Best Practices for the Management of Foot Ulcers in People with Diabetes

Kevin Y. Woo, PhD, RN • Assistant Professor • School of Nursing Queen’s University • Kingston, Ontario, Canada • Wound Care Consultant • West Park Health Centre • Toronto, Ontario, Canada • Web Clinical Editor • Advances in Skin & Wound Care
Mariam Botros, DCh • Chiropodist • Women’s College Hospital • Toronto, Ontario, Canada
Janet Kuhnke, RN, MSc ET • PhD Student • University of Ottawa • Ottawa, Ontario, Canada
Robyn Evans, MD, MSc • Director of Wound Clinic • Women’s College Hospital • Toronto, Ontario, Canada
Afsaneh Alavi, MD • Lecturer • Toronto Dermatology Clinic • Toronto, Ontario, Canada

All faculty, staff, and planners, including spouses/partners (if any), in any position to control the content of this CME activity have disclosed that they have no financial relationships with, or financial interests in, any commercial companies pertaining to this educational activity.

To earn CME credit, you must read the CME article and complete the quiz and evaluation on the enclosed answer form, answering at least 13 of the 18 questions correctly.

This continuing educational activity will expire for physicians on November 30, 2014.

PURPOSE:
To enhance the learner’s competence with information about best practices in management of foot ulcers in people with diabetes.

TARGET AUDIENCE:
This continuing education activity is intended for physicians and nurses with an interest in skin and wound care.

OBJECTIVES:
After participating in this educational activity, the participant should be better able to:
1. Identify assessment parameters to discern causes and risk factors for foot ulcers.
2. Apply evidence-based practices to case scenarios for the prevention and management of diabetic foot ulcers.
ABSTRACT
The care of persons with diabetic foot ulcers requires a systematic approach following the wound bed preparation paradigm and the existing best practice recommendations. The purpose of this article is to summarize key evidence and recommendations regarding prevention and management of diabetic foot ulcers that can be translated into practice.

KEYWORDS: diabetic foot ulcer, evidence-based practice

Diabetes is one of the leading chronic diseases that has become an epidemic worldwide. According to the International Diabetes Federation, the global number of people with diabetes will increase from 246 million or 5.9% in 2007 to 380 million or 7.1% by 2025. Of persons with diabetes (PWDs), 2% to 3% will develop a foot ulcer annually, whereas the lifetime risk of developing a foot ulcer is as high as 25%, primarily because of neuropathy and potential coexisting vascular disease. Following patients with diabetes and neuropathy for 1 year, it was estimated that 7.2% of this population would develop their first foot ulcer. More than 80% of all nontraumatic amputations in diabetes are preceded by foot ulcers that should be considered as one of the prognostic indicators for advanced diabetes. In most countries, the healthcare system costs of diabetic foot ulcers are exorbitant and include a high likelihood of hospitalizations. In the United States, the care of diabetes-related foot ulcers constitutes 25% to 50% of the total costs associated with diabetic care. Despite these staggering statistics, foot ulcers and related adverse sequelae in PWDs are deemed highly preventable.

For optimal patient outcomes, the care of people with diabetic foot ulcers requires a systematic approach following the wound bed preparation paradigm and the existing best practice recommendations. Integral to the recommended best practices is the primary emphasis on addressing patient concerns and the causative factors prior to instituting local wound care. Foot ulcers are often precipitated by neuropathy and complicated by vascular insufficiency that necessitates thorough evaluation and specific intervention to promote healing. Local wound care of wounds with healing potential usually involves 3 core components: debridement of nonviable tissue, infection management, and moisture balance (DIM). By applying the principles to optimal wound healing, it has been demonstrated that 50% surface area reduction at week 4 is predictive of complete wound closure at week 12. If the wound is not healing at the expected rate, advanced therapies may be considered. If the wound cause cannot be corrected, compromising healing potential, local wound care should focus on maintenance to prevent secondary infection and further deterioration. This article summarizes key evidence and recommendations regarding the prevention and management of diabetic foot ulcers that clinicians can translate into practice.

RECOMMENDATIONS FOR THE PREVENTION AND MANAGEMENT OF DIABETIC FOOT ULCERS

1. Evaluate diabetes management and conduct a systematic assessment of the PWD including A1C, blood pressure, cholesterol, diet, exercise, and smoking history.

