A step-wise approach for surgical management of diabetic foot infections

Timothy K. Fisher, DPM, Christy L. Scimeca, DPM, Manish Bharara, PhD, Joseph L. Mills Sr, MD, and **David G. Armstrong, DPM, MD, PhD,** *Tucson, Ariz*

Diabetic foot disease frequently leads to substantial long-term complications, imposing a huge socioeconomic burden on available resources and health care systems. Peripheral neuropathy, repetitive trauma, and peripheral vascular disease are common underlying pathways that lead to skin breakdown, often setting the stage for limb-threatening infection. Individuals with diabetes presenting with foot infection warrant optimal surgical management to effect limb salvage and prevent amputation; aggressive short-term and meticulous long-term care plans are required. In addition, the initial surgical intervention or series of interventions must be coupled with appropriate systemic metabolic management as part of an integrated, multidisciplinary team. Such teams typically include multiple medical, surgical, and nursing specialties across a variety of public and private health care systems. This article presents a stepwise approach to the diagnosis and treatment of diabetic foot infections with special emphasis on the appropriate use of surgical interventions and includes the following key elements: incision, wound investigation, debridement, wound irrigation and lavage, and definitive wound closure. (J Vasc Surg 2010;52:72S-75S.)

Diabetes is a global problem with significant socioeconomic and health care implications, both in developed as well as developing nations. In the United States alone, there are 23.6 million (7.8% of the population) people affected by diabetes and its attendant increased mortality.[1,2]

Diabetes continues to be the single most common underlying factor contributing to lower-extremity amputation in the US and Europe,[3-6] primarily due to the development of diabetic peripheral neuropathy and the resultant loss of protective sensation (LOPS) of the feet. A simple neuropathic foot ulcer is the major antecedent risk predisposing to diabetic foot infection[7] and precedes 85% of all non-traumatic lower limb amputations in the US.[8]

We herein present a stepwise approach to the diagnosis and treatment of diabetic foot infections with special emphasis on appropriate and timely surgical intervention. Optimal management often involves a multidisciplinary team that integrates the complementary expertise of different specialties; these may include internal medicine, diabetology, infectious disease, medical microbiology, vascular surgery, podiatry, plastic surgery, emergency medicine, nursing, prosthetics/orthotics, and physical therapy.

From the Southern Arizona Limb Salvage Alliance (SALSA), Department of Surgery, University of Arizona College of Medicine.

Competition of interest: none.

This article is being co-published in the *Journal of Vascular Surgery*® and the *Journal of the American Podiatric Medical Association.*

Reprint requests: David G. Armstrong, DPM, MD, PhD, University of Arizona, Department of Surgery, Southern Arizona Limb Salvage Alliance (SALSA), 1501 N. Campbell Ave., Tucson, AZ 85724 (e-mail: armstrong@usa.net).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a competition of interest.

0741-5214/$36.00

doi:10.1016/j.jvs.2010.06.011

STEPWISE APPROACH TO MANAGEMENT

Determination of the presence and severity of infection is the first step in its treatment. The diabetic foot infection classification system (Infectious Diseases Society of America - International Working Group on the Diabetic Foot) displayed in the Table is a simple and clinically useful tool that has been validated by Lavery et al.[9] This system facilitates accurate risk classification and identifies high-risk patients that are prone to adverse outcomes and increased risk of major limb amputation.[9]

A STEPWISE SURGICAL APPROACH TO MANAGEMENT OF DIABETIC FOOT INFECTIONS

While many diabetic foot infections are considered superficial because they do not extend beneath the superficial fascia,[10] the infection will not uncommonly penetrate more deeply into underlying soft tissue and create a deep space abscess.[11,12] In such cases, surgical intervention is mandated to evacuate the abscess, remove necrotic tissue, and minimize the risk for further spread. In this section, we discuss steps including incision, investigation, debridement, lavage, and considerations for closure.

Incision. The concept of fascial spaces is of critical importance when performing an incision and drainage of the foot. All but the simplest infections may require staged procedures; thus, the initial skin incision and dissection should take into account future surgical plans.[13] Grodinsky identified three major plantar spaces: the medial, central (superficial and deep), and lateral spaces. He recommended a medial surgical approach due to potential discomfort of a plantar incision.[14] However, Loeffler and Ballard described success with a plantar-based incision for drainage of foot infections.[15] They described it as beginning proximally, posterior to the medial malleolus, and extending distally and laterally toward the midline, ending between the heads of the first and second metatarsals.

