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# Infection in the Neuroischemic Foot

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*Infection in the neuroischemic foot can lead to cellulitis, which often progresses to necrosis as a result of septic vasculitis. Therefore, it is important to diagnose infection early. However, the signs and symptoms of infection are diminished in the neuroischemic foot. Microbiological investigation is essential. Severe infection needs intravenous antibiotic therapy and urgent assessment of the need for surgical drainage and debridement. Infected neuroischemic feet need vascular assessment and intervention where appropriate. It is important*

*to maintain strict metabolic control and optimize cardiovascular function. Recent modern approaches based on multidisciplinary clinics have resulted in improved results in the management of infection in the ischemic diabetic foot.*

**Key words:** diabetic foot disease, infection, ischemia, neuropathy, neuroischemia, amputation

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At some time in their lives, 15% of people with diabetes develop foot ulcers, which are highly susceptible to infection. This infection may spread rapidly, leading to overwhelming tissue destruction and amputation. Indeed, 85% of amputations in diabetic patients are preceded by an ulcer that develops in the 2 main types of the diabetic foot, namely, the neuropathic foot, in which neuropathy predominates but the major arterial supply to the foot is intact, and the neuroischemic foot, in which both neuropathy and ischemia contribute to the clinical presentation.<sup>1</sup> Infection is rarely a sole factor but often complicates ulceration and is responsible for considerable tissue necrosis in both the neuropathic and the neuroischemic foot. An international consensus on the management of diabetic foot infection has recently been published.<sup>2</sup> This article will concentrate on infection in the neuroischemic foot.

## NEUROISCHEMIC FOOT

Ischemia results from atherosclerosis of the leg vessels. This is often bilateral, multisegmental, and distal, involving arteries below the knee. Intermittent claudication and rest pain may be absent because of coexisting neuropathy and the distal distribution of the arterial disease to the leg. Ulcers in the neuroischemic foot develop on margins of the foot at sites made vulnerable by underlying ischemia to the moderate but continuous pressure, often from poorly fitting shoes. They are susceptible to infection, which can rapidly lead to necrosis. In the neuroischemic foot, infection is the most common cause of necrosis, although ischemia itself can directly lead to necrosis. It is crucial to diagnose and treat infection aggressively.

This article will address the pathogenesis, presentation, and management of infection in the neuroischemic diabetic foot.

## PATHOGENESIS

Infection in the diabetic foot is caused by bacteria that invade the ulcer from the surrounding skin. The diabetic patient is immunocompromised and shows increased susceptibility to bacterial infection.<sup>3</sup> White blood cell function is diminished, in particular, the function of bacterial killing.<sup>4-6</sup> *Staphylococci* and *streptococci* are the most common pathogens, particularly in superficial ulcers in patients who have had no previ-

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ous antibiotic therapy.<sup>7</sup> However, infection due to gram-negative and anaerobic organisms occurs in approximately 50% of patients, particularly in chronic lesions and in those who have received prior antibiotic treatment. Often, infection is polymicrobial. In a recent prospective study in which the infected wounds of 86 consecutive diabetic patients were cultured, *Staphylococcus aureus* was the most common isolate, being recovered from 38.4% of cases.<sup>8</sup> Other organisms were *Pseudomonas aeruginosa* (17.5%) and *Proteus mirabilis* (18%), as well as anaerobic gram-negative organisms (10.5%), mainly *Bacteroides fragilis*. Recent studies have shown an increased frequency of coliforms in neuroischemic patients compared with neuropathic patients and an increased frequency of *S aureus* in neuropathic patients compared with neuroischemic patients.<sup>9</sup> Over recent years, methicillin-resistant *S aureus* (MRSA) infections have been increasingly diagnosed in diabetic foot ulcers.<sup>10,11</sup>

The progression to tissue necrosis in the neuroischemic foot is usually mediated by a neutrophilic vasculitis on the background of an intimal hyperplasia. Although atherosclerotic large-vessel disease in the leg, particularly in the tibial arteries, contributes to reduced perfusion in the neuroischemic foot, tissue necrosis results from a vasculitis of the digital arteries. This may affect transcutaneous oxygen measurements, which may be falsely low as infection impairs oxygen diffusion in the neuroischemic foot. After the infection is treated with antibiotics, the transcutaneous oxygen pressure rises even though there has been no vascular intervention.<sup>12</sup>

