

# Evaluation and Treatment of Diabetic Foot Ulcers

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**D**iabetic foot problems, such as ulcerations, infections, and gangrene, are the most common cause of hospitalization among diabetic patients. Routine ulcer care, treatment of infections, amputations, and hospitalizations cost billions of dollars every year and place a tremendous burden on the health care system.

The average cost of healing a single ulcer is \$8,000, that of an infected ulcer is \$17,000, and that of a major amputation is \$45,000. More than 80,000 amputations are performed each year on diabetic patients in the United States, and ~ 50% of the people with amputations will develop ulcerations and infections in the contralateral limb within 18 months. An alarming 58% will have a contralateral amputation 3–5 years after the first amputation. In addition, the 3-year mortality after a first amputation has been estimated as high as 20–50%, and these numbers have not changed much in the past 30 years, despite huge advances in the medical and surgical treatment of patients with diabetes.

## Etiology

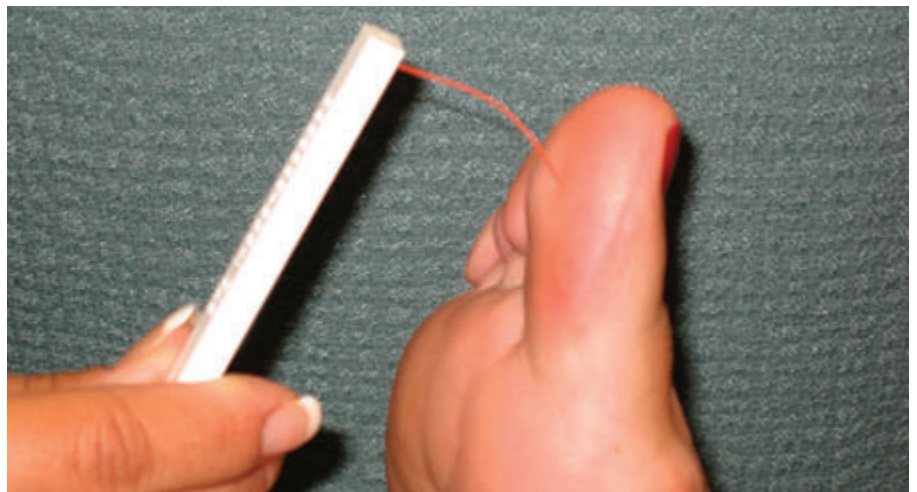
“The majority of foot ulcers appear to result from minor trauma in the presence of sensory neuropathy.” This famous but simple quote from McNeely et al.<sup>1</sup> best describes the critical triad most commonly seen in patients with diabetic foot ulcers: peripheral sensory neuropathy, deformity, and trauma. All three of these risk factors are present in 65% of diabetic foot ulcers. Calluses, edema, and peripheral vascular disease have also been identified as etiological factors in the development of diabetic foot ulcers.

Although the pathogenesis of peripheral sensory neuropathy is still poorly understood, there seem to be multiple mechanisms involved, including the formation of advanced glycosylated end products and diacylglycerol, oxidative stress, and activation of protein kinase C $\beta$ . Furthermore, the Diabetes Control and Complications Trial<sup>2</sup> and other prospective studies have confirmed the pivotal role of hyperglycemia in the onset and progression of neuropathy. The data linking glycemic control and neuropathy are not as clear cut as those for retinopathy because of the difficulty in identifying objective measures to assess the many stages of neuropathy over time and because the symptoms, or lack thereof, of neuropathy may be mis-

leading if assessed only through patient questionnaires. Finally, the differential diagnosis of peripheral neuropathy is quite large, and patients may have other etiologies, as well. Even so, it is important for clinicians to know the basics of evaluation and treatment of foot ulcers seen in diabetic patients.

## Evaluation

Foot ulcer evaluation should include assessment of neurological status, vascular status, and evaluation of the wound itself. Neurological status can be checked by using the Semmes-Weinstein monofilaments to determine whether the patient has “protective sensation,” which means determining whether the patient is sensitive to the 10-g monofilament (Figure 1).