Inadequate management of diabetes can put individuals at risk for a number of serious complications including foot ulceration. Hyperglycemia triggers a constellation of metabolic events leading to excessive production of advanced glycation end-products and overproduction of oxygen free radicals that can delay healing of foot ulcers (Figure 1).

Recognizing the multifaceted nature of diabetes management and risk factors for foot ulcers, several salient factors should always be part of a careful patient history, and their associated risks for foot ulceration are summarized in Table 1. Practitioners may consider close monitoring, early referral to specialists, and intensive treatment based on the risk profile.

2. Conduct a lower-leg and foot assessment to differentiate neuropathic, neuroischemic, and ischemic diseases (ulcers). A thorough foot examination should be conducted at least on an annual basis to identify risk factors that can lead to foot ulcers in order to institute early intervention. Only half of the individuals with diabetes, however, receive routine foot examinations by their healthcare providers. To help identify the key and relevant risk factors, Inlow et al developed a 60-second diabetic foot screening tool that allows clinicians to quickly assess for skin, nail, foot deformity, footwear, temperature (hot and cold), range of motion, loss of sensation, pedal pulses, dependent rubor, and erythema. The key elements and supporting evidence are summarized in Table 2. The interrater reliability of Inlow’s 60-second foot screening tool has been supported by high intraclass correlation coefficients ranged from 0.83 to 0.93. There is a need to explore if the PWD understands the implications of various risk factors and the importance of self-care practices in diabetic foot ulcer prevention.

Neuropathic Foot
Diabetic neuropathy is present in almost 60% of diabetic patients with foot ulcers; associated nerve dysfunction may be described as sensory, autonomic, or motor. Sensory neuropathy removes the protective sensation rendering the individual to be less aware of potential or actual trauma to his or her skin. To screen for individuals with sensory neuropathy, the 5.07 (10 g) Semmes-Weinstein monofilament test is recommended. Individuals with significant
sensory impairment (4 of the 10 points in Figure 2) are likely to develop foot ulcers (odds ratio [OR], 5.4; 2.6–11.6).  

Autonomic neuropathy is associated with decreased production of sweat and components of the natural moisturizing factor leaving the skin dry that leads to disruption of the epidermal barrier. The skin should be inspected for dryness, especially the presence of fissures or cracks that may become a portal of entry for bacteria. Areas with blisters, cuts, scratches, redness, or hemorrhage are indicative of local damage from local trauma, friction, or shear commonly caused by walking barefoot and poorly fitting footwear. Callus formation is a reaction to increased local pressure and heralds impending skin breakdown and ulceration (relative risk [RR], 11.0). By recognizing early signs of injury from pressure and friction, prompt interventions can be instituted to prevent actual ulceration. Fungal infection is not uncommon in PWDs. The most occlusive areas are the fourth and fifth toe web spaces allowing excessive moisture accumulation that promotes fungal proliferation as evident by skin maceration in the area. A plethora of antifungal agents are available for local or systemic management.

Motor neuropathy interferes with the normal signaling to the lumbrical and interosseus muscles, leading to atrophy and wasting of the muscles, foot deformity, upper displacement of fat pads, and altered foot biomechanics. Common foot deformities including foot drop, equinovarus deformity, hammertoes, and prominent plantar metatarsal heads create areas that sustain high impact and pressure and are prone to ulcer formation (especially with ill-fitting and poorly designed footwear).

Ischemic foot

Diabetes is associated with a 2- to 3-fold increased risk of accelerated atherosclerosis. Poor arterial blood supply compromises not only the delivery of oxygen and nutrients to the skin but also the availability of white blood cells to defend the host against bacterial invasion if the skin is broken down. The severity of macrovascular and microvascular disease may hinge upon the duration and degree of diabetes, severity of dyslipidemia, obesity, hypertension, smoking, and family history of atherosclerosis and anatomical location (proximal versus distal). Over time, chronic hemodynamic and metabolic damages to the

Figure 1.

