Imaging of foot and ankle disorders

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Abstract
This article gives an overview of the imaging modalities used in the assessment of acute and chronic foot and ankle disorders in the adult patient. The relative merits of each imaging modality are explained and examples are given of the common conditions.

Keywords ankle; computed tomography; foot; magnetic resonance imaging; ultrasound

Introduction
Virtually every patient with a foot and ankle disorder will have conventional radiography performed. This is clearly quick and easy to perform and has a pivotal role to play in the assessment of acute bony injury. Whilst the bony alignment can suggest the integrity of the ligamentous structures, it is generally of limited use in the assessment of soft tissue injuries. Computed tomography (CT) adds sectional imaging to the assessment of the foot and ankle, can demonstrate undisplaced fractures not seen on conventional radiography and can show good anatomical definition, even in the presence of a substantial amount of metalwork. It shares conventional radiography’s limited ability to assess the soft tissues. Ultrasound (US) is now far more widely available in the UK since it became a core part of the training for musculoskeletal radiologists. In many aspects it is superior to MRI in the assessment of tendons and ligaments, having a greater resolution and the ability to scan dynamically. It is limited in the assessment of the bony structures and the articular surfaces. MRI therefore provides the best overall assessment of combined bone and soft tissue injuries.

These imaging modalities cover the vast majority of techniques, and their use in the adult patient will be explored in greater detail in this article. MR arthrography has a very limited role in the assessment of the stability of osteochondral fractures and in the assessment of ankle impingement syndromes. Isotope scanning may have a very limited role in assessing infection or chronic bone injury in patients who have contraindications to MR scanning, or where the quantity of metalwork renders the images non-diagnostic.

Box 1 summarizes the advantages and disadvantages of each imaging modality.

Conventional radiography
Conventional radiography is the initial imaging modality for the majority of foot and ankle disorders. It’s main role remains in the assessment of acute osseous injury and most injuries can be managed without resorting to any other imaging modality. It has very limited value in the assessment of chronic soft tissue disorders.

The standard views of the ankle are the AP and lateral. The AP should be performed routinely with 15° of internal rotation giving the “mortise view”. A variety of measurements of the syndesmosis have been reported to assess the integrity of the distal tibiofibular joint but all the measurements are prone to inaccuracy, as they are subject to marked variation with slight alterations in the degree of rotation. A good rule of thumb is that the fibula and tibia should overlap by at least 1 mm. The medial joint space should be less than or equal to the superior joint space (Figure 1). In this situation a radiograph of the whole fibula may be required to detect the Maisonneuve fracture.

On the lateral view Boehler’s angle can be measured to assess disruption of the subtalar joint due to a calcaneal fracture. The normal Boehler’s angle should measure between 28° and 40°.

A variety of other views have been described, including oblique and subtalar views. Most centres have now abandoned these and proceed straight to CT if further imaging is required. The presence of a cast on the limb is no hindrance to CT or MRI scanning of the ankle.

Weight bearing views of the ankle allow assessment of the thickness of the articular cartilage and joint congruity under loading, but are not used in the context of acute trauma. Stress views can be performed on both the AP and lateral views for the assessment of chronic ligamentous instability but in a lot of situations this adds little to the clinical assessment and US and MRI provide a more direct assessment of ligamentous integrity.

Standard trauma views of the foot are the dorsiplantar (DP), the 30° oblique and the lateral projection. The tarsal metatarsal

Box 1

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Summary of the advantages and disadvantages of each imaging modality

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alignment requires particular attention in order to diagnose a Lisfranc injury. The tarsal metatarsal joint spaces are not well visualized on the DP view due to the normal plantar arch resulting in an oblique projection of the articular surfaces. Particular care should be given to the alignment of the joints on the oblique projection (Figure 2). Small bony avulsions around the Lisfranc joint should not be dismissed, since these are indications that severe stress has been applied to the joint and a Lisfranc disruption is very likely.

The lateral view is particularly helpful in assessing disruption of the talo-navicular and calcaneal-cuboid joints, the Chopart fracture (Figure 3).

**Computed tomography**

Advances in CT technology, with multi-detector imaging the norm for state of the art scanners, ensure that a scan of the ankle can be performed in a matter of seconds giving high quality coronal and sagittal re-formats. Radiation dose is minimal since none of the vital organs enters the radiation beam.

CT is either used to further characterize and plan an operation for a fracture seen on conventional radiographs, or to detect occult injury not visible on the radiographs. Common occult injuries include undisplaced talus, calcaneal and cuboid fractures and Lisfranc disruption. Whilst the primary role of CT is in the assessment of bony pathology it is worth remembering that some information can be gleaned about the soft tissues, with entrapment of the peroneal tendons within a calcaneal fracture being a particular example (Figure 4).

CT also plays a role in the assessment of post-operative complications following internal fixation, where the presence of metalwork would result in too much artefact on an MRI scan. (Figure 5).

