Debridement of the wound in the OR setting is often necessary because routine debridement of foot ulcers in patients with diabetes facilitates and accelerates wound healing.^{29,30} Perioperative nurses have a vital role in the collection and setup of operating equipment for the debridement procedure. Communication with the surgeon enables

the proper assembly of instruments, tissue implants, and equipment required for the procedure. Sharp debridement includes the use of a scalpel, curette, scissors, and rongeurs to remove tissue. Debridement typically involves the removal of all callus (ie, pathologically hyperkeratotic tissue), necrotic, and infected tissue.³⁰ Debridement also stimulates the nonmigratory edge epithelium, releases growth factors, and reduces the local inflammatory and proteolytic environment.³¹ Although studies have not been performed to determine the appropriate depth of debridement, the absence of fibrotic (ie, scar) tissue and the presence of organisms is a reasonable clinical parameter.

Clinical judgment by the surgical team alone is often insufficient to determine if all hyperkeratotic and callus tissue has been debrided. Preliminary studies have demonstrated that there are distinct histopathologic differences between a nonhealing edge compared with a healing edge.³¹ The histopathologic analysis of debrided tissue may be beneficial in predicting whether additional surgical procedures are necessary based on the margin of debridement.^{30,32} Therefore, the perioperative nurse must assist in accurate specimen management, including providing proper labeling and transport medium (eg, formalin, saline, sterile cup alone). This requires effective multidisciplinary communication with minimal distractions and an awareness of the opportunities for error, especially when the nurse retrieves multiple specimens.³³ Debridement in the OR setting should extend past the hyperkeratotic tissue into the soft epithelium immediately confluent to any callus.

Perioperative nurses have a vital role in the collection and setup of operating equipment for the debridement procedure.

Multiple products are approved by the US Food and Drug Administration for use in managing foot ulcers in patients with diabetes in both the OR and the clinical setting, including

- recombinant human-derived platelet growth factor,³⁴
- cryopreserved placental membrane,³⁵
- cryopreserved human fibroblast dermal substitute,³⁶
- bilayered bioengineered living skin substitute,³⁷ and
- bilayered type I bovine collagen.³⁸

These products are biologically distinct; function by different mechanisms; and should not be used in the presence of drainage, infection, or before wide debridement of the ulcer.³⁰ Clinicians can use these products intraoperatively to assist in wound healing. Perioperative nurses can work with the surgeon to determine which product to use after the debridement and assist in the collection and preparation of the product. Some products (eg, bilayered living skin substitute) are stored at room temperature and can be easily obtained before or during the operation. However, some products (eg, cryopreserved placental membrane, cryopreserved human fibroblast dermal substitute) may be frozen and require time to thaw or involve extra steps before use (eg, soaking in predetermined solution, meshing). By anticipating these factors, perioperative nurses play a vital role in keeping the procedure running smoothly.

Many topical agents are also available for foot ulcer treatment; however, none have been demonstrated conclusively to accelerate the healing of foot ulcers in patients with diabetes.^{39,40} These topical agents include antimicrobials such as sustained release silver products; slow release iodine preparations; and dressings to manage the exudative, proteolytic, and inflammatory environment of chronic wounds. Although these advanced therapies are associated with high costs, clinicians should consider their use when a wound fails to show signs of healing after four weeks of standardized therapies.⁴¹

Intraoperative Offloading

It is essential to ensure proper offloading and padding of any bony prominences during the surgical procedure. Heel offloading during surgery by the use of dynamic support surfaces (eg, alternating-pressure mattresses, low-air-loss beds, air-fluidized mattresses) and evidence-based pressure-reducing surfaces (eg, gel pad overlays) are important to use to ensure that the heels or any bony prominences do not incur unnecessary pressure during the procedure that can cause injury, such as blisters, bruising, and redness.⁴² It is also imperative to not elevate the heels too high because this can increase pressure on the sacral area or cause sliding resulting in shearing, which occurs when the skin remains stationary and the underlying tissue shifts.⁴² Offloading the feet of patients with diabetes reduces mechanical stress on the wound. Frequent monitoring and skin care is mandatory and should be considered the minimum standard of care.^{43,44}