Table. Diabetic foot infection classification schemes

Clinical description	*Infectious Diseases Society of America*	*International Working Group on the Diabetic Foot*
Wound without purulence or any manifestations of inflammation	Uninfected	1
≥2 Manifestations of inflammation (purulence or erythema, pain, tenderness, warmth, or induration); any cellulitis or erythema extends ≤2 cm around ulcer, and infection is limited to skin or superficial subcutaneous tissues; no local complications or systemic illness	Mild	2
Infection in a patient who is systemically well and metabolically stable but has ≥1 of the following: cellulitis extending >2 cm; lymphangitis; spread beneath fascia; deep tissue abscess; gangrene; muscle, tendon, joint, or bone involvement	Moderate	3
Infection in a patient with systemic toxicity or metabolic instability (eg, fever, chills, tachycardia, hypotension, confusion, vomiting, leukocytosis, acidosis, hyperglycemia, or azotemia)	Severe	4

The current approach in many diabetic foot units, including the authors' own, reverses the proximal to distal approach as described by Loeffler and Ballard. We prefer a distal to proximal approach in class IV, emergency, diabetic foot infections. The starting point coincides with the distal most area of infection or ulceration and extends proximally. The incision continues until evidence of infection has been eradicated or until viable, healthy-appearing tissue is observed. This approach eliminates the need for unnecessarily long incisions that could pose future problems, particularly in a patient with vascular insufficiency. As stated above, plans for closure or future reconstruction should always be considered. In any case, the infected space(s) must be drained completely and all grossly necrotic tissue debrided. Following the incision, drainage, and debridement of all non-viable and necrotic appearing tissue, the wound should be thoroughly examined.[10] The presence of further abscess, sinus tracts, or exposed bone should be sought and treated accordingly.

When planning surgical intervention for deep diabetic foot infections, the Loeffler-Ballard incision utilizes a single-incision approach to diabetic foot infections of the plantar compartment to expose all five central plantar spaces. This incision begins at the distal aspect of the first intermetatarsal space and proceeds, as needed, proximally through the medial longitudinal arch toward the medial malleolus. This approach follows the natural anatomy of the flexor tendons and soft tissues.

A suggested modification to this approach involves termination of the incision into each of the affected interspaces (see Fig).

Investigation. Wound evaluation should include the size and extent of soft tissue involvement and the presence of any foreign bodies, abscesses, or sinus tracts. Surgical exploration should then follow the appropriate tissue planes and enable the surgeon to examine the compartments and open all adjacent areas to remove any possible remaining infection. The surgeon must decide if additional exploration or blunt dissection is needed based on his or her knowledge of compartmental anatomy and the communications between each of these compartments. Tissue planes should also be investigated either manually or with instrumentation. If tissue planes are easily separated, this may be an indication of potential necrotizing fasciitis in need of debridement.[16]

Debridement. Following wound investigation, and determination of any tissue planes and foot compartments that are violated, debridement of any and all non-viable tissue and bone should be completed regardless of size and quantity.[17,18] This should commence with the removal of all sloughed, ischemic-appearing (purple) and grossly necrotic (black, gray) tissue. Following soft tissue debridement, exposed tendons should also be removed in order to reduce the spread of infection along these pathways (that serve as pus highways). We avoid use of a tourniquet in this situation because it obscures the identification of viable tissue, potentially leading to over-debridement. Once adequate soft tissue debridement has been completed, exposed bone is frequently evident. Removal of this exposed bone is recommended, as it will assist the surgeon in planning soft tissue coverage in the future. Multiple surgical debridements are common in the infected diabetic foot prior to wound closure, and it has been shown that the adequate removal of all nonviable tissue is associated with quicker healing times and better outcomes.[17,19]

