Chapter 6
Imaging in the Patient with Foot Complications

Duncan F. Ettles and Lynn Ling

Overview

Imaging and image-guided intervention play key roles in the management of the diabetic patient with foot complications. Plain radiographs, magnetic resonance imaging (MRI), nuclear medicine scintigraphy, computed tomography, ultrasound and digital subtraction angiography with or without endovascular intervention, offer complementary or adjunctive imaging modalities in managing these cases. In this chapter, we consider the imaging of soft tissue and bony infection, neuropathic arthropathy and ischaemia in the diabetic foot. Despite significant advances in imaging techniques, differentiating between osteomyelitis and neuropathic arthropathy can be problematic, but MRI offers important advantages in this respect. Early identification and stratification of peripheral vascular disease contributes to a reduction in overall morbidity and mortality. In the patient with critical limb ischaemia, imaging of the vessels is used to optimise management

D.F. Ettles, MBChB (Hons), MD, FRCP, FRCR
L. Ling, MBChB, FRCR (✉)
Department of Radiology, Hull and East Yorkshire Hospitals NHS Trust, Anlaby Road, Hull, East Yorkshire HU3 2JZ, UK
e-mail: lynn.ling@hey.nhs.uk

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by open or endovascular means and reduce the extent and frequency of amputation.

Plain Radiographs

The investigation of all patients presenting with a new diabetic foot complication should include plain radiographs. This allows rapid assessment of the presence of bony deformity and destruction in neuropathy and overt or established osteomyelitis, as well as identification of soft-tissue gas and radio-opaque foreign bodies. Evidence of vascular calcification is a common feature.

Osteomyelitis is usually the result of contiguous spread of infection from an ulcer or wound. The distribution tends towards the pressure points of the heel or hind-foot, metatarsal heads or forefoot and the interphalangeal joints. The typical radiological features of osteomyelitis include periosteal reaction, cortical erosion, mixed bony lucency and sclerosis (Fig. 6.1). The presence of soft-tissue gas suggests abscess formation, a sinus tract, fascitis or cellulitis (Fig. 6.2). If soft-tissue gas is detected, the joint proximal to it should be carefully evaluated to define the extent of the infection (see Chap. 3). Any bony changes or destruction beneath a soft-tissue ulcer should be considered osteomyelitis until proven otherwise. However, it is well known that plain radiographic abnormalities can lag behind the clinical infection by up to a month and can be limited in their ability to differentiate the bony destruction of osteomyelitis from neuropathic arthropathy. A recent meta-analysis reported a pooled sensitivity of 0.54 and specificity of 0.68 for osteomyelitis [1]. Therefore, osteomyelitis should not be excluded on the basis of plain radiographs alone, except where serial radiographs performed several weeks apart have not demonstrated any bony abnormality. Negative radiographic findings should not delay commencement of empirical antibiotic therapy, pending the results of further imaging or bacteriological investigations. Neuropathic arthropathy occurs as the result of occult recurrent injury due

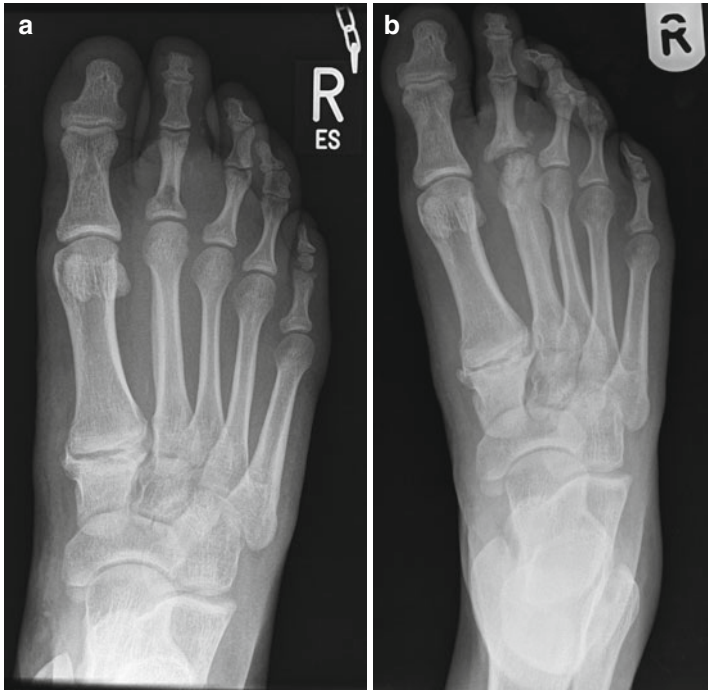

FIGURE 6.1 (**a**) Resorptive change is seen affecting the proximal and middle phalanges of the fifth toe with focal lucency at the base of the proximal phalanx of the second toe. Features are consistent with osteomyelitis. There is also established arthropathy affecting the first tarsometatarsal joint. (**b**) In the same patient after treatment, remodelling and sclerosis of the second metatarsal with cortical erosion of the base of the proximal phalanx is seen consistent with chronic osteomyelitis

to reduced pain and proprioception and impaired healing in diabetic patients. The joint deformity and instability with cartilagenous destruction causes a progressive arthropathy with often typical appearances. The Lisfranc (tarso-metatarsal) joint or midfoot is classically affected with increased load on the cuboid bone and collapse of the foot arch being demonstrated in established cases, clinically presenting with a

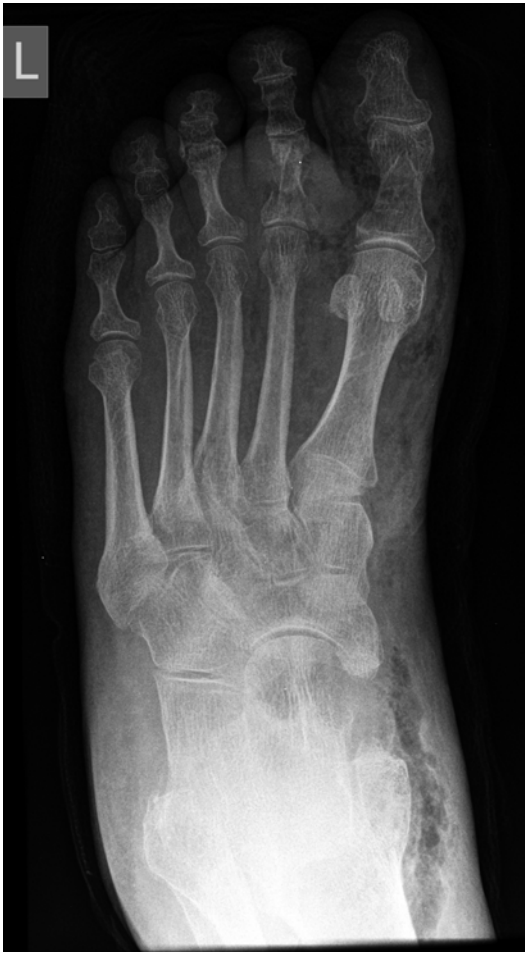

FIGURE 6.2 In this patient with cellulitis there is extensive soft-tissue gas along the medial aspect of the foot and ankle. Fracture of the second toe is also demonstrated

'rockerbottom' deformity. On plain radiographs, early changes indicative of the condition are focal demineralisation, fragmentation and flattening of the metatarsal heads. The interphalangeal joints are not commonly involved. Delayed

changes include subchondral cyst formation, erosions and reactive bony hypertrophy.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is the most accurate and next most appropriate imaging tool for assessment of suspected osteomyelitis where plain radiographic findings have been equivocal. In addition to bony abnormalities, MRI provides exquisite detail about the soft tissues and has a reported sensitivity of 90 % and specificity of 82.5 % for the detection of osteomyelitis [2]. MRI provides additional anatomical definition of soft-tissue infection, sinus tracts, abscess formation, joint effusion and necrosis. The characteristic MRI features of osteomyelitis are a diffuse decreased T1-weighted and increased T2-weighted signal intensity of the affected bone, with contrast enhancement (Fig. 6.3). There is often replacement of intramedullary fat around the affected bone and a sinus tract to an ulcer. Secondary findings of an abscess may be identified by its high signal intensity on fat-suppressed imaging with high signal intensity rim-enhancement on post-contrast T1-weighted images.

Features favouring neuropathic arthropathy are the involvement of multiple joints, subchondral cysts and intra-articular loose bodies. In the early or sub-acute stage of neuropathic arthropathy, subchondral bone marrow oedema and bone resorption is the common initial finding. In the late or chronic stage, there is usually established subluxation and dislocation but with minimal bone marrow oedema. In distinction to osteomyelitis, the subcutaneous tissues are usually not involved. However, a mixture of findings can be encountered in patients with pre-existing neuropathic arthropathy who go on to develop infection.

Prior to performing the MRI, it is useful to mark any cutaneous defect so that any sinus tract can be followed and the bone marrow immediately beneath it may be evaluated. MRI is of particular value, not only in determining the need for surgical intervention, but in planning the surgical approach.

