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Imaging in metatarsalgia

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Abstract

Metatarsalgia is a common clinical conundrum that requires careful assessment. There are a variety of causes and understanding these can help manage the pain. These causes have different imaging characteristics and require specific imaging. By understanding core imaging principles and how they apply to causes of metatarsalgia, pathology can be more efficiently investigated. This article covers primary, secondary and iatrogenic causes of metatarsalgia with the most appropriate imaging modalities for each and the salient imaging findings. This article reviews the common forefoot pathologies and how they may be optimally radiologically investigated, with an emphasis on the key imaging findings.

Key words: Forefoot; Metatarsalgia; Metatarsal

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Introduction

Metatarsalgia is defined as pain in the region of the metatarsophalangeal joints. There are multiple causes of metatarsalgia which can be subdivided based on aetiology into primary, secondary and iatrogenic. Diagnosis can often be made by history and examination, but imaging can assist in areas where there is diagnostic doubt, and help to grade pathology and guide treatment options (Besse, 2017).

The forefoot is a complex structure that contains numerous structures, such as tendons, bones and bursae, which are best imaged with different modalities. For instance, plain radiography is likely to be unhelpful in a patient in which Morton's neuroma is suspected. Often it can be difficult to request the correct imaging when necessary, but this article reviews the key imaging features of common pathologies that can cause metatarsalgia as outlined in the linked article (https://doi.org/10.12968/hmed.2021.0348) and Table 1.

Table 1. Causes of metatarsalgia

Type	Problem	Pathology
Primary	Long second metatarsal	Increased point loading on second metatarsal head
	Enlarged metatarsal head or condyle	Trauma, infection, arthritis, congenital malformation or hereditary factors
Secondary	Trauma	Stress fracture of malalignment of metatarsals
	Metatarsophalangeal joint instability or hyperextension	Acute trauma Plantar plate, medial and lateral collateral ligament tears
	Freiberg's disease	Avascular necrosis of the metatarsal head
	Morton's neuroma	Fibrosis of common digital nerves found in intermetatarsal spaces
	Systemic conditions	Rheumatoid and psoriatic arthritis Charcot–Marie–Tooth disease and other neurological conditions
Iatrogenic	Metatarsalgia post forefoot surgery	Hallux valgus surgery, lesser metatarsal osteotomies

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Primary metatarsalgia: long second metatarsal and enlarged metatarsal head or condyle

Primary metatarsalgia includes disorders in which pain is caused by anatomical variation with the metatarsals, either congenital or acquired. Metatarsals that are too long or too short can lead to forefoot imbalance and pain (Besse, 2017).

Conditions that are a cause of primary metatarsalgia, such as long second metatarsal and enlarged metatarsal head or condyle, can be assessed with dorsoplantar and lateral foot radiographs, as these bony structures can be easily delineated. Computed tomography could be used to provide three-dimensional view to provide additional information for preoperative surgical planning.

Secondary metatarsalgia

Secondary metatarsalgia refers to pathology that increases loading on the metatarsal head via indirect mechanisms. Unlike the primary causes of metatarsalgia, secondary metatarsalgia is caused by a variety of structures including soft tissue, bones and tendons. As such, a wider variety of imaging approaches may be required.

Stress fracture: metatarsal head or neck fracture

Repetitive impact on the metatarsals is well recognised to cause stress fractures. Stress fractures can cause metatarsalgia, and these fractures are often non-displaced and can be difficult to identify on plain radiography with 15–30% sensitivity at the time of presentation, increasing to 30–70% at follow up (Lassus et al, 2002). Magnetic resonance imaging is more sensitive in early detection of stress fractures. Plain film is appropriate to identify stress fractures in the first instance (**Figure 1**), but if sufficient clinical suspicion exists, magnetic resonance imaging is the most sensitