The Diabetic Foot: The Importance of Coordinated Care

Dean Y. Huang, FRCR, EBIR¹ C. Jason Wilkins, MRCP, FRCR¹ David R. Evans, FRCS, FRCR¹
 Thoraya Ammar, FRCR¹ Colin Deane, PhD² Prashanth R. Vas, MRCP, MRCP(Diab)³
 Hisham Rashid, MS, FRCS⁴ Paul S. Sidhu, MRCP, FRCR¹ Michael E. Edmonds, MD, FRCP³

¹ Department of Radiology, King's College Hospital, London, United Kingdom

² Vascular Laboratory, Department of Medical Engineering and Physics, King's College Hospital, London, United Kingdom

³ Department of Medicine, King's College Hospital, London, United Kingdom

⁴ Department of Vascular Surgery, King's College Hospital, London, United Kingdom

Address for correspondence Michael E. Edmonds, MD, FRCP, Department of medicine, King's College Hospital, Denmark Hill, London SE5 9RS, United Kingdom (e-mail: michael.edmonds@nhs.net).

Semin Intervent Radiol 2014;31:307–312

Abstract

Keywords

- diabetic foot
- multidisciplinary team
- coordinated diabetic foot care service
- peripheral vascular diseases
- wound healing
- interventional radiology

Because of the severe morbidity and mortality associated with diabetes, diabetic foot care is an essential component of a peripheral vascular service. The goal of this article is to describe the vascular diabetic foot care pathway and how the coordinated foot care service for diabetic patients is delivered at King's College Hospital, London.

Objectives: Upon completion of this article, the reader will be able to describe the utility of a multidisciplinary approach to the treatment of diabetic foot patients, and the role of the interventional radiologist in this approach.

Accreditation: This activity has been planned and implemented in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of Tufts University School of Medicine (TUSM) and Thieme Medical Publishers, New York. TUSM is accredited by the ACCME to provide continuing medical education for physicians.

Credit: Tufts University School of Medicine designates this journal-based CME activity for a maximum of **1 AMA PRA Category 1 Credit™**. Physicians should claim only the credit

commensurate with the extent of their participation in the activity

This article describes the central role of the diabetic foot clinic (DFC) in the coordination of a multidisciplinary team (MDT) in applying a dedicated care pathway for the management of the diabetic foot complications.

The DFC provides rapid access to protocol-driven management, ensuring prompt recognition of complications and early, definitive treatment. These are the keys to preventing amputation and improving outcomes.^{1,2} The MDT is centered on the DFC but extends its work to inpatient wards, angiography suites, and operating theaters.

Ischemic and neuroischemic complications are common and patients are managed according to a dedicated vascular

Issue Theme Peripheral Arterial Disease; Guest Editors, David Kessel, MB, BS, MA, MRCP, FRCR, EBIR and Iain Robertson, MD, MBChB, MRCP, FRCR, EBIR

Copyright © 2014 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

DOI <http://dx.doi.org/10.1055/s-0034-1393966>. ISSN 0739-9529.

diabetic foot care pathway, which has the following three main aims:

1. *To make a rapid, accurate assessment of condition of the foot:* To allow initiation of appropriate treatment to prevent further deterioration and manage ulceration and tissue loss. Imaging must be readily available and is central to planning the optimal strategy for wound care and revascularization.
2. *To diagnose infection:* To start immediate antibiotics and decide on the need for debridement.
3. *To perform an assessment of ischemia:* To evaluate the necessity and mode of early revascularization in the ischemic foot. Angioplasty and bypass are regarded as complementary treatments, and hybrid procedures are increasingly being performed.

Diabetic Foot Disease

Diabetic foot disease is a combination of neuropathy, deformity, ischemia, and increased susceptibility to infection. Most diabetic patients with foot problems have evidence of autonomic and sensory neuropathy. The symptoms and signs depend on whether the neuropathy or the ischemia is dominant. The foot is classified accordingly and this dictates the management path. In the neuroischemic foot, necrosis is secondary to infection and ischemia often with a septic vasculitis; in the remaining scenarios, ischemia is the dominant force. Regardless of etiology, the complications of the diabetic foot are prone to rapid progression and tissue loss.