PATHOPHYSIOLOGY OF DIABETIC FOOT AND ULCERATION

© Woo KY, 2013.
Table 1.
DIABETIC FOOT ULCERS AND ASSOCIATED RISK FACTORS

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Recommendations</th>
<th>Evidence for Increased Risk of Foot Ulcers</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: HbA1c</td>
<td>Target for diabetes in control is 7.0% and should be checked every 3 mo</td>
<td>Elevated HbA1c (HR, 1.1; 95% CI, 1.06–1.15) predicts foot ulcer</td>
</tr>
<tr>
<td>B: Blood pressure</td>
<td>Target for blood pressure control is &lt;130 mm Hg systolic and 80 mm Hg diastolic</td>
<td>Increased pulse pressure had a 2.39-fold (95% CI, 1.14–5.02) risk of foot ulcers</td>
</tr>
<tr>
<td>C: Cholesterol--creatinine</td>
<td>Reduce cholesterol levels: LDL-C &lt;2.0 mmol/L, TC: HDL-C &lt;4.0, lower triglycerides to &lt;1.7 mmol/L, and raise HDL cholesterol to &gt; 1.0 mmol/L Maintain creatinine &lt;110 IU</td>
<td>Foot ulcers are related to high creatinine RR, 1.16 (1.04–1.29) and nephropathy (repeated evidence of proteinuria or dialysis) RR, 2.23; CI, 1.33–3.75</td>
</tr>
<tr>
<td>D: Diet and weight</td>
<td>Calculate BMI (kg/m²), which should be within reference range of 18.5–24.9. Measure waist circumference taking into account ethnicity and gender (men = 40 in; women = 35 in)</td>
<td>Patients with BMI 40–44.9 were 25% more likely (OR, 1.25; 95% CI, 1–1.56), and patients with BMI 45 were 85% more likely (OR, 1.85; 95% CI, 1.46–2.34) to develop foot ulcers after 1 y</td>
</tr>
<tr>
<td>E: Exercise</td>
<td>Recommend regular exercise (aerobic, resistance, or both) of &gt;150 min per week, associated with improved glycemic control</td>
<td>Exercise is linked to an absolute HbA1c reduction of 0.89% (95% CI, 1.26–0.51)</td>
</tr>
<tr>
<td>F: Smoking</td>
<td>Promote smoking cessation as 1 cigarette will decrease local circulation 30% for 1 h</td>
<td>Smoking increases risk of foot ulcers (OR, 2.1; P &lt;.0000)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; HR, hazard ratio; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; RR, relative risk; TC, total cholesterol.
Modified from @Woo 2010. Recommendations according to the Canadian Diabetic Association: http://guidelines.diabetes.ca.

Endothelium result in functional and structural changes. The typical changes may involve thickening of the basement membrane and sclerosis of capillary walls. Common tests for vascular assessment are summarized in Table 3. Although measuring ankle-brachial pressure index (divide ankle systolic blood pressure by brachial systolic blood pressure obtained by a handheld Doppler) and palpation for pedal pulses are considered the most convenient noninvasive diagnostic method for detecting peripheral vascular disease (PVD), false elevation is not uncommon in people with diabetes due to noncompressible arteries associated with advanced atherosclerosis and vascular calcification. To improve the accuracy, the Wound, Ostomy and Continence Nurses Society’s Wound Committee has published a quick clinical guide for the performance of ankle-brachial pressure index.

In general, an ankle-brachial pressure index of less than 0.5 indicates significant PVD (Table 3).

The loss of triphasic waveform, as indicated by pulsed wave Doppler, indicates stiff atherosclerotic vessels, providing further validation for the presence of arterial disease. A full segmental arterial Doppler examination should be obtained to provide accurate assessment of lower-extremity arterial disease (82% sensitivity and 92% specificity).

Vascular tests should be considered in consultation with the clinical team and patient in conjunction with the clinical signs of arterial disease. According to a systematic review, the complaint of claudication increases the likelihood of PVD (likelihood ratio [LR], 3.30; 95% confidence interval [CI], 2.30–4.80). Physical findings of atrophic skin, cool skin, blue/purple skin, or absence of lower limb hair (LR, 1.50; 95% CI, 1.20–1.70) and clinical assessment of capillary refill time (LR, 1.90; 95% CI, 1.20–3.20) are considered to be valuable for identifying advanced PVD. Individuals with ischemic foot would warrant a thorough assessment by a vascular specialist to determine the most appropriate interventions based on the location, the involved angiosomes, and the extent of arterial compromise.

**Neuroischemic foot**

Clinicians should recognize that neuropathy and PVDs often coexist, which was previously discussed.

**3. Optimize plantar pressure redistribution to prevent and treat diabetic foot ulcers.**

In general, plantar pressure redistribution should be considered for all individuals with neurotrophic foot ulcers (Table 4). Most experts advocate the pneumatic walker (made nonremovable with flexible cohesive bandage or casting material to increase adherence) or the total contact cast (TCC) for forefoot ulcers. The TCC is an effective pressure redistribution measure but contraindicated in the presence of ischemia or deep infection or if trained
professionals are not available to apply and manage the TCC. Deep-toed shoes and orthotics are more appropriate for maintenance after healing to prevent recurrence. Individuals with ulcers that are located in the heel area could benefit from modified shoes (pneumatic walkers and contact casts will actually increase local pressure). All persons with neurotrophic foot ulcers should see a foot specialist with appropriate training (e.g., podiatrist, chiropodist, pedorthist, occupational therapist, physiotherapist, foot care nurse, or physician). Reevaluation, including further education and rationale for the devices, should occur at regular intervals (2–6 weeks with an active ulcer, 6–12 weeks with deformity or previous ulcer, 6–12 months with neuropathy alone). Despite best practice recommendations, clinicians need to consider the patient’s financial and vocational demands, as well as his/her mobility to individualize a realistic and achievable plan of care.  

4. Address the individual’s concerns and modify a plan of care to promote self-care and treatment adherence.

The paradigm that shifts the focus to self-management and patient engagement is the cornerstone of chronic disease management. Self-management support is “the systematic provision of education and supportive interventions, by healthcare staff (and others), to increase patients’ skills and confidence in managing their health problems, including regular assessment of progress and problems, goal setting, and problem-solving support.”

Without appropriate interventions to support self-management, studies document that less than one-third of patients with
diabetes and active ulcers were actually wearing downloading devices during activities on a regular basis. Chin et al identified a number of action cues from family, friends, and healthcare professionals that may enhance daily foot examination by people with diabetes. Valk et al identified 9 randomized controlled trials (RCTs) that evaluated patient education to prevent diabetic foot ulceration. The evidence is weak, with only 1 study of high-risk individuals with diabetes that reported a reduction in ulcer incidence (Peto OR, 0.28; 95% CI, 0.13–0.59) and reduced amputation rate (Peto OR, 0.32; 95% CI, 0.14–0.71) 1 year after intensive educational interventions. Ismail et al. identified 25 trials that utilized various psychological interventions (eg, problem solving, contract setting, goal setting, self-monitoring of behaviors) to improve diabetic self-management. Patients allocated to psychological therapies demonstrated improvement in Hg. (12 trials, standardized effect size = -0.32; -0.57 to -0.07) and reduction of psychological distress including depression and anxiety (5 trials, -0.5; -0.95 to -0.20).

Individuals living with foot ulcers experience poor quality of life because of limited mobility, social isolation, disruption to work and leisure activities, sleep disturbance, depression, and pain. According to a systematic review, the prevalence of depression is 3 times higher in type 1 diabetes (12% [range, 5.8%–43.3%] vs 3.2% [range, 2.7%–11.4%]) and 2 times higher prevalence of depression in people with type 2 diabetes (19.1% [range, 6.5%–33%] vs 10.7% [range, 3.8%–19.4%]) than in those without diabetes. The impact of depression and related distress on individuals with diabetes cannot be underestimated.

In a 5-year follow-up study of a cohort of PWDs, Winkley et al. explored the association between depressive disorders and mortality. Matched with age and gender, participants with a documented history of depression were associated with 2-fold increased risk in mortality (hazard ratio, 2.09; 95% CI, 1.34–3.25) compared with those without depression. Healing of diabetic foot ulcers can be predicted by depression.

Similarly, PWDs who report pain most or all of the time had statistically and clinically significantly poorer health-related quality of life than those who did not report pain. However, pain in diabetes is often underestimated and undertreated.

5. Optimize local wound environment for healing through debridement, infection control (bacterial burden control), and moisture balance (DIM).