## PRESENTATION OF INFECTION

Diabetic foot infections do not always present with the classical signs of local infection. Erythema and pain may be absent. The signs of inflammation and early infection often may be difficult to detect because of the presence of neuropathy and vascular disease in the lower limb. The reason for this is that neuropathy leads to a diminished axon reflex and failure of vasodilatation.<sup>13</sup> Furthermore, ischemia also leads to absence of erythema in the ischemic limb. Immunopathy results in limited abscess formation.

Furthermore, there is a reduced systemic response to infection in the diabetic foot. Only 50% of episodes of severe cellulitis will provoke a fever or leukocytosis. In a study of acute osteomyelitis of the foot in diabetic mellitus, 54% of patients with acute osteomyelitis had a normal white blood cell count.<sup>14</sup> Thus, the white blood count and body temperature should not be re-

garded as reliable indicators of infection in the diabetic foot. This reduced host response to infection is particularly noticeable in diabetic patients with impaired renal and liver function.<sup>15</sup>

The most common manifestation of infection in the neuroischemic foot is cellulitis. However, cellulitis covers a spectrum of presentations, ranging from local infection of the ulcer to spreading cellulitis, sloughing of soft tissue, and vascular compromise of the skin. This is seen as a blue discoloration when there is an inadequate supply of oxygen to the soft tissues, leading finally to necrosis. Blue discoloration can occur in both the neuropathic and the neuroischemic foot, particularly in the toes, and in the neuroischemic foot it must not be automatically attributed to worsening ischemia. For descriptive purposes, the infected neuroischemic foot can be divided into the locally infected ulcer, mild infection, severe infection, and necrosis. Any of these presentations may be complicated by osteomyelitis.

### Locally Infected Ulcer

Local signs that an ulcer has become infected include the following: the base of the ulcer changes from healthy pink granulations to yellowish or gray tissue and becomes moist, possibly accompanied by a purulent discharge, with an unpleasant smell. Sinuses may develop in the ulcer, and the edges may become undermined with bone or tendon becoming exposed.

### Mild Infection

This presents as erythema, warmth, and swelling usually associated with ulceration. In the pigmented (eg, Afro-Caribbean) foot, cellulitis can be difficult to detect, but careful comparison with the other foot may reveal a tawny hue. In the neuroischemic foot, it may be difficult to differentiate between the erythema of cellulitis and the redness of ischemia. However, the redness of ischemia is usually cold, although not always so, and is most marked on dependency, while the erythema of inflammation is warm. Erythematous inflammation of the feet also occurs in eczema, which is characterized by crusting and scaling. This is not seen in cellulitis. Erythema also occurs in response to traumas, including insect stings.

### Severe Infection

There is an intense, widespread erythema and swelling. Lymphangitis, regional lymphadenitis, malaise, flu-like symptoms, fever, and rigors may be pres-

ent. In the presence of neuropathy, pain and throbbing are often absent, but if present, they usually indicate pus within the tissues. Palpation may reveal fluctuance, suggesting abscess formation, but discrete abscesses are relatively uncommon in the infected neuroischemic foot. Many inexperienced practitioners are unaware of this and feel that the only indication for operation is fluctuance with abscess formation. This is rare in the diabetic foot because the poor white cell function cannot localize the infection to create an abscess. Often, there is a generalized sloughing of the ulcer and surrounding subcutaneous tissues, which eventually liquefy and disintegrate. Puncture wounds may be complicated by cellulitis.<sup>16</sup> Bacteria are inoculated at the base of the puncture wound and then tracked back toward the surface of the skin, with infection eventually manifesting itself as a cellulitis.