Arterial disease in diabetes is characterized by the distal anatomical localization of the disease. The calf arteries typically show diffuse medial calcification, which renders the vessel incompressible and can limit the utility of assessing the ankle-brachial index (ABI). Long-segment occlusions are common.³ In addition, there is functional impairment of the microcirculation that may contribute to the lesions of the foot.⁴

Diabetic patients have an increased risk of soft tissue infection due to multifactorial immune dysfunction.⁵ In addition, diabetic patients may fail to mount a leukocytosis in response to sepsis.⁶ Gram-positive aerobic and gram-negative aerobic and anaerobic bacteria, singly or in combination, trigger a septic vasculitis and in situ thrombosis of digital arteries and veins resulting in wet necrosis (the so-called diabetic gangrene).

The Diabetic Foot Service

The King's College Hospital diabetic foot service is coordinated through the diabetic foot clinic (DFC), which has taken on the role of an "operations center" or a "command" center" as well as acting as an admission and follow-up center.

The multidisciplinary team (MDT) comprises a podiatrist, nurse, orthotist, microbiologist, diabetologist, interventional radiologist and vascular, orthopedic, and plastic surgeons. The MDT cares for the patient in the clinic and also following admission to hospital. Patients with metabolic, cardiac, and renal comorbidities may require additional specialist input.

After initial assessment and intervention, all diabetic patients are followed up in joint clinics in the DFC. Follow-up includes regular patient education on problem recognition, preventive foot care, arterial and bypass graft surveillance, and the secondary prevention of cardiovascular disease. The care pathway ensures early detection and rapid, aggressive management of ulcers and other complications.

Day-to-day assessment and treatment is performed in the clinic by the podiatrists, nurses, orthotists, and diabetologists. Patients are given education and receive advice on foot care. There is access to a wide range of treatments including podiatry, specialist footwear, and immobilization casts and devices. Foot clinic nurses conduct a domiciliary intravenous antibiotic program.

Regular joint multidisciplinary clinics are held in the DFC with vascular, orthopedic, and plastic surgeons. This allows a "fast-track" service in a "one-stop" visit, comprising clinical assessment, same day investigations, and urgent treatment. Vascular scientists are available to carry out noninvasive Doppler ultrasonography imaging and conduct a graft surveillance program.

Interventional radiologists play an important role by advising on appropriate imaging, conducting the multidisciplinary vascular radiology meeting, and making joint decisions regarding intervention with the MDT. The radiologists in our unit work in three interventional suites with a 10-bedded interventional day case and recovery unit staffed by dedicated radiology specialist nurses (RSN).

Diabetic patients with severe foot problems are admitted to hospital under the care of the most appropriate clinician (vascular or orthopedic surgeons and diabetologists), but they continue to be managed by the MDT who input through joint ward rounds and multidisciplinary MDT meetings. Diabetic foot practitioners (experienced podiatrists) coordinate all inpatient care, including wound, microbiology, mechanical, vascular, and metabolic aspects. The diabetic foot practitioners also provide an "early warning system" for the deteriorating diabetic foot.

Clinic Structure

The DFC hosts a wide range of clinics running all day, 5 days a week. These include: open access urgent care (SOS) clinics, joint vascular clinics, a joint orthopedic and plastic surgery clinic, dedicated Charcot and total contact casting clinics, clinics for high risk patients with healed ulcers, and additional clinics throughout the week for patients with ulceration.

Urgent Open Access Clinic

Patients are educated to present early to the clinic allowing treatment before severe sequelae supervene. Patients with new ulcers, pain, or discoloration can self-refer to an open access SOS clinic. Patients are seen the same day, and following assessment there is rapid access to diagnostic imaging, the vascular laboratory, and clinical biochemistry for measurement of inflammatory markers such as serum C-reactive protein. Outpatient podiatric, nursing, surgical, and medical

treatments are all available and, if necessary, the clinic arranges emergency admission of patients with severe infection or ischemia.