Table 3. COMMON VASCULAR ASSESSMENT TECHNIQUES AND PARAMETERS

<table>
<thead>
<tr>
<th>Test (Reference Values)</th>
<th>Evidence</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palpable pedal pulse (80 mm Hg)</td>
<td>• Absent or reduced pedal pulses increases the likelihood of PVD (LR, 4.70; 95% CI, 2.20–9.90)</td>
<td>• Palpable pulses can be misleading because of noncompressible blood vessels associated with advanced atherosclerosis</td>
</tr>
<tr>
<td>• PPP compared with color duplex imaging PWD with PVD (sensitivity = 81%, specificity = 56%; PPV = 42%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Absence of foot pulses Risk of new DFU (RR, &lt;4.72; 3.28–6.78)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle-brachial pressure index (ABI) (&gt;0.5 and &lt;1.2)</td>
<td>• Outside reference range, PVD identified (sensitivity = 90%; specificity = 95%)</td>
<td>• False elevation in patients with calcified vessels</td>
</tr>
<tr>
<td>• ABPI compared with color duplex imaging PWD with PVD (sensitivity = 53%; specificity = 95%; PPV = 80%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcutaneous oxygen tension (&gt;30 mm Hg)</td>
<td>• Below-the-knee values of &lt;30 mm Hg predict the need for above-the-ankle amputation in diabetic patients (sensitivity = 78.6%; specificity = 83%)</td>
<td>• Expensive equipment and labor intensive</td>
</tr>
<tr>
<td>• &gt;30 mm Hg predicts healing of DFU (sensitivity = 15%; specificity = 97%; PPV = 79%; NPV = 94%)</td>
<td>• 15 mm Hg higher dorsal foot transcutaneous Po2 0.8 (0.7–0.9)</td>
<td></td>
</tr>
<tr>
<td>Toe pressure (&gt;55 mm Hg)</td>
<td>• &gt;55 mm Hg has the ability to predict healing of arterial ulcers (sensitivity = 75%; specificity = 86%)</td>
<td>• Large toe is of a small caliber without a fully developed adventitial layer to allow circumferential calcium deposits</td>
</tr>
<tr>
<td>• &gt;55 mm Hg compared with color duplex imaging in diagnosed PVD in PWD (sensitivity = 100%; specificity = 61%; PPV = 48%)</td>
<td>• Cannot be calibrated if there is previous toe amputation</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; LR, likelihood ratio; NPV, negative predictive value; OR, odds ratio; PPP, palpable pedal pulses; PPV, positive predictive value; PVD, peripheral vascular disease; PWD, persons with diabetes.
<table>
<thead>
<tr>
<th>Device</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCC (foot and ankle)</td>
<td>• Offloads foot and midfoot pressure</td>
<td>• Contraindicated in infected and ischemic wounds</td>
<td>RCT: healing of DFU compared with RCW and half shoe in 12 wk; OR, 5.4; 1.1–26.1³³</td>
</tr>
<tr>
<td></td>
<td>• Protection from trauma</td>
<td>• May cause new pressure areas in the cast</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Immobilization of skin edges</td>
<td>• Requires skilled technician</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduction of edema</td>
<td>• Does not reduce heel pressure significantly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduction of pressure over the ulcers</td>
<td>• May cause back pain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Forced adherence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCW (eg, air cast, walker, pneumatic walker)</td>
<td>• Easy to use and fit, reusable</td>
<td>• Potential adherence issue</td>
<td>RCT: higher number of DFU healed at week 12 in the iTCC group than the RCW group (OR, 1.8; 1.1–2.9)³⁶</td>
</tr>
<tr>
<td></td>
<td>• Allows easy access to an ulcer for evaluation</td>
<td>• Should not be used on heel wounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be used on infected/ischemic wounds</td>
<td>• High cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The ankle is fixed at 90 degrees, and the sole has a rocker</td>
<td>• May cause and aggravate back pain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Offloads foot and midfoot pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be made nonremovable by applying flexible cohesive bandage or zinc oxide paste bandage around it (instant TCC or iTCC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half shoes</td>
<td>• Reduce forefoot pressure by eliminating propulsive gait</td>
<td>• Requires balance and stability to use the device</td>
<td>Case-control study: in the half-shoe cases vs controls, median overall healing time was 70 vs 118 d, the median difference being 48 (95% confidence interval [CI], 5 to 82 d) (not statistically significant)⁴²</td>
</tr>
<tr>
<td></td>
<td>• Inexpensive</td>
<td>• Can increase heel pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduce metatarsal phalangeal (first metatarsal-phalangeal area) pressure by 65%⁴¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt padding</td>
<td>• Can be incorporated into all of the devices to reduce further pressure</td>
<td>• Increase shear at the wound edges</td>
<td>Comparative study: felted foam was more effective than postoperative and canvas shoes in reducing per Ulcer pressure⁴³</td>
</tr>
<tr>
<td></td>
<td>• Reduce MTPI (first metatarsal-phalangeal area) pressure by 48%⁴¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ankle foot orthosis</td>
<td>• Correct foot drop</td>
<td>• Costly</td>
<td>No data available</td>
</tr>
<tr>
<td></td>
<td>• Correct pressure from chronic Charcot deformity</td>
<td>• May cause secondary ulceration especially under 1st IPJ</td>
<td></td>
</tr>
<tr>
<td>Off-the-shelf orthopedic shoes and orthotics</td>
<td>• Extra depth to fit customized insoles and toe deformities</td>
<td>• Costly</td>
<td>RCT: cork inserts compared for controls, RR, 0.88 (95% CI, 0.51–1.52). Prefabricated inserts compared for controls, re ulcerations was RR 0.85 (95% CI, 0.48–1.48)⁴⁶</td>
</tr>
<tr>
<td></td>
<td>• Can be relatively aesthetically pleasing</td>
<td>• Accumulate up to 900% more pressure in the foot compared to TCC³⁵</td>
<td>continues</td>
</tr>
<tr>
<td></td>
<td>• Preventive care</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be incorporated into shoes and removable cast</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Debridement