### Necrosis

Wet necrosis in the diabetic foot is usually owing to infection. The signs that parts of a foot are becoming necrotic are subtle in the early stages and may mimic bruising or chilblains. Early signs consist of a toe that is developing a blue or purple tinge, having been previously pink because of infection. It was previously thought a microangiopathic arteriolar occlusive disease was responsible for tissue necrosis. It is now considered that tissue necrosis results from poor tissue perfusion that is caused by a combination of atherosclerotic narrowing of the arteries of the leg and a septic occlusive vasculitis of the digital arteries. However, intimal hyperplasia in the digital arteries may also contribute.

### Osteomyelitis

If a sterile probe inserted into the ulcer reaches bone, this strongly suggests the diagnosis of osteomyelitis.<sup>17</sup> In the initial stages, plain radiograph may be normal, and localized loss of bone density and cortical outline may not be apparent until at least 14 days later. The radionuclide bone scan using technetium-99m diphosphonate is very sensitive but not specific for osteomyelitis. Gallium or indium scans may improve specificity, but magnetic resonance imaging may be most helpful in demonstrating loss of bony cortex.<sup>18-20</sup> A sign that an underlying joint is involved is the drainage of viscous, bubbly synovial fluid, which is clear and sometimes has a yellowish tinge. Chronic osteomyelitis of a toe has a swollen, red, sausage-like appearance in the initial stages, and plain radiograph may be normal.<sup>21</sup>

### MANAGEMENT

Infection in the neuroischemic foot needs full multidisciplinary treatment. If infection is not controlled, it can spread with alarming rapidity and can cause extensive tissue necrosis. There are 2 crucial decisions to be made when managing infected ischemic diabetic feet: first, to confirm the presence of infection so as to start antibiotic therapy rapidly and, second, to decide whether the patient needs surgical debridement to remove extensive infected tissue.<sup>22</sup> Often, the latter is a very difficult decision. It should be clearly understood that diabetic feet can be severely infected and need operative removal of infected tissue yet may not exhibit the classical signs of fluctuance and abscess formation.

All patients presenting with clinical signs of infection should have a radiograph of the foot to detect (1) gas in the deep tissues, (2) foreign body, and (3) bony destruction, secondary to infection. In very severe cases of infection, gram-negative and anaerobic organisms produce gas, which can be detected by palpating crepitus and can be seen on radiographs. Serum C-reactive protein is a good indicator of the extent of infection, and a subsequent fall in its level during treatment is a useful monitor of resolution of infection. Management of the infected neuroischemic foot can be divided into the following sections: antibiotic treatment, surgical debridement, revascularization, and metabolic control.

### ANTIBIOTIC TREATMENT

The microbiology of the diabetic foot is unique. Infection can be caused by gram-positive, gram-negative, and anaerobic bacteria, singly or in combination. Antibiotics alone do not always treat foot infections successfully. Severe infection in the diabetic foot may be accompanied by deep soft tissue involvement, which spreads through the fascial planes and needs early extensive surgical debridement and concomitant antibiotic therapy. At initial presentation, it is important to prescribe a wide spectrum of antibiotics because it is impossible to predict the organisms from the clinical appearance.

In view of the unreliability of clinical signs of infection, it is important to pay special attention to the microbiological diagnosis of infection. However, there is considerable controversy as to the most useful techniques to obtain cultures and, furthermore, much discussion on the interpretation of results.<sup>23</sup> Isolation of bacteria from an ulcer may indicate either colonization when organisms multiply on the surface of the wound

or invasive infection when the organisms are actively penetrating the soft tissues around the ulcer. It is vital to send swabs for culture without delay in all patients with suspected infection. Deep swabs or tissue should be taken from the ulcer after initial debridement, and if the patient undergoes operative debridement, then deep tissue should also be sent.

As there is a poor immune response of the diabetic patient to sepsis, even bacteria regarded as skin commensals may cause severe tissue damage. This includes gram-negative organisms such as *Citrobacter*, *Serratia*, and *Pseudomonas*. When gram-negative bacteria are isolated from an ulcer swab, they should not be regarded automatically as insignificant. Group A streptococcus is a rare isolate from ulcers but when present can cause severe systemic upset. Infection in the neuroischemic foot is often more serious than in the neuropathic foot, which has a good arterial blood supply; therefore, we regard a positive ulcer swab in a neuroischemic foot as having serious implications, and this influences antibiotic policy. Blood cultures should be sent if there are fever and systemic toxicity.