Patient Referral

Patients are referred to DFC from primary or secondary care by telephone, facsimile, or letter. Urgent patients are seen on the same day. Otherwise, patients are appointed to the next most appropriate clinic according to the referral information.

Initial Assessment

All patients undergo a brief assessment in the foot clinic together with additional investigation in the vascular laboratory, if necessary. The assessment consists of inspection, palpation, and a short neurological examination. The entire foot should be fully inspected for signs of ischemia, deformity, edema, callus, skin breakdown, infection, and necrosis. Leg and foot pulses should be palpated. Peripheral neuropathy can be detected by performing a simple sensory examination.

The aim of the initial assessment is to establish the relative contribution of neuropathy and ischemia to the etiology of the problem and to document the severity of the changes. The latter is graded according to the following "simple staging system."⁴

Stage 1: The foot is not at risk of ulceration.

Stage 2: Development of one or more of the following risk factors for ulceration: neuropathy, ischemia, deformity, callus, and edema. Treatment is aimed at preventing ulceration, for example, podiatry and appropriate footwear.

Stage 3: There is skin ulceration or blisters, splits, or grazes that may progress to ulceration. Charcot osteoarthropathy and critical ischemia are also included. Patients with stage 3 changes may progress rapidly and intervention is required.

Stage 4: The ulcer has developed infection with the presence of cellulitis.

Stage 5: Necrosis has supervened. Infection is usually the cause although ischemia contributes.

Stage 6: The foot cannot be saved and will need a major amputation. This is usually a consequence of major acute reduction in perfusion, overwhelming infection, intractable ischemic (rest pain or unstable), or inoperable Charcot ankle joint.

Preliminary Classification

Diabetic foot exists on a spectrum ranging from a predominantly neuropathic foot to a predominantly ischemic foot. The pathway of care differs according to the relative contributions of neuropathy and ischemia. If the pedal pulses are absent or reduced, the foot is considered ischemic. The patient is investigated in the vascular laboratory on the same day. The ABI is measured, remembering that this may be artifactually raised if the arteries are incompressible. Doppler ultrasonography should be performed on femoral, popliteal, and foot pulses.

Preserved pedal pulses and a normal triphasic Doppler waveform indicates that neuropathy is the dominant pathology.

Although the neuropathic foot is often complicated by ulceration or Charcot osteoarthropathy, it is managed by a diabetic/orthopedic/plastic surgery pathway and will not be discussed further here.

The Ischemic Foot

There are four subdivisions of the ischemic foot, which are as follows:

Neuroischemic Foot

Claudication and rest pain may be absent due to peripheral neuropathy. Tissue loss and infection are common at presentation. Ulceration is often caused by unsuitable footwear and typically affects the margins of the foot, including the tips of the toes and the areas around the back of the heel. Infection leads to wet necrosis. The perfusion pressure is typically insufficient to allow ulcer and wound healing, and to eradicate infection.

Critically Ischemic Foot

When ischemia is the dominant problem, patients can experience typical rest pain. The pink painful "sunset foot" with taut shiny skin and a positive Buerger test is characteristic. Dry necrosis of the toes leads to auto amputation. Revascularization is often required to avoid major amputation by allowing healing and preventing progressive necrosis.

Acutely Ischemic Foot

Acutely ischemic foot presented initially with sudden pallor. The foot is extremely cold and becomes mottled. There is paresthesia, numbness, and eventually paralysis. The severity of pain will depend on the degree of neuropathy.

Renal Ischemic Foot

Diabetic patients with end-stage renal failure often have heavily calcified arteries below the knee and the ankle. These patients classically present with spontaneous dry necrosis of the toes and superadded infection is common.