Wound lavage. Wound cleansing following surgical debridement of infected tissue has been reported as a good complement to systemic antibiotics and appears to be safe in reducing the incidence of continued infection.[10] However, there is no consensus regarding the most effective solution(s) to use due to the lack of appropriate randomized controlled human studies, and the irrigant selected has largely been left to surgeon preference. Animal studies suggest that the use of saline alone on infected wounds is effective in reducing the bacterial counts compared with untreated controls; saline has also performed favorably when compared with povidone iodine solution and cefazolin solution.[20,21] Recently, Parcells et al reported a comparative study of irrigation with solutions of normal saline (0.9%), Dakin's (0.25%), and Imipenem (1 mg/mL) in a series of 1063 appendectomy sites. They found that the use of an antibiotic solution irrigation resulted in a wound

Fig. Example of modifications to a standardized plantar incision for inspecting, draining, and debriding diabetic foot infections.

infection rate of 0.5%, compared with 7.3% and 15.9% when using normal saline and Dakin's solution, respectively.[22] While this study may not be directly applicable to diabetic foot wounds with pre-existing infections, it does suggest a potential use for irrigation with antibiotic solutions to assist in the complete eradication of infection and allow earlier wound closure.[23] More investigation in this area is clearly necessary.

Closure. Once clinical signs of infection have been eliminated in the infected diabetic foot wound, closure of the wound is usually conducted. However, it is common for heavily contaminated wounds and previous amputation sites to require revision or re-debridement to a higher level.[10] There are three methods for wound closure: primary, delayed-primary, and secondary intention. In primary closure, the wound is closed at the time of the initial surgical intervention. In secondary closure, the wound is left open at the end of the surgical intervention to granulate and to contract. Delayed-primary closure refers to when the wound is left open at the time of the initial surgical intervention then closed at a later date, usually once the wound is free from any sign of infection. Such an approach is usually carried out in conjunction with wet-to-dry dressings and/or negative pressure wound therapy (NPWT) to facilitate granulation prior to closure and is associated with fewer wound complications than primary closure.[24,25] Additionally, the use of split-thickness skin grafts, local flaps, muscle flaps, pedicle flaps, and musculotendinous flaps are options for achieving proper wound closure. Decisions regarding closure are ultimately dependent on the volume of viable soft tissue remaining after surgery, the amount of drainage, and the presence of any residual infection.[10]

CONCLUSION

Diabetic foot wounds complicated by infection all too commonly result in amputations, thereby imposing a major socioeconomic burden on available health care resources.

Accurate identification of the infecting pathogens is the sine qua non in selecting the choice and duration of antimicrobial therapy. Because the standard, current microbiologic approach is lengthy and time-consuming, broad-spectrum antibiotics directed against the most likely pathogens are typically administered until tissue culture and sensitivity results are available. This approach has obvious inherent disadvantages, but these are outside the scope of current review and are discussed elsewhere.[38] Improved, advanced diagnostic modalities are now or soon will be available that may further reduce the health care costs associated with diabetic foot infections.[26]

When considering the surgical intervention itself, especially for moderate and severe infections, a stepwise approach as presented in this article facilitates patient care. In the patient with diabetes and neuropathy, the interdisciplinary team can ideally operate in both inpatient as well as outpatient settings to identify people at risk for amputations. It is generally the combination of infection and ischemia that complicate the wound and result in major limb amputation. Therefore, the combined roles of podiatry and vascular surgery working in tandem, in a coordinated fashion, with complementary skill sets, cannot be overstated. We believe that combining podiatric and vascular surgical skill sets in a single, highly integrated service may equal more than the sum of their collective parts.