Aggressive use of antibiotics is recommended, but a very close surveillance should be kept for side effects, particularly vomiting and diarrhea. If this does occur, it is advisable to stop the antibiotics, at least for a short period, to prevent the development of clostridium difficile colitis. Stools should be sent for culture, but therapy should be started immediately with either vancomycin, 125 mg 4 times a day (qds) orally (intravenous [IV] vancomycin does not treat clostridium difficile), or metronidazole, 400 mg 3 times a day (tds) orally. *Acidophilus lactobacillus* tablets can also be given to help to restore the intestinal bacterial flora. In severe cases of clostridium difficile infection, there is abdominal pain associated with diarrhea and a raised white blood cell count and fever, and patients may need hospitalization and IV fluids. A useful diagnostic investigation is an abdominal CT scan, which will reveal loops of edematous large bowel. When patients with foot infections develop diarrhea with a high white cell count and fever, it is difficult to know whether the fever and raised white blood cell count are owing to either worsening of the foot infection or the onset of clostridium difficile diarrhea. Close examination of the foot will determine whether infection here has worsened. If this is not the case, then the high white count and fever are likely to be owing to colitis, and the antibiotics should be stopped immediately.

Chantelau et al randomized patients with neuropathic ulcers (some of which had cellulitis) to oral

amoxicillin plus clavulanic acid or matched placebo. At 20-day follow-up, there was no significant difference in outcome.<sup>24</sup> Lipsky et al randomized 56 patients with an infected lesion to oral clindamycin or oral cephalexin in an outpatient setting and at 2 weeks; there was no difference in treatment.<sup>7</sup> Grayson randomized 93 patients to intravenous (IV) imipenem/cilastatin or IV ampicillin/sulbactam, and after 5 days, cure had been effected in 60% of the ampicillin/sulbactam group and 58% of the imipenem/cilastatin group.<sup>25</sup> A further study comparing the efficacy and safety of IV piperacillin/tazobactam and ampicillin/sulbactam for infected diabetic foot ulcers showed similar beneficial results for both agents, although piperacillin/tazobactam had the advantage of covering *P aeruginosa* (bacteriologic success rate of 85.7%), the most commonly isolated gram-negative pathogen in that study.<sup>26</sup>

Antibiotic treatment is to be discussed as both initial treatment and follow-up treatment and is divided into treatment of the infected ulcer and the foot with mild infection and the foot with severe infection. The infected ulcer and the foot with mild cellulitis are of equally serious import and have been grouped together. The following regimen has been developed and is based on many years of treating the diabetic foot and significantly reducing amputation.<sup>27</sup>

#### Local Signs of Infection in the Ulcer and Mild Infection

If the wound is suitable for outpatient care, prescribe amoxicillin, 500 mg tds; flucloxacillin, 500 mg qds; metronidazole, 400 mg tds; and ciprofloxacin, 500 mg 2 times a day (bd). Infection on the borderline of mild to severe can be treated with ceftriaxone 1 g intramuscularly in 3.5 mL 1% lidocaine. On follow-up, if there are no signs of infection and no organisms growing, consider stopping antibiotics. However, if severely ischemic and ankle-brachial pressure index is < 0.5, consider continuing antibiotics until healing. If there are no signs of infection but organisms are present, focus the antibiotics according to sensitivities. If signs of infection are present but no organisms are growing, continue to give broad-spectrum antibiotics, with amoxicillin, 500 mg tds; flucloxacillin, 500 mg qds; metronidazole, 400 mg tds; and ciprofloxacin, 500 mg bd. If signs of infection are still present, and organisms are growing, focus the antibiotics according to sensitivities. If MRSA is growing, whether signs of infection are present or not, consider oral therapy with 2 of the fol-

lowing: sodium fusidate, 500 mg tds; rifampicin, 300 mg tds; trimethoprim, 200 mg bd; and doxycycline, 100 mg daily and topical therapy with mupirocin 2% ointment.<sup>28</sup> Recently, linezolid has been introduced as a new antibiotic active against gram-positive infections, including MRSA.<sup>29</sup>