Vascular Diabetic Foot Care Pathway and Intervention

If the presenting foot is deemed ischemic, it will follow the vascular DFC pathway. Patients presenting during a joint vascular diabetic foot clinic are seen by a vascular surgeon, podiatrist, and diabetologist. At other times, the patient will be seen by a podiatrist and diabetologist, and if the patient is deemed urgent they will call the vascular surgeon to the clinic. Less urgent patients are seen in the next available joint vascular diabetic foot clinic. The foot is further examined to evaluate the degree of ischemia, the condition of any ulcer, the existence of infection, and the presence of comorbidities.⁷

Ulceration and Tissue Loss

Ulceration provoked by minor trauma is a prominent feature of the neuroischemic foot, and digital necrosis also precipitated by minor trauma is characteristic of the renal ischemic foot. In the

critically ischemic foot, healing is prevented by the severe compromise in blood supply. Uncomplicated ulceration is treated in the DFC by local debridement, preventable causes such as ill-fitting shoes are corrected, if necessary, with made-to-measure insoles and shoes. If ulceration and necrosis is extensive and needs surgical debridement, patients are admitted urgently to dedicated inpatient beds with ongoing multidisciplinary input including blood glucose control and treatment of comorbidities.⁸

Infection

Development of infection is a major feature in neuroischemic and renal ischemic feet and constitutes a foot care emergency. Infection must be diagnosed early and treated rapidly with referral to the foot care team within 24 hours. It is important to maintain a high index of suspicion as local signs and symptoms of infection may often be reduced or absent. This is due to neuropathy and poor blood supply to the limb, combined with a reduced systemic response to infection. Bacterial cultures are obtained before starting antibiotic therapy. Localized infections can generally be treated with oral antibiotics on an outpatient basis. Spreading periwound infection should be treated with systemic antibiotics. Severe deep tissue infections need urgent admission to hospital for wide spectrum intravenous antibiotics and surgical debridement, which is performed by the vascular surgical team.

All feet with clinically infected ulcers should have a plain radiograph which to look for signs of osteomyelitis, gas in the deep tissues, and foreign body. Radiologic changes of osteomyelitis (loss of cortex, lucency, fragmentation, and bony destruction) take 10 to 14 days to develop. Magnetic resonance imaging is more sensitive to early changes and can demonstrate edema and abscesses in bone.

Investigation and Treatment of Ischemia

Small, uncomplicated ulcers caused by obvious pressure trauma may be initially treated conservatively by debridement and relief of pressure, and subsequently monitored in the foot clinic. Measurement of hemodynamic indices such as transcutaneous oxygen and toe pressure may help deciding to proceed to further imaging with a view to revascularization. However, one should not be bound by strict cut off levels of hemodynamic criteria but should also be guided by the clinical presentation of the patient.

More severe changes will require imaging and some form of revascularization. Infected diabetic neuroischemic feet have a poor prognosis, and rapid diagnosis of ischemia and urgent revascularization is an important aspect of management to treat infection and also to promote healing of ulcers and postoperative wounds following surgical debridement. Dry necrosis is a feature of the renal ischemic foot, and mummified toes are ideally removed surgically after revascularization.

Transcutaneous Oxygen Tension

Transcutaneous oxygen tension measurement is a noninvasive method for monitoring arterial oxygen tension and

reflects local arterial perfusion pressure. It is measured on the dorsum of the foot. A reading below 30 mm Hg indicates severe ischemia, but levels can be falsely lowered by edema and cellulitis. Levels between 30 and 50 mm Hg indicate moderate ischemia. A level above 50 mm Hg is associated with healing.

Toe Pressures

A toe-brachial pressure index below 0.7 is indicative of ischemia. Absolute toe pressure below 30 mm Hg indicates severe ischemia.

Imaging the Arteries of the Lower Limb

To plan revascularization, it is crucial to have rapid access to diagnostics that provide a clear idea of the location of the vascular disease. Duplex ultrasonography is used in our institution as the first line imaging modality for the leg and foot arteries in diabetic patients. Duplex ultrasonography has been shown to be superior to conventional angiography in predicting suitability of pedal vessels to receive vascular grafting.⁹ Other important considerations in diabetic patients are contrast nephropathy and, as the patients are typically younger than those with classical peripheral arterial disease, the lifetime risk from ionizing radiation.