**Figure 1.** Using the 10-g Semmes-Weinstein monofilament. The monofilament is applied to various areas on the foot (e.g., at the dorsum of the great toe just proximal to the nail bed and the plantar surface of the big toe, metatarsal heads, and heel) with enough pressure to bend the nylon filament. Patients are asked to identify the location of the filament, preferably with their eyes closed. Patients who cannot feel the monofilament on their feet are termed “insensate” and are 10 times more likely to develop a foot ulcer than their “sensate” counterparts.

Another useful instrument is the 128 C tuning fork, which can be used to determine whether a patient's vibratory sensation is intact by checking at the ankle and first metatarsal-phalangeal joints. The notion is that metabolic neuropathies have a gradient in intensity and are most severe distally. Thus, a patient who cannot sense vibration at the big toe but can detect vibration at the ankle when the tuning fork is immediately transferred from toe to ankle demonstrates a gradient in sensation suggestive of a metabolic neuropathy. In general, you should not be able to sense vibration of the tuning fork in your fingers for more than 10 seconds after the time when the patient can no longer sense vibration at the great toe. Many patients with normal sensation only demonstrate a difference between sensation at their toe and sensation in the practitioner's hand of  $\leq 3$  seconds.

Both of these tests can be performed quickly in any office setting. Achilles and patellar reflexes can also be checked easily but are unreliable in the assessment of diabetic peripheral neuropathy. More in-depth analysis can be performed using a vibrometer (a device designed to more objectively measure vibratory sense), assessing temperature sense, performing nerve conduction studies, and checking position sense and balance. These tests are usually performed in a neurological laboratory. A much more detailed review of peripheral neuropathy has been published in the journal *Diabetes Care* and is available online in full text at no charge.<sup>3</sup>

Vascular assessment is important for eventual ulcer healing and is essential in the evaluation of diabetic ulcers. Vascular assessment includes checking pedal pulses, the dorsalis pedis on the dorsum of the foot, and the posterior tibial pulse behind the medial malleolus, as well as capillary filling time to the digits. The capillary filling time is assessed by pressing on a toe enough to cause the skin to blanch and then counting the seconds for skin color to return. A capillary filling time  $> 5$  seconds is considered

prolonged. If pedal pulses are nonpalpable, the patient should be sent to a noninvasive vascular laboratory for further assessment, which may include checking lower extremity arterial pressures by Doppler and recording pulse volume waveforms. The ankle brachial index is often not helpful because of high pressures resulting from noncompressible arteries. However, toe pressures are very useful in determining the healing potential of an ulcer. In addition, transcutaneous oxygen measurements are often useful in determining whether a foot wound can heal.

Ulcer evaluation should include documentation of the wound's location, size, shape, depth, base, and border. A sterile stainless steel probe is useful in assessing the presence of sinus tracts and determining whether a wound probes to a tendon, joint, or bone. X-rays should be ordered on all deep or infected wounds, but magnetic resonance imaging often is more useful because it is more sensitive in detecting osteomyelitis and deep abscesses. Signs of infection, such as the presence of cellulites, odor, or purulent drainage, should be documented, and aerobic and anaerobic cultures should be obtained of any purulent exudates. Culturing a dry or clean

wound base has proven to be useless because most wounds are colonized, and this practice leads to overprescribing of antibiotics.

After all physical findings have been noted, a differential diagnosis should be established. One cannot assume that an ulcer is a diabetic foot ulcer without considering other possibilities, such as malignancies or vasculitic disorders (Figure 2).

### Treatment

Successful treatment of diabetic foot ulcers consists of addressing these three basic issues: debridement, offloading, and infection control.

### Debridement

Debridement consists of removal of all necrotic tissue, peri-wound callus, and foreign bodies down to viable tissue. Proper debridement is necessary to decrease the risk of infection and reduce peri-wound pressure, which can impede normal wound contraction and healing. After debridement, the wound should be irrigated with saline or cleanser, and a dressing should be applied.