Key Takeaways

- ◆ Patients with diabetes who have foot ulcers have an increased risk of infection and amputation. Perioperative nurses have a role in ensuring optimal perioperative care for patients with foot ulcers to help decrease their risk of amputation.
- ◆ Preoperatively, patients with diabetes who have foot ulcers should undergo a comprehensive foot examination, screening for neuropathy, and infection management.
- ◆ Patients with diabetes who have foot ulcers may undergo multiple surgical debridement procedures to help the ulcer heal. Intraoperative nurses must assist with optimal positioning (including offloading), accurate specimen management, and preparation of biologic products that may be used for the procedure.
- ◆ Postoperative skin assessment and education is essential. Patients may be candidates for hyperbaric oxygen therapy postoperatively, which could improve patients' outcomes and decrease the risk of amputation.

POSTOPERATIVE NURSING CARE

Postoperatively, the nurse should perform a skin assessment to identify any skin integrity changes that may have occurred during the surgical procedure. The nurse should compare the results of this assessment with the preoperative skin assessment. Postoperative glycemic control is also essential to decrease the likelihood of surgical site infections.⁴⁵ Blood glucose levels rise as part of the surgical stress response and this leads to the secretion of cortisol. Cortisol inhibits insulin secretion and promotes insulin resistance, which can lead to hyperglycemia and an increased risk for surgical site infections.⁴⁵ Other postoperative care may include adjuvant therapies to help heal the surgical wound, such as hyperbaric oxygen therapy (HBOT).

HYPERBARIC OXYGEN THERAPY

Indications for HBOT in patients with diabetes and foot ulcers are the presence of a Wagner grade III ulcer and failure to respond to standard of care therapy for ≥ 30 days.⁴⁶ Treating postoperative patients who meet these indications and who have diabetes, neuropathy, and foot ulcers using HBOT may improve their outcomes and help decrease amputation rates.⁴⁷ It is common to perform a surgical debridement and treat the patient with HBOT the same day. Perioperative nurses can advocate for patients to receive HBOT and facilitate transport from the postoperative care unit to the HBOT unit when located in the same or nearby facilities. The perioperative nurse maintains a critical role in ensuring that the patient's glucose level is within an acceptable range before HBOT

treatment because blood glucose levels may decrease during treatment.⁴⁸

The use of perioperative HBOT has been shown to increase the rate of wound healing,⁴⁹ improve the survival of partially viable tissue,⁵⁰ and increase the survival benefit of patients with necrotizing soft tissue infections.⁵¹ Clinicians use transcutaneous oxygen measurements to assess the degree of periwound hypoxia, which is important in assessing the usefulness of HBOT for the patient.⁵²

Hyperbaric oxygen therapy has multiple therapeutic effects, including the reversal of hypoxia, increased angiogenesis, improved leukocyte function, and release of growth factors and stem cells.⁵³ Although a recent large retrospective review reported that HBOT is not effective,⁵⁴ the majority of clinical trials have shown a decrease in amputation rates if patients are appropriately chosen for this therapy.⁴⁷ Figure 1 provides an example of a patient with diabetes and a foot ulcer who underwent HBOT.

Postoperative Offloading

Teaching the patient offloading techniques and how to use offloading products must be part of the postoperative discharge education plan. Multiple offloading techniques have been described in the literature⁵⁵ and include

- casts,
- half-shoes,



Figure 1. Male patient with a history of bilateral ischemic diabetic foot ulcers. No revascularizable lesions were found on angiography and the patient repeatedly refused amputation, opting for local wound care, including hyperbaric oxygen therapy, despite multiple inpatient admissions for failure to thrive, wound infections, and osteomyelitis. Patient had dry gangrene of the left distal foot (a,b), resulting in progressive loss of the left fourth toe (c), left second and third toes (d), and ultimately, a transmetatarsal amputation (e). Currently, the patient is receiving a regenerative medicine product in combination with a vacuum-assisted closure device and has decreased pain and wound size.