### Severe Infection

Admission for IV antibiotics is the treatment of choice for this serious condition. Quadruple therapy may be indicated: amoxicillin, 500 mg tds IV; flucloxacillin, 500 mg qds IV; metronidazole, 500 mg tds IV; and ceftazidime, 1 g IV tds. If the patient is allergic to penicillin, replace amoxicillin and flucloxacillin with erythromycin, 500 mg qds IV, or vancomycin, 1 g IV bd (with doses adjusted according to serum levels). On admission, the foot should be urgently assessed as to the need for surgical debridement. If admission is not possible, then give ceftriaxone, 1 g intramuscularly in 3.5 mL 1% lidocaine daily, and metronidazole, 400 mg tds orally. Trace the distribution of the cellulitis with a marker pen so that extension can be detected, and review it in 2 days. Patients should be on bed rest at home with daily visits from a community nurse to redress the foot and to alert the diabetic foot clinic if the foot is deteriorating so as to arrange admission to hospital. Antibiotic therapy should be reviewed when results of initial cultures are available.

### Osteomyelitis

At first, antibiotics will be given for the infected foot as above. On review, antibiotic selection is guided by the results of deep swabs or tissue, but it is useful to choose antibiotics with good bone penetration, such as sodium fusidate, 500 mg tds; rifampicin, 300 mg tds; clindamycin, 300 mg tds; and ciprofloxacin, 500 mg bd. Antibiotics should be given for at least 12 weeks. During this time, the ulcer will have regular debridement, and bone fragments at the base of the ulcer can be easily removed. Such conservative therapy is often successful and is associated with resolution of cellulitis and healing of the ulcer.<sup>30</sup> However, if after 3 months' treatment the ulcer persists, with continued probing to bone that is fragmented on radiograph, resection of the underlying bone is favored, and this may entail toe amputation or removal of the metatarsal head. Parenteral therapy has in the past been given for 4 to 6 weeks followed by oral therapy for 6 weeks. It may be possible to limit the parenteral therapy to

2 weeks and follow this with appropriate oral antibiotics.

### Adjunctive Therapies for Diabetic Foot Infection

Recently, granulocyte colony stimulating factors have been used to augment the host response to infection. An initial randomized study showed a beneficial effect with increased rates of resolution of the infection.<sup>31</sup> Subsequently, 5 randomized control studies have been carried out, and a recent meta-analysis has shown a statistically significantly reduced risk of lower extremity amputation as well as other foot infection-related invasive interventions.<sup>32</sup> The role of hyperbaric oxygen in the management of wounds is not yet established, but 2 small randomized controlled trials found that systemic hyperbaric oxygen reduced the absolute risk of foot amputation in people with severely infected ulcers compared with routine care.<sup>33</sup>

### SURGICAL DEBRIDEMENT

The definite indications for urgent surgical intervention are a large area of infected sloughy tissue, localized fluctuance and expression of pus, crepitus with gas in the soft tissues on radiograph, and purplish discoloration of the skin, indicating subcutaneous necrosis. It is often necessary to perform a surgical debridement as the initial intervention. However, by definition, the neuroischemic patient has a reduced perfusion, and early investigations, such as Duplex angiography, should be carried out with a view to revascularization. However, it is important to proceed to surgical debridement as soon as possible with the plan to revascularize after the debridement has been carried out.

As preparation for debridement, the following investigations should be carried out: full blood count and cross-matching, serum electrolytes and creatinine, blood glucose, liver function tests, electrocardiogram, and chest radiograph. Often, it is difficult to assess how much debridement will be necessary, and in some cases, it may need to be accompanied by toe or ray amputation. Therefore, consent for these procedures should be obtained prior to anesthesia.