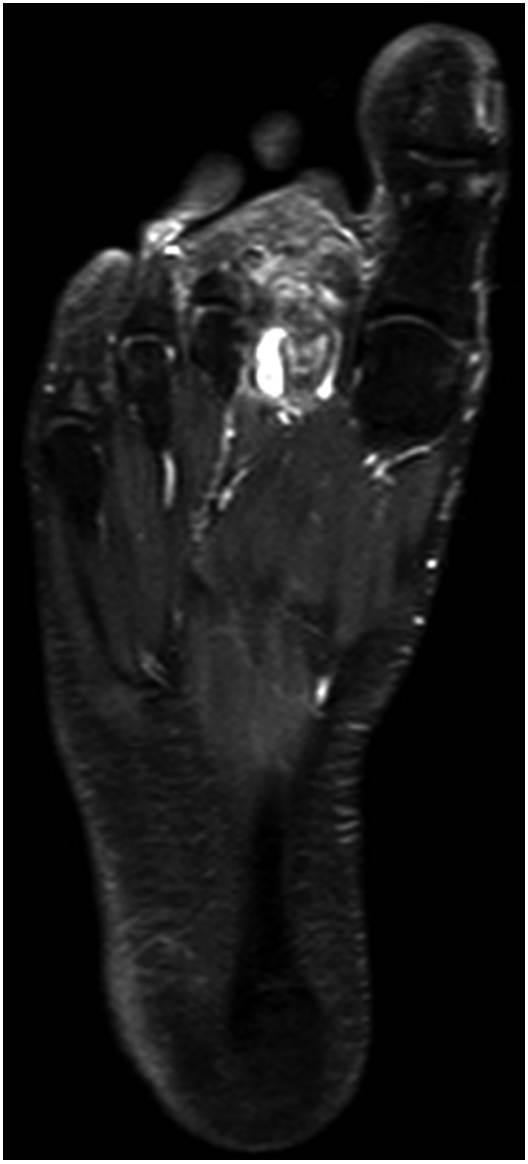

Figure 6.3 MRI (T1-weighted sequence with fat saturation and intravenous contrast) shows bone marrow and soft-tissue oedema centred on the second metatarsal, which enhance with contrast

Magnetic resonance angiography is not routinely performed in patients with diabetic foot complications but is undertaken for the assessment of peripheral vascular disease and in planning revascularisation for critical limb ischaemia. This is described in greater detail below. The potential limitations of MRI relate to its lack of availability in some hospitals and the need for expert interpretation by a specialist in musculoskeletal radiology. Contraindications to MRI include most cochlear implants, older types of cardiac pacemakers, orbital metallic foreign bodies and some surgical implants and prostheses. When MRI is contraindicated alternatives such as nuclear medicine scintigraphy or PET/CT should be considered.

Nuclear Medicine Scintigraphy

The practice of isotope imaging in assessing diabetic foot complications varies considerably and may not be available in some centres. Its principal value lies in the ability to discriminate between infection and other causes of inflammation, but these techniques are limited by a relative lack of resolution and anatomical detail. A number of techniques are utilised, including Technetium (Tc) -labelled bone scans, leukocyte-labelled and anti-granulocyte antibody-labelled scintigraphy and bone marrow scintigraphy. The triple-phase 99mTc-MDP (methylene diphosphonate) bone scan alone is of limited value in assessing diabetic foot complications because although it has high sensitivity in demonstrating areas of high metabolic activity, its specificity is significantly reduced in the presence of any other abnormalities such as fractures, arthropathy, tumour or recent surgery [3]. A four-phase bone scan in which an additional 24-h static image is acquired, is not routinely recommended as it does not increase the specificity of the study for the detection of osteomyelitis.

The triple-phase bone scan is more useful when utilised in conjunction with the Indium-111 or 99mTc-HMPAO (hexamethylpropyleneamineoxime) leukocyte-labelled study to diagnose and differentiate arthropathy from osteomyelitis. If the initial bone scan is negative, osteomyelitis is unlikely. When the

bone scan is positive, the leukocyte-labelled study is performed to confirm or exclude osteomyelitis. However, the leukocyte-labelled study may be positive in the early stages of neuropathic arthropathy, due to reactive joint effusion from peri-articular microfractures. In such cases, if a follow-up scan shows a reduction in leukocyte accumulation, the changes are more likely to be due to arthropathy rather than osteomyelitis. The use of alternative techniques such as bone marrow and anti-granulocyte scintigraphy are likely to be restricted to specialist centres.

Computed Tomography

CT is more sensitive than plain radiography in depicting bony margins and therefore periosteal reaction, cortical erosions and areas of lucencies and sclerosis are more easily identifiable on CT than on plain radiography. CT is also useful for demonstrating dystrophic soft-tissue calcification, soft-tissue gas and foreign bodies. On its own, it has a lower specificity for detecting infection when compared to MRI. However, CT in conjunction with FDG PET (fluoro deoxyglucose positron emission tomography) is useful for differentiating between osteomyelitis, soft-tissue infection and neuropathic arthropathy, with a high sensitivity of 80–95 % and specificity of 90–100 % [4, 5]. The FDG radioisotope tracer accumulates avidly at sites of acute infection whilst the high spatial resolution of CT provides precise localisation of the infection on the fused images, enabling accurate differentiation between non-infective arthropathy, osteomyelitis and soft-tissue infection. It is likely that CT will play an increasing role in imaging of the diabetic foot.

Ultrasound

Two-dimensional ultrasound, like plain radiography, is a readily accessible imaging modality. However its role in managing the diabetic foot is limited. It is most useful for the localisation

of foreign bodies and for guiding aspiration of effusions, abscesses, cysts or sterile collections where clinically indicated. However, duplex ultrasound has a very important role in the assessment of the lower limb vessels in patients with critical limb ischaemia, and this is further described below.

Critical Limb Ischaemia

The severity of peripheral arterial disease (PAD) is often underestimated in the diabetic population because early signs may be masked by concomitant neuropathy. Patients often present with advanced disease or critical limb ischaemia (CLI). Diabetic patients are at much greater risk of developing CLI, leading to amputation. In diabetic patients, the distribution of disease predominantly affects the infra-popliteal circulation, is associated with significant diffuse medial sclerosis and occluded segments of the distal vessels are more common than focal stenoses (Fig. 6.4).

Duplex ultrasound and MR angiography (MRA) are employed for the initial assessment of peripheral vascular disease and for planning revascularisation. Duplex sonography is unique in providing functional assessment of the vessels and is valuable in the follow-up of patients following revascularisation procedures. A three-stage MRA is used to assess the aorto-iliac, femoro-popliteal and infra-popliteal circulation. Imaging of the distal vessels can be problematic in diabetics due to venous "contamination" on the acquired images but various techniques can be used to overcome this problem (Fig. 6.5).

Intra-arterial digital subtraction angiography (DSA) is often considered the gold standard for the evaluation of PVD but is invasive and carries the small risk of contrast-induced nephrotoxicity. This risk needs to be considered in patients with diabetic renal disease but does not preclude the investigation. DSA is increasingly used only when the decision to proceed with endovascular intervention has been determined by non-invasive imaging. All radiology departments have protocols for the administration of contrast media in patients with

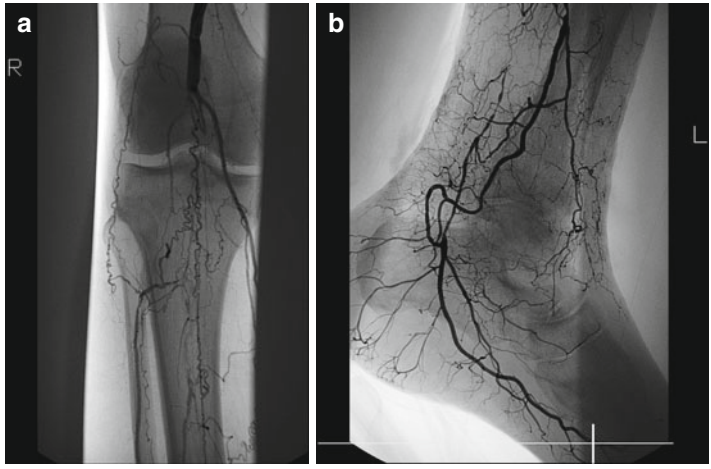

FIGURE 6.4 (**a**) DSA shows occlusion of the popliteal artery and tibio-peroneal trunk with collateralisation to diseased anterior tibial and peroneal arteries. (**b**) The dorsal foot arch is also occluded

impaired renal function, including advice on pre-hydration and use of renal protection drugs. More recent studies have suggested that contrast-enhanced MRA is equivalent or superior to DSA in demonstrating the infra-popliteal vessels [6–8].