The decision to proceed to further visualization of the lower limb arteries is discussed in the twice weekly joint vascular diabetic clinic. Patients with stenoses or occlusions are discussed with interventional radiologists individually or else discussed at the weekly multidisciplinary vascular radiology meeting. Patients with disease in the common femoral artery or extensive disease, which may not be suitable for angioplasty, have further imaging with computed tomography angiography or magnetic resonance angiography.

Weekly Vascular Radiology Multidisciplinary Meeting

Weekly Vascular Radiology Multidisciplinary Meeting presents a review of all the previous week's imaging led by the interventional radiologists and attended by vascular surgeons, vascular scientists, and diabetologists. Clinical history, hemodynamic vascular data, and imaging are discussed and treatments planned. Treatment decisions are made for each patient by consensus and based on current evidence. Peripheral angioplasty of single or multiple stenoses or short segment occlusions of the distal arteries down to the foot arteries has been found to be safe and effective in a high percentage of diabetic neuroischemic limbs. When there is extensive arterial disease and considerable tissue loss distal arterial bypass in conjunction with surgical debridement, adjunctive plastic surgery and antibiotic therapy may be necessary. Surgical revascularization in the diabetic leg now include ultra-distal as well as distal bypasses.¹⁰

In the diabetic foot vascular integrated care pathway, angioplasty and bypass are regarded not as competing but as complementary treatments, and hybrid procedures are

increasingly being performed. This commonly involves angioplasty of the inflow or outflow angioplasty to improve graft flow. The hybrid procedure may be performed in separate stages, or as a single procedure in a hybrid theater environment. Angioplasty is also used to treat at risk grafts. After either angioplasty or bypass or both, patients are followed up closely in the diabetic foot clinic to assess clinical outcome and the need for further intervention.

Care of the Diabetic Patient during Angioplasty

Patients with diabetes are at increased risk during interventional procedures, especially in the presence of autonomic neuropathy. Specific measures for periprocedural blood sugar control are a mandatory aspect of the care pathway. Close monitoring of blood glucose is important as patients may not recognize hypoglycemia and signs such as sweating and tremor may be absent. They may fail to respond to hypotension if they lack reflex vasoconstriction and tachycardia. Myocardial ischemia may be silent.

Day case insulin-dependent patients are placed first on the radiological intervention list. Insulin is held until after the procedure is finished. Inpatients have a sliding scale intravenous insulin pump and intravenous 10% glucose.

Nephropathy is common and the risk of contrast nephrotoxicity is related to the extent of preexisting renal impairment, dose of contrast agent administered, and the state of hydration of the patient. Risk reduction includes adequate periprocedural hydration and limiting the dose of contrast medium. Renal function should be rechecked 24 hours postprocedure. Blood coagulation indices should also be measured.

Day Case Endovascular Intervention

With continuous improvement of equipment and techniques, it is now possible in suitable patients to carry out transfemoral angiography and angioplasty as an outpatient procedure.¹¹ Radiologic revascularization on diabetic patients well controlled on diet, oral medication, or insulin can be successfully treated as day case procedures. RSN select appropriate patients for day case intervention and are responsible for preprocedure assessment, as well as appropriate patient care before, during, and after interventional procedures.

Screening follows a preset assessment protocol and the patient should be free of concurrent serious medical illness. Relative contraindications to day case angiography include the following: poorly controlled hypertension, myocardial infarction/cerebrovascular event within the last 6 months, severe cardiac/respiratory disease, major surgery within the last month, warfarin therapy with unstable control of international normalized ratio, and renal failure. A capable adult who demonstrates the ability to recognize potential complications must be available to accompany the patient for up to 24 hours after the procedure. Close access to medical facilities should be confirmed.