An IV insulin sliding scale should be started. It is important to avoid veins in the lower limb as insertion of IV cannula into the veins of the foot can lead to ulceration, especially if the tip of the cannula goes into the subcutaneous tissues. The anesthesiologist must be aware that virtually all of these pa-

tients will have autonomic as well as peripheral neuropathy, and respiratory reflexes may be diminished. Postoperative respiratory arrests have been reported. Careful anesthetic attention, particularly in the recovery room, is necessary.

During surgery, it is important that a meticulous wound exploration is carried out, with removal of infected sloughy tissue and opening of all sinuses. It is rare to find a well-defined abscess. The usual presentation is of heavily infected sloughy, gray tissue, which needs to be removed down to healthy, bleeding tissue. All dead tendon and necrotic tissue should be removed. Wide excision is necessary; small incisions with drains should be avoided. Fragmented infected and nonbleeding bone should be removed. Deep infected tissue should be sent urgently to the microbiology laboratory. It is important to remove all necrotic tissue, down to bleeding tissue, as well as opening up all sinuses. Deep necrotic tissue should be sent for culture immediately. In addition to debridement, it may be necessary to perform a formal digital or ray amputation to establish drainage.

The wound should not be sutured but left to heal by secondary intention. A foot with a large gaping wound following extensive tissue removal may be lightly held together by winding long strips of paraffin gauze around the foot; however, the strips should be cut through to accommodate swelling and must not prevent drainage of exudate. Large wounds are treated with a vacuum-assisted closure (VAC) pump™ (KCI, San Antonio, Texas, USA) to encourage granulation.<sup>34</sup> Skin grafting may then be the best way to achieve healing of large tissue deficits. The VAC dressing should not be placed adjacent to an arterial anastomosis site for fear of disturbing the anastomosis and causing an arterial bleed. Ischemic wounds are extremely slow to heal even after revascularization, and wound care needs to continue on an outpatient basis in the diabetic foot clinic but with patience—outcomes may be surprisingly good.

In the neuroischemic foot, wet necrosis should also be removed when it is associated with severe spreading sepsis. This should be done whether pus is present or not. In cases in which the limb is not immediately threatened and the necrosis is limited to 1 or 2 toes, it may be possible to control infection with IV antibiotics and proceed to urgent revascularization and, at the same operation, perform digital or ray amputation. If angioplasty or bypass is not possible, then a decision must be made either to amputate the toes in the presence of ischemia or to allow the toes, if infection is controlled, to convert to dry necrosis and autoamputate. Surgical amputation should be undertaken if the circu-

lation is not severely impaired, that is, an ankle-brachial pressure index > 0.5 or a transcutaneous oxygen tension pressure > 30 mmHg on the dorsum of the foot. The recent use of the VAC pump™ promptly applied to such postoperative wounds has encouraged healing in ischemic limbs that cannot be revascularized.

After surgery, the edges of the wound are debrided every 3 days, and all callus, slough, and nonviable tissue is removed. The wound is kept open and drained to heal from the base. However, large surgical defects are now treated with VAC™ therapy until they are granulating, when they can either have split skin grafts applied or otherwise be left to heal by secondary intention. When there is an initial fever preoperatively, the patient's temperature is a useful indication of his or her progress. A steady fall in temperature is expected over the subsequent 3 to 4 days. If this does not occur, then uncontrolled infection should be suspected. At operation, it is sometimes difficult to remove all infected tissue. It is important to inspect the wound every day after the operation, and if signs of infection recur, then the patient may need further surgical intervention. Signs that the foot is settling include a decrease in erythema, less edema, and a pink wound. Patients will need bed rest, and it is wise to give prophylactic subcutaneous heparin. Low molecular weight heparin can be used except in patients in renal failure. Antithrombotic stockings should not be used on neuroischemic feet.

Debridement of necrotic lesions of the foot often leads to severe tissue deficits. Management of these soft tissue deficits is complex, and skin grafts, local flaps, and free tissue transfer have been used. In free tissue transfer, donor tissue from above the waist is used, particularly the muscle flaps, rectus abdominis, and latissimus dorsi. The arteriovenous pedicle accompanies the transferred tissue and is anastomosed to usually a pedal or tibial vessel, which is either a bypass graft or a native revascularized artery. These serve as the inflow tract for the free flap, and anastomosis is achieved using microsurgical techniques.<sup>35</sup> Free tissue transfer for limb salvage is a major undertaking in diabetic patients and should be carried out with caution in diabetic patients who may be of advanced age and have significant comorbidities.