Key Points

- Every institution should have a clearly defined referral and multi-disciplinary care pathway in place for managing diabetic foot complications.
- A plain radiograph should be performed at the first presentation of a diabetic foot complication for structural bony assessment.
- Initiation of empirical antibiotic therapy should not be delayed by imaging and microbiology investigations if osteomyelitis is clinically suspected, although subsequent results should guide the choice of therapy.
- MRI is the most useful imaging modality for detecting osteomyelitis and delineating the soft-tissue

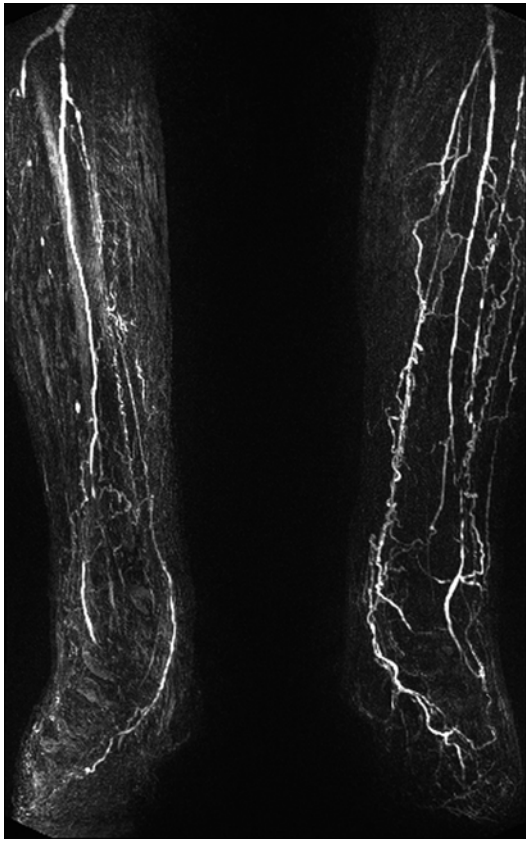

Figure 6.5 Contrast-enhanced MRA showing extensive disease of the crural vessels

extent of infection. If contraindicated, consider performing a PET-CT or a bone scan in conjunction with leukocyte-labelled scintigraphy.

- Evidence of critical limb ischaemia warrants urgent specialist vascular assessment for revascularisation, to prevent minor and major amputation. Duplex ultrasound, MRA and DSA are complementary imaging modalities for planning revascularisation.

References

1. Dinh MT, Abad CL, Safdar N. Diagnostic accuracy of the physical examination and imaging tests for osteomyelitis underlying diabetic foot ulcers: meta-analysis. Clin Infect Dis. 2008;47:519–27.
2. Kapoor A, Page S, Lavalley M, Gale DR, Felson DT. Magnetic resonance imaging for diagnosing foot osteomyelitis: a meta-analysis. Arch Intern Med. 2007;167:125–32.
3. Love C, Din AS, Tomas MB, Kalapparambath TP, Palestro CJ. Radionuclide bone imaging: an illustrative review. Radiographics. 2003;23:341–58.
4. Nawaz A, Torigian DA, Siegelman ES, Basu S, Chryssikos T, Alavi A. Diagnostic performance of FDG-PET, MRI, and plain film radiography (PFR) for the diagnosis of osteomyelitis in the diabetic foot. Mol Imaging Biol. 2010;12:335–42.
5. Basu S, Zhuang H, Alavi A. Imaging of lower extremity artery atherosclerosis in diabetic foot: FDG-PET imaging and histopathological correlates. Clin Nucl Med. 2007;32:567–8.
6. Dorweiler B, Neufang A, Kreitner KF, Schmiedt W, Oelert H. Magnetic resonance angiography unmasks reliable target vessels for pedal bypass grafting in patients with diabetes mellitus. J Vasc Surg. 2002;35:766–72.
7. Lapeyre M, Kobeiter H, Desgranges P, Rahmouni A, Becquemin JP, Luciani A. Assessment of critical limb ischemia in patients with diabetes: comparison of MR angiography and digital subtraction angiography. AJR Am J Roentgenol. 2005;185:1641–50.
8. Huegli RW, Aschwanden M, Bongartz G, Jaeger K, Heidecker HG, Thalhammer C, et al. Intraarterial MR angiography and DSA in patients with peripheral arterial occlusive disease: prospective comparison. Radiology. 2006;239:901–8.

Suggested Reading

Berquist TH. Imaging of the foot and ankle. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2010.
National Institute for Health and Care Excellence. Diabetic foot problems – inpatient management. [CG119]. London: National Institute for Health and Care Excellence; 2011.