Postprocedure mobilization is achieved over 2 to 4 hours using a gradual step-wise method. The overall complication

following discharge is rare. In the published King's experience of 401 procedures, there was an admission rate of 2.1% in the diagnostic group and 5.8% in the interventional group.¹² A follow-up clinic appointment is routinely made 2 to 4 weeks after the procedure.

Arterial Bypass

Arterial bypass surgery carries a higher risk and is usually reserved for patients unsuitable for endovascular treatment or those with extensive tissue destruction that cannot be managed without the restoration of pulsatile blood flow to the foot. Patients frequently have cardiovascular disease and need preoperative assessment to optimize cardiorespiratory status. Distal bypass can be performed with an autologous vein from the femoral or popliteal artery down to a calf artery, the dorsalis pedis, or plantar arteries of the foot. In our experience, the quality of the pedal arch does not influence the patency or the amputation-free survival rates. However, the rates for healing and time to healing are directly influenced by the quality of the pedal arch rather than the angiosome revascularized.¹³ After bypass, the patient should enter a graft surveillance program.

Conclusion

Diabetic foot patients with peripheral arterial disease are the most complex of diabetic patients with a high morbidity, but they benefit from coordinated care embracing aggressive treatment of infection and active revascularization within a multidisciplinary forum.

References

- 1 Sanders LJ, Robbins JM, Edmonds ME. History of the team approach to amputation prevention: pioneers and milestones. *J Vasc Surg* 2010;52(3, Suppl):3S–16S
- 2 Caravaggi C, Ferraresi R, Bassetti M, et al. Management of ischemic diabetic foot. *J Cardiovasc Surg (Torino)* 2013;54(6):737–754
- 3 Faglia E. Characteristics of peripheral arterial disease and its relevance to the diabetic population. *Int J Low Extrem Wounds* 2011;10(3):152–166
- 4 Edmonds M. Facts that every vascular surgeon needs to know about the diabetic foot. *J Cardiovasc Surg (Torino)* 2014;55(2, Suppl 1):255–263
- 5 Turina M, Fry DE, Polk HC Jr. Acute hyperglycemia and the innate immune system: clinical, cellular, and molecular aspects. *Crit Care Med* 2005;33(7):1624–1633
- 6 Armstrong DG, Lavery LA, Scharfetter M, Ashry H. Leukocytosis is a poor indicator of acute osteomyelitis of the foot in diabetes mellitus. *J Foot Ankle Surg* 1996;35(4):280–283
- 7 Edmonds M. Modern treatment of infection and ischaemia to reduce major amputation in the diabetic foot. *Curr Pharm Des* 2013;19(27):5008–5015
- 8 El Sakka K, Fassiadis N, Gambhir RP, et al. An integrated care pathway to save the critically ischaemic diabetic foot. *Int J Clin Pract* 2006;60(6):667–669
- 9 Hofmann WJ, Forstner R, Kofler B, Binder K, Ugurluoglu A, Mago-metschnigg H. Pedal artery imaging—a comparison of selective digital subtraction angiography, contrast enhanced magnetic

- resonance angiography and duplex ultrasound. *Eur J Vasc Endovasc Surg* 2002;24(4):287–292
- 10 Slim H, Tiwari A, Ahmed A, Ritter JC, Zayed H, Rashid H. Distal versus ultradistal bypass grafts: amputation-free survival and patency rates in patients with critical leg ischaemia. *Eur J Vasc Endovasc Surg* 2011;42(1):83–88
 - 11 Zayed HA, Fassiadis N, Jones KG, et al. Day-case angioplasty in diabetic patients with critical ischemia. *Int Angiol* 2008;27(3):232–238
 - 12 Huang DY, Ong CM, Walters HL, et al. Day-case diagnostic and interventional peripheral angiography: 10-year experience in a radiology specialist nurse-led unit. *Br J Radiol* 2008;81(967):537–544
 - 13 Rashid H, Slim H, Zayed H, et al. The impact of arterial pedal arch quality and angiosome revascularization on foot tissue loss healing and infrapopliteal bypass outcome. *J Vasc Surg* 2013;57(5):1219–1226