**Box 2** summarizes the uses of CT.

**Ultrasound**

US provides images of soft tissue structures at a greater resolution than MRI. It can distinguish the internal fascicular structure of tendons, allowing small partial tears to be detected. The ability to

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**Figure 1**

a There is a slight widening of the medial joint space. There remains overlap of the distal tibia and fibula. b A repeat radiograph shows more obvious widening of the medial joint space and there is a clear evidence of disruption of the syndesmosis with no overlap between the tibia and fibula. c Radiograph of the whole fibula confirmed a proximal fibula fracture, a Maisonneuve fracture.

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**Summary of the uses of CT**

- **Acute Trauma**
  - Pre-operative planning prior to internal fixation
  - Detection of radiographically occult fractures
- **Chronic pain**
- **Complications following previous fracture particularly in the presence of metalwork-assessment of post traumatic osteoarthritis eg subtalar following calcaneal fracture, mid foot following Lisfranc injury.**
dynamically scan whilst putting the tendons and ligaments through a range of motion is an advantage over MRI, which only visualizes static structures. Moving the foot whilst scanning an achilles tendon tear can distinguish a high grade partial tear from a full thickness tear and give an accurate measurement of the tendon gap (Figure 6). Subluxation of the peroneal tendons due to rupture of the peroneal retinaculum can be demonstrated whilst scanning the tendons in resisted eversion.

US can demonstrate acute ligamentous ankle disruption, most commonly the anterior talo-fibular (ATFL) component of the lateral collateral ligament (Figure 7). Scanning is infrequently performed acutely since it rarely affects the immediate management of the patient. It is more commonly employed in the assessment of chronic ankle instability following a previous inversion, or a series of inversion injuries. Scanning the lateral collateral ligament in inversion can demonstrate a ligament

Figure 2

very subtle widening between the bases of the first and second MTs. The second MT aligns normally with the intermediate cuneiform. b Weight bearing view. The second MT shifts laterally and no longer aligns with the intermediate cuneiform. This is a Lisfranc disruption.

Figure 3

a Chopart disruption. There is malalignment of the calcaneal—cuboid joint. b The disruption of the calcaneal—cuboid and talo-navicular joints is much easier to appreciate on the true lateral projection.
which, though it may have healed with scar tissue, has lengthened resulting in laxity.

US is frequently used in the assessment of chronic tendinopathy, most frequently in the evaluation of the achilles tendon. The most common finding is degenerative tendinopathy (Figure 8). Inflammation of the surrounding soft tissues, the so-called paratenon, or a retrocalcaneal bursa are important diagnoses to make, since these may respond to a steroid injection, a treatment which is not recommended for an intrinsic degenerative tendinopathy since the steroid may further weaken the tendon.

A Morton’s neuroma occurs between the metatarsal heads, most commonly in the third/fourth intermetatarsal space. US can be used to detect these neuromas and dynamic scanning whilst

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**Figure 4** Bilateral calcaneal fractures. On the left the peroneal tendons lie free of the fracture (large arrow). On the right the peroneal longus is lying within the fracture (small arrow).

**Figure 5**

- **a** AP and **b** lateral radiographs of the ankle. The patient was complaining of continued pain following internal fixation. **c** Sagittal CT shows part of the metalwork is sitting within the subtalar joint.
compressing the toes can displace the neuroma, demonstrating that it is the cause of the clinical finding known as a Mulder's click.

Conventional radiography is frequently requested for the assessment of a calcaneal spur in patients with chronic foot pain, because of its association with plantar fasciitis. In fact a calcaneal spur can occur in completely asymptomatic individuals and if any imaging is required, then US is the imaging modality of choice (Figure 9). US can also be used to target a steroid injection into the area of inflamed plantar fascia.
One disadvantage of US is the limited ability to assess the bones and articular surfaces. US can assess the surface of the bone but not the internal structure. Stress fractures are only demonstrated if there is a periosteal reaction. If a combination of bone and soft tissue injury is suspected it is much better to perform an MRI.

Box 3 summarizes the use of US.

**Summary of the uses of US**

**Acute Trauma**
- Tendon and ligament injury in the absence of clinical osteochondral fracture

**Chronic Pain**
- Chronic tendinopathy
- Chronic ligament instability in the absence of clinical osteochondral injury
- Plantar fasciitis
- Morton’s neuroma

**Magnetic resonance imaging**

**Ligament and osteochondral injury**

The great advantage of MRI over US is the ability to assess the bony structures as well as the soft tissues, and specifically the ability to assess the articular surfaces. MRI is useful both in acute ligamentous and osteochondral injuries and in subacute/chronic ankle and foot pain. Bone contusion is reliably demonstrated on T2-weighted fat suppressed sequences and usually resolves 8–12 weeks after the injury. Continued bone oedema following this is evidence of continued abnormal stress forces.