- sandals,
- felted foam dressings,
- Multi Podus boots,
- foam-based heel offloading boots, and
- calf rests.

Offloading options such as the instant total-contact cast have become available, making contact casting more accessible to providers. This technique involves rendering a removable cast walker, thus avoiding the need for a skilled casting technician. This may improve patient compliance and can be as effective as a total contact cast.⁵⁶ In addition, clinicians can measure dynamic in-shoe plantar pressure distribution, allowing for the development of

customized footwear. These viable options should be fully explained to the patient postoperatively and education must be provided before the patient leaves the hospital. Follow-up during postoperative discharge phone calls can ensure that any additional questions or concerns are addressed.

The presence of a foot ulcer mandates offloading by an experienced professional.⁵⁷ Whichever offloading device is used, it is important that a designated person such as a podiatrist, physiatrist, pedorthist, or physical therapist routinely apply the device. Even after a wound has healed, the ulcer may recur (eg, with the use of ill-fitting footwear). Therefore, clinicians must take care to assess offloading practices continually to maintain

ulcer-free feet. Patients must be informed regarding the need for this specialized care and be given the appropriate resources to contact the correct health care professional.

CONCLUSION

Perioperative nurses are integral members of the provider team and play a critical role in ensuring optimal patient care before, during, and after wound debridement. Preoperatively, nurses can identify potentially damaging, improper footwear; help the patient avoid surgical complications associated with hypo- or hyperglycemia; and identify new injuries or ulcerations during the preoperative and postoperative check. Nurses can also serve as a crucial line of defense by reviewing laboratory results and identifying abnormalities. Intraoperatively, nurses are essential for patient positioning, padding, warming, and gathering of surgical equipment. Postoperatively, nurses can facilitate the education of patients in all aspects of care. Ensuring optimal care for patients with diabetes and foot ulcerations can lead to an improved quality of life, a decreased number of amputations, and increased limb salvage.

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Raelina S. Howell, MD, is a clinical research fellow in the Division of Wound Healing and Regenerative Medicine, Department of Surgery, New York University (NYU) Winthrop Hospital, Mineola. *As a recipient of a grant for this work from the NIDDK of the National Institutes of Health under award number K24DK090135, Dr Howell has declared an affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Theresa Criscitelli, EdD, RN, CNOR, is the assistant vice president in administration and perioperative services in the Division of Wound Healing and Regenerative Medicine, Department of Surgery, NYU Winthrop Hospital, Mineola. *Dr Criscitelli has no declared affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Jon S. Woods, MD, is a clinical research fellow in the Division of Wound Healing and Regenerative Medicine, Department of Surgery, NYU Winthrop Hospital, Mineola. *Dr Woods has no declared affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Brian M. Gillette, PhD, is a research scientist in the Division of Wound Healing and Regenerative Medicine,

Department of Surgery, NYU Winthrop Hospital, Mineola. *Dr Gillette has no declared affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Harold Brem, MD, FACS, is the chief of the Division of Wound Healing and Regenerative Medicine, Department of Surgery, Newark Beth Israel Medical Center, RWJBarnabas Health, Newark, NJ. *As a recipient of a grant for this work from the NIDDK of the National Institutes of Health under award number K24DK090135, Dr Brem has declared an affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Scott Gorenstein, MD, Fellow of the American College of Emergency Physicians (FACEP), is the clinical director of the Division of Wound Healing and Regenerative Medicine, Department of Surgery, NYU Winthrop Hospital, Mineola. *As the medical director of Life Support Technologies and the recipient of an honorarium for speaking at the Symposium on Advanced Wound Care from BSN Therapeutics and Grand Rounds-Westchester, Dr Gorenstein has declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.*

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