### Autoamputation

Careful sharp debridement is performed along the demarcation line between necrosis and viable tissue to debulk dead tissue, drain pockets of pus, and prevent accumulation of debris. Dry sterile dressings are used to separate necrotic toes from their fellows, for if necro-

sis is in direct contact with viable tissue, it can absorb perspiration and become wet. This provides an ideal culture medium for bacteria, and infection and necrosis can spread. Patients should not bathe to ensure that necrotic tissues are kept dry, since moistening necrosis may encourage infection.

### REVASCULARIZATION

Most patients with neuroischemic infections will need consideration for revascularization, which is considered an important part of the treatment of infection. Angioplasty is now the initial means of revascularization, followed, if unsuccessful, by peripheral arterial bypass (especially distal bypass), which has been established as a valuable procedure in the diabetic lower limb, especially with considerable tissue loss.<sup>36</sup> Furthermore, bypass can be performed safely and effectively in patients who have undergone renal transplantation<sup>37</sup> and in a dialysis-dependent patient population.<sup>38,39</sup> Thus, angioplasty is indicated in the treatment of single or multiple stenoses or short-segment occlusions.<sup>40</sup> If angioplasty is not possible because of long arterial occlusions, bypass should be considered. If the infection is responding to conservative treatment, with resolution of cellulitis on IV antibiotics, then bypass, with its inherent risks, is probably not indicated. However, if operative debridement is necessary with amputation of a toe or ray, then arterial bypass may be necessary to achieve full wound healing.

### Metabolic Control

In severe infections, considerable metabolic decompensation may occur. Full resuscitation is urgently required with IV fluids and IV insulin sliding scale, which is often necessary to achieve good blood glucose control while the patient is infected. This is followed by a basal-bolus regimen of tds short-acting insulin before meals and long-acting insulin at night.

Diabetic patients with neuroischemic foot infections are complex patients, and cardiac and renal function should be assessed.<sup>41-43</sup> Echocardiography will identify patients with left ventricular dysfunction. This is expressed as the ejection fraction, and a value less than 35% increases the risk of noncardiac surgery.<sup>44</sup> Close observation and monitoring of cardiovascular and renal function are essential to maintain correct electrolyte and fluid balance. Neuroischemic patients should be regularly taking statins, angiotensin-converting enzyme inhibitors, and antiplatelet agents, and these should be continued if the patient is admitted to hospital. Aspirin should not be stopped before

angiography or angioplasty, although if the patient is taking aspirin and clopidogrel, the latter should be stopped. High blood glucose is associated with reduced white cell function, which improves when the blood glucose is lowered.

### DISCUSSION

Over the past 20 years, there has been considerable progress in the care of the diabetic foot.<sup>45</sup> There is an increased limb survival rate in patients attending multidisciplinary clinics.<sup>46-48</sup> This has resulted from advances in the care of the neuropathic foot and of the neuroischemic foot, including advances in the management of infection, which have been described in this article.<sup>49</sup>

### APPENDIX Antibiotics

| Nonproprietary Name | Example Trademark Name |
|---------------------|------------------------|
| Amoxicillin         | Amoxyl                 |
| Ceftazidime         | Fortrum                |
| Ceftriaxone         | Rocephin               |
| Ciprofloxacin       | Ciproxin               |
| Clindamycin         | Dalacin C              |
| Doxycycline         | Vibramycin             |
| Erythromycin        | Erythrocin             |
| Flucloxacillin      | Floxapen               |
| Imipenem            | Primaxin               |
| Linezolid           | Zyvox                  |
| Metronidazole       | Flagyl                 |
| Rifampicin          | Rifadin                |
| Sodium fusidate     | Fucidin                |
| Teicoplanin         | Targocid               |
| Trimethoprim        | Monotrim               |
| Vancomycin          | Vancocin               |

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