The commonest mechanism of ankle injury is the supination–adduction injury, which is commonly referred to as an inversion injury. This can result in ligamentous injury of the lateral collateral ligament, which in 70% of cases involves an isolated injury of the ATFL. More severe injury involves the calcaneo-fibular ligament as well as the ATFL. Injury of the posterior talo-fibular ligament is very rare. Since the ATFL is the most susceptible component of the lateral collateral ligament to injury, an intact ATFL usually implies there is no injury to the lateral collateral ligament. It runs close to the axial plane of the ankle and is therefore best seen on the axial sections, where it is identified on one or two contiguous slices. Signs of ligamentous disruption include non-visualization of the ligament, ligament discontinuity and a contour alteration with a wavy or curved ligament (Figure 10).

Osteochondral injury is commonly associated with severe inversion injuries. A common pattern of injury is an impaction injury of the medial talus and an osteochondral fracture of the lateral talus which impacts on the fibula during a severe inversion injury (Figure 10). Osteochondral fractures can be seen on conventional radiographs, but impaction injuries and purely cartilage damage can only be diagnosed with MRI. The normal articular cartilage of the ankle is very thin so assessment of cartilage defects and flaps can be very difficult. Visualization is aided in acute injury by the presence of a joint effusion, which acts as a natural contrast agent outlining the cartilage. In subacute and chronic osteochondral injury assessment of the cartilage may be improved by performing an MR arthrogram.

In addition to osteochondral injuries, chronic lateral collateral ligament injury can lead to a number of consequences, all of which can be assessed by MRI. These include post-traumatic arthritis, peroneal tendon injury and subtalar instability leading to the sinus tarsi syndrome (Figure 11).

**Ankle impingement**

Anterior impingement occurs in young athletic patients and is the result of repeated stress in ankle dorsiflexion with impingement.
of soft tissues between bony spurs at the anterior rim of the tibial plafond and the apposing margin of the talus. Whilst MRI can assess the extent of the soft tissue impingement, most cases are simply diagnosed by clinical assessment and conventional radiography (Figure 12).

Posterior impingement occurs as a result of repetitive plantarflexion of the foot which compresses the talus or os trigonum and adjacent soft tissues between the tibia and the calcaneus. Anatomical variants which pre-dispose to the development of this condition are the presence of an os trigonum and a prominent posterior process of the talus. Whilst conventional radiography can demonstrate these anatomical variants, they are so common that their demonstration is not diagnostic of posterior impingement. MRI demonstrates oedema, either within the os trigonum or the posterior process of the talus and oedema of the adjacent soft tissues (Figure 13).

Anterolateral impingement can cause chronic ankle pain in the anterolateral gutter and typically occurs following an ankle inversion sprain. MRI can demonstrate synovial thickening when an ankle effusion is present. In the absence of an effusion MR

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**Figure 10**

- **a** Axial T2-weighted, fat suppressed MRI. Rupture of the ATFL. There is discontinuity of the ligament and a wavy contour (arrow).
- **b** Acute osteochondral fracture of the lateral dome of the talus (arrow). There is joint fluid between the fragment and the talus indicating that the fragment is unstable.

**Figure 11**

- **a** Sagittal T1-weighted MRI. Inflammation within the sinus tarsi is demonstrated as low signal with loss of definition of the interosseous and cervical ligaments (arrow).
- **b** T2-weighted fat suppressed MRI. There is high signal inflammation within the sinus tarsi (arrow).
arthrography is required. Medial impingement is an uncommon cause of chronic medial ankle pain. Again MR arthrography is required in the absence of a joint effusion and careful clinical correlation of the MR findings is required.

**Chronic bone injury**

Common sites of chronic stress injury in the ankle and foot include the metatarsals, the navicular and the calcaneum. Changes on conventional radiography are a relatively late feature, particularly in the navicular, and MRI is very useful to demonstrate the bone oedema of micro-trabecular stress fracture in the early stages and fracture lines when they are present (Figure 14).

Box 4 summarizes the uses of MRI.

Summary

Conventional radiography is useful in acute bone injury but has a limited role in chronic pain, with the exception of osteoarthritis, anterior impingement and established stress fractures. CT gives the best anatomical bone detail and is useful for the assessment of occult acute bone injury and in the presence of extensive metalwork, which renders MRI non-diagnostic. Ultrasound is the investigation of choice for isolated tendon and ligament injury that allows dynamic assessment of integrity and direct correlation of patient’s pain and tenderness with pathological findings during the scan. MRI gives the best overall assessment of soft tissue and bone injury and is the most useful investigation for chronic ligament instability and impingement syndromes, osteochondral injury and chronic stress fractures.◆

**Summary of the uses of MRI**

- **Acute injury**
  - Severe acute ligamentous injury particularly when acute osteochondral fracture also suspected
- **Chronic pain**
- **Chronic osteochondral injury**
- **Ligament laxity and impingement syndromes**
- **Chronic bone stress fracture**
- **Infection eg in the diabetic foot**

**Box 4**

**FURTHER READING**