Nonviable tissue including eschar or soft slough promotes bacteria growth and creates a proinflammatory environment that inhibits healing. However, not all wounds need and benefit from debridement. The decision to perform debridement should take into consideration whether complete wound closure is realistic and achievable. For wounds with the ability to heal, surgical debridement of callus and abnormal surface granulation with a curette, scissors, or scalpel blade has been considered to be the most effective way to destroy the biofilm structure and reduce the number of senescent cells that impede healing. In a 143-patient study by Saap and Falanga, wound closure of diabetic foot ulcers was predicted by whether the ulcers were adequately debrided (OR, 2.4; 95% CI, 1.0–5.6). Removal of hyperkeratosis and callus has been shown to reduce the risk of diabetic foot ulcers by lowering overall peak plantar pressure by 29%. Edwards and Stapley reviewed RCTs pertaining to debridement of diabetic foot ulcers. Combining results from 3 RCTs suggests hydrogels are superior to gauze or standard ulcer care to assist tissue autolytic debridement and healing in diabetic foot ulcers (RR, 1.84; 95% CI, 1.3–2.61). For wounds that do not have the potential for healing, debridement is contraindicated. Without adequate blood supply and immune defense, debridement can increase the risk of infection (especially when moisture is donated into the wound) and create a larger and deeper wound that does not heal. It is recommended that non-healable wounds be kept dry and only loose-hanging slough be removed under judicious consideration (Figure 3).

Infection

Individuals with diabetes are susceptible to wound infection as a result of immunodeficiency, neuropathy, and arteriopathy. Mowat et al documented an in vitro leukocyte chemotaxis defect in PWDs. Phagocytosis and bactericidal capacity were significantly reduced in the presence of hyperglycemia. Galkowska et al compared ulcer margin of foot biopsies in PWDs (n = 12) to normal controls (n = 5) and found no increased ratio of the CD4 and CD8 T lymphocytes indicating a relative lymphocyte response defect. Loots et al examined the cellular infiltrate patterns of punch biopsies from acute and chronic wounds including PWDs and foot ulcers. The CD4/CD8 ratio in all chronic wounds was significantly lower (P < .0027) compared with acute wounds. In light of the ubiquitous presence of microbes, proposed clinical presentations (Table 5) may help to distinguish whether significant bacterial damage occurs in the upper superficial or extends to the lower deep compartments. Early assessment and prompt treatment may help to prevent untoward outcomes.

Increased surface bacterial burden may be treated with topical antimicrobials, whereas systemic treatment is required for lower compartment involvement (Figure 4). There is no one individual sign or symptom that will accurately confirm the diagnosis of wound infection, but a combination of 2 or more indicators...
should be sought for the diagnosis in each level (Table 5).46,47 Wounds that probe to bone (OR, 6.7; 95% CI, 2.3–19.9) exist for more than 30 days (OR, 4.7; 95% CI, 1.6–13.4), recur (OR, 2.4; 95% CI, 1.3–4.5), and relate to trauma (OR, 2.4; 95% CI, 1.1–5.0) and PVD (OR, 1.9; 95% CI, 1.0–3.6) are independent risk factors for foot infection.48 Furthermore, osteomyelitis should be suspected if ulcers probe to bone (sensitivity = 38%–87%, specificity = 85%–91%; positive predictive value = 53%–89%; negative predictive value = 56%–98%).49–51 Although magnetic resonance imaging is more sensitive and specific for the diagnosis of osteomyelitis, changes in radiographic appearance over a 2-week interval are considered as a viable alternative.52 Elevation in erythrocyte sedimentation rate and C-reactive protein, in the absence of other inflammatory conditions, are both valuable diagnostic indicators to validate the diagnosis of osteomyelitis.53,54 To manage damage associated with increased bacterial burden in the upper or superficial compartment, an array of antibacterial dressings (cadexomer iodine,55 silver dressings56) or topical antimicrobial agents (silver sulfadiazine, mupirocin, fusidic acid, or polysporin-gramicidin cream) have been used. There was no evidence that any particular topical agent was associated with better clinical outcomes compared with another.55,56 When individuals exhibit signs associated with deep and surrounding wound infection, systemic antimicrobial therapies should be considered (Figure 4). Although most infections are caused by gram-positive cocci, broad-spectrum antibiotic therapy may be needed for long-standing and refractory ulcers.47 Systematic reviews of trials to evaluate the effectiveness of antimicrobial treatment for diabetic

Figure 3.
LOCAL WOUND CARE FOR HEALABLE AND NONHEALABLE WOUNDS

Management objective

Healable wounds: healing

Nonhealable wounds: palliation

Debridement

Aggressive and regular

Conservative
Only for symptom management

Moisture balance

Maintain moisture for healing

Keep dry
Avoid moisture to decrease risk of infection

Infection

Topical antimicrobials for local wound infection

Topical antiseptics, (eg, povidone iodine)

Systemic antimicrobials for deep infection

Systemic antimicrobials for deep infection

©Woo KY, 2011.
foot ulcers fail to support the superiority of any intravenous or oral antibiotic regimen over any other. \(^\text{57}\) When wound healing is not a realistic goal, use of topical antiseptic agents that are often considered to be cytotoxic may be appropriate (Figure 4).

**Moisture**

Moisture balance is a critical element during the entire healing process. Although a desiccated wound environment can slow keratinocyte migration, too much moisture can cause damage to the surrounding skin and promote bacteria growth. \(^\text{47}\) A variety of dressings have been developed to maintain moisture balance. For instance, foam dressings wick up and lock in a large volume of exudate. Alginate and hydrofibers are also capable of handling copious exudate, while the gelling effect of these materials will keep the wound base moist without maceration. Hydrogels and occlusive dressings are usually indicated for dry wounds.

Despite the availability of different types of dressings, previous systematic reviews \(^\text{58-61}\) of RCTs have failed to reveal the benefit of one dressing class over another in various chronic wound types. Furthermore, there was no significant difference between modern advanced moisture-controlling dressings and daily application of normal saline gauze in healing outcomes. However, saline gauze usually requires frequent dressing changes to maintain moisture balance, increasing the likelihood of pain (compared with foam dressings [RR, 0.27; 95% CI, 0.10-0.69]) and discomfort (weighted mean difference [WMD] = 1.5; 95% CI, 0.63-2.37) as well as higher nursing costs (WMD = -30.5; 95% CI, -37.71 to -23.29, favoring foam dressings). \(^\text{58}\)

6. Consider the use of biological agents and adjunctive therapies for stalled wounds despite optimal treatment and potential for healing.

Neuropathy reduces growth factor production and leukocyte activities that are crucial to wound healing. \(^\text{5}\) Advance therapies (such as biological agents, skin substitutes, hyperbaric oxygen therapy, and negative-pressure wound therapy) may have a role in chronic wounds but only after debridement, infection, and...
Clinicians ask if there is sufficient evidence to support advanced therapies. Analysis of pooled data from 3 RCTs of 140 people with a diabetic foot ulcer demonstrated an increase in the rate of ulcer healing (RR, 5.20; 95% CI, 1.25–21.66; P = .02) in favor of hyperbaric oxygen therapy at 6 weeks, but long-term benefits remained unequivocal. There was no difference in major amputation rate according to results from 5 trials with 312 participants (RR, 0.36; 95% CI, 0.11–1.18).

Negative-pressure wound therapy has been widely used. In a recent review of 7 RCTs involving 580 patients with diabetic foot ulcers, 5 studies documented accelerated wound healing with the treatment of negative-pressure wound therapy.

7. Establish and empower an interprofessional team to improve care of PWDs and foot ulcers

The optimal care of individuals with chronic leg and foot ulcers is complex and time-consuming and requires the support of an interprofessional team. Management of these ulcers involves a detailed examination and discussion with patients to adequately address their concerns. The management of a chronic wound may be further complicated by the fragmentation of communication and services between acute, chronic, and home care.