REFERENCES

1. Centers for Disease Control. National Diabetes Fact Sheet, 2007. Atlanta, Georgia: US Centers for Disease Control and Epidemiology; 2007.
2. World Health Organizaiton. World Health Organization Facts Sheet. Geneva: World Health Organization; 2009. N(312).
3. Boulton AJ, Vileikyte L. The diabetic foot: the scope of the problem. J Fam Pract 2000;49(11 Suppl):S3-8.
4. Van Houtum WH, Lavery LA. Outcomes associated with diabetes-related amputations in The Netherlands and in the state of California, USA. J Intern Med 1996;240:227-31.
5. van Houtum WH, Lavery LA, Harkless LB. The impact of diabetes-related lower-extremity amputations in The Netherlands. J Diabetes Complications 1996;10:325-30.
6. Lavery LA, Ashry HR, van Houtum W, Pugh JA, Harkless LB, Basu S. Variation in the incidence and proportion of diabetes-related amputations in minorities. Diabetes Care 1996;19:48-52.
7. Lipsky BA, Berendt AR, Deery HG, Embil JM, Joseph WS, Karchmer AW, et al; Infectious Diseases Society of America. Diagnosis and treatment of diabetic foot infections. Clin Infect Dis 2004;39:885-910.
8. Galer BS, Gianas A, Jensen MP. Painful diabetic polyneuropathy: epidemiology, pain description, and quality of life. Diabetes Res Clin Pract 2000;47:123-8.
9. Lavery LA, Armstrong DG, Murdoch DP, Peters EJ, Lipsky BA. Validation of the Infectious Diseases Society of America's diabetic foot infection classification system. Clin Infect Dis 2007;44:562-5.
10. Armstrong DG, Lipsky BA. Diabetic foot infections: stepwise medical and surgical management. Int Wound J 2004;1:123-32.
11. Boulton AJ, Meneses P, Ennis WJ. Diabetic foot ulcers: a framework for prevention and care. Wound Repair Regen 1999;7:7-16.
12. Eneroth M, Larsson J, Apelqvist J. Deep foot infections in patients with diabetes and foot ulcer: An entity with different characteristics, treatments, and prognosis. J Diabetes Complications 1999;13:254-63.
13. Frykberg RG, Wittmayer B, Zgonis T. Surgical management of diabetic foot infections and osteomyelitis. Clin Podiatr Med Surg 2007;24:469-82, viii-ix.
14. Grodinsky M. A study of the fascial spaces of the foot and their bearing on infections. Surg Gyencol Obstet 1929;49:739-51.
15. Loeffler RD Jr, Ballard A. Plantar fascial spaces of the foot and a proposed surgical approach. Foot Ankle 1980;1:11-4.
16. Childers BJ, Potyondy LD, Nachreiner R, Rogers FR, Childers ER, Oberg KC, et al. Necrotizing fasciitis: a fourteen-year retrospective study of 163 consecutive patients. Am Surg 2002;68:109-16.
17. Wieman TJ. Principles of management: the diabetic foot. Am J Surg 2005;190:295-9.
18. Attinger CE, Bulan E, Blume PA. Surgical debridement. The key to successful wound healing and reconstruction. Clin Podiatr Med Surg 2000;17:599-630.
19. Steed DL, Donohoe D, Webster MW, Lindsley L. Effect of extensive debridement and treatment on the healing of diabetic foot ulcers. Diabetic Ulcer Study Group. J Am Coll Surg 1996;183:61-4.
20. Badia JM, Torres JM, Tur C, Sitges-Serra A. Saline wound irrigation reduces the postoperative infection rate in guinea pigs. J Surg Res 1996;63:457-9.
21. Howell JM, Stair TO, Howell AW, Mundt DJ, Falcone A, Peters SR. The effect of scrubbing and irrigation with normal saline, povidone iodine, and cefazolin on wound bacterial counts in a guinea pig model. Am J Emerg Med 1993;11:134-8.
22. Parcells JP, Mileski JP, Gnagy FT, Haragan AF, Mileski WJ. Using antimicrobial solution for irrigation in appendicitis to lower surgical site infection rates. Am J Surg 2009;198:875-80.
23. Giovinco NA, Bui TD, Fisher T, Mills JL, Armstrong DG. Wound chemotherapy by the use of negative pressure wound therapy and infusion. Eplasty 2010;10:e9.
24. Zgonis T, Stapleton JJ, Roukis TS. A stepwise approach to the surgical management of severe diabetic foot infections. Foot Ankle Spec 2008;1:46-53.
25. Fisher DF Jr, Clagett GP, Fry RE, Humble TH, Fry WJ. One-stage versus two-stage amputation for wet gangrene of the lower extremity: a randomized study. J Vasc Surg 1988;8:428-33.
26. Fisher TK, Wolcott R, Wolk DM, Bharara M, Kimbriel HR, Armstrong DG. Diabetic foot infections: a need for innovative assessments. Int J Low Extrem Wounds 2010;9:31-6.