Dressings should prevent tissue desiccation, absorb excess fluid, and protect the wound from contamination.



**Figure 2.** A foot lesion confirmed as malignant melanoma. The patient was originally referred for suspected gangrene on the heel.

There are hundreds of dressings on the market, including hydrogels, foams, calcium alginates, absorbent polymers, growth factors, and skin replacements. Becaplermin contains the  $\beta$ -chain platelet-derived growth factor and has been shown in double-blind placebo-controlled trials to significantly increase the incidence of complete wound healing. Its use should be considered for ulcers that are not healing with standard dressings.

In case of an abscess, incision and drainage are essential, with debridement of all abscessed tissue. Many limbs have been saved by timely incision and drainage procedures; conversely, many limbs have been lost by failure to perform these procedures. Treating a deep abscess with antibiotics alone leads to delayed appropriate therapy and further morbidity and mortality.

### Offloading

Having patients use a wheelchair or crutches to completely halt weight bearing on the affected foot is the most effective method of offloading to heal a foot ulceration. Total contact casts (TCCs) are difficult and time consuming to apply but significantly reduce pressure on wounds and have been shown to heal between 73 and 100% of all wounds treated with them. Armstrong et al.<sup>4</sup> have achieved similar healing rates with an "instant TCC," made by wrapping a removable cast walker with a layer of cohesive bandage or plaster of Paris. Inappropriate application of TCCs may result in new ulcers, and TCCs are contraindicated in deep or draining wounds or for use with noncompliant, blind, morbidly obese, or severely vascularly compromised patients.

Clinicians often prefer removable cast walkers because they do not have some of the disadvantages of TCCs. Removability is an advantage in that it allows for daily wound inspection, dressing changes, and early detection of infection. But removability is also the greatest disadvantage in that studies have shown that patients wear them only

~ 30% of the time they are walking (usually to and from the doctor's office).<sup>5</sup>

Postoperative shoes or wedge shoes are also used and must be large enough to accommodate bulky dressings. Proper offloading remains the biggest challenge for clinicians dealing with diabetic foot ulcers.

### Infection control

Limb-threatening diabetic foot infections are usually polymicrobial. Commonly encountered pathogens include methicillin-resistant *staphylococcus aureus*,  $\beta$ -hemolytic streptococci, enterobacteriaceae, *pseudomonas aeruginosa*, and enterococci. Anaerobes, such as *bacteroides*, *peptococcus*, and *peptostreptococcus*, are rarely the sole pathogens but are seen in mixed infections with aerobes. Antibiotics selected to treat severe or limb-threatening infections should include coverage of gram-positive and gram-negative organisms and provide both aerobic and anaerobic coverage. Patients with such wounds should be hospitalized and treated with intravenous antibiotics.

Mild to moderate infections with localized cellulitis can be treated on an outpatient basis with oral antibiotics such as cephalexin, amoxicillin with clavulanate potassium, moxifloxacin, or clindamycin. The antibiotics should be started after initial cultures are taken and changed as necessary.

### Summary

The etiology of diabetic foot ulcers is multifactorial, but minor trauma in the presence of peripheral sensory neuropathy remains the primary culprit. Prevention of foot ulcers in high-risk individuals, such as those with neuropathy, peripheral vascular disease, or structural foot abnormalities, is of primary importance through appropriate patient education, the use of emollients, and the use of appropriately fitting shoes. The patient information page that accompanies this article (p. 94) offers a complete list of self-care behaviors that should be provided to patients with high-risk feet.

Evaluation of foot ulcers includes checking vascular and neurological status and accurately assessing wounds. The depth of infection is arguably the most critical assessment and one that is not commonly performed in many clinicians' offices because it requires at least partial debridement and a probe to bone.

Treatment should address all three major concerns: debridement, offloading, and infection control. Not all physicians need to be capable of treating diabetic foot ulcers themselves, but it is extremely important to be knowledgeable enough to perform an initial evaluation, refer patients promptly, and help with follow-up of patients with healing wounds.

### REFERENCES

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