An interprofessional team approach that draws on the required expertise from a number of healthcare professionals, including diabetic education, medicine, nursing, infection control, chiropody, rehabilitation, and nutrition, is required to address the complexity of diabetic foot ulcer care. A patient education sample handout is illustrated in Table 6.

**Summary**

People with diabetes are at risk for foot problems, including skin ulcerations. This article highlighted the need to complete a comprehensive and holistic assessment to include laboratory evaluation, physical examination, lifestyle modifications, and patients’ perception and readiness to participate in self-management of the disease. Lower leg and foot assessment should be part of routine practice at each patient encounter to identify risks and needs for early intervention. Although debridement, infection management, and moisture balance are the key elements to optimize local wound environment for healing, clinicians must consider all available options to redistribute plantar pressure. The care of an active foot ulcer would necessitate involvement of an interprofessional team and ongoing psychosocial support.

### Table 6.

**PATIENT HANDOUT**

You need to ensure that your feet last a lifetime. The care of your feet can be summarized with the 12 words beginning with the letter “S” in the chart below. You can prevent foot complications: Act to protect your own feet.

<table>
<thead>
<tr>
<th>Things to Consider</th>
<th>Take Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>• Take care of your diabetes; check your blood glucose regularly and have your doctor check your long-term glucose control with a test called the hemoglobin A1c every 3 months.</td>
</tr>
<tr>
<td>Smoking</td>
<td>• Stop smoking. Every cigarette will decrease the circulation in your legs by 30% for an hour.</td>
</tr>
<tr>
<td>Sores (blisters, cuts, open skin)</td>
<td>• Check for sores on your feet every day. The skin breaks down because of a loss of protective sensation and the silent trauma of rubbing or increased pressure points during walking. Seek help!</td>
</tr>
<tr>
<td>Scale and callus</td>
<td>• Check for scale and callus on your feet every day. Scale because of dry skin or a fungus infection and callus because of too much local pressure. Seek help!</td>
</tr>
<tr>
<td>See the bottom of your feet daily</td>
<td>• Make sure you can see and check the bottom of your feet. You may want to have someone else to help check your feet if your vision is poor.</td>
</tr>
<tr>
<td>Socks</td>
<td>• Socks should have no seams and should not bunch up in the shoes creating new areas of increased pressure. Wear socks at night if your feet are cold.</td>
</tr>
<tr>
<td>Shoes</td>
<td>• Wear proper-fitting deep-toed shoes with orthotics. Avoid pointed toes and sandals. Have your shoes fitted at the end of the day by a professional shoe fitter. You will often choose shoes that are too tight.</td>
</tr>
<tr>
<td>Steps:</td>
<td>• Wear your shoes all the time with each step, inside and outside of your home (including going to the bathroom at night). Do not walk barefoot or in socks or with slippers that have no support.</td>
</tr>
<tr>
<td>Shower and wash</td>
<td>• Shower and wash your feet every day.</td>
</tr>
<tr>
<td>Soaks</td>
<td>• Never soak your feet!</td>
</tr>
<tr>
<td>Safe nail care</td>
<td>• Cut nails straight across and see your foot care specialist.</td>
</tr>
<tr>
<td>Skin care</td>
<td>• Avoid adhesive tape and chemical treatments, such as wart removers. Use moisturizers to keep your skin soft. Do not put oil or cream between the toes.</td>
</tr>
</tbody>
</table>
PRACTICE PEARLS

This article focuses on the current state of care recommendations for persons living with diabetic foot ulcers. These include the following:

- Perform a comprehensive clinical assessment that includes \( A_1 \) blood pressure, cholesterol, diet, exercise, and smoking history.
- Conduct a lower-leg and foot assessment to differentiate neuropathic from neuroischemic diseases (ulcers).
- Optimize plantar pressure redistribution to prevent and treat diabetic foot ulcers.
- Address the individual’s concerns and modify plan of care to promote self-care and treatment adherence.
- Optimize local wound environment for healing through debridement, infection control (bacterial burden control), and moisture balance (DIM).
- Consider the use of biological agents and adjunctive therapies for stalled wounds despite optimal treatment and potential for healing.
- Establish and empower an interprofessional team to improve the care of persons with diabetes and foot ulcers.

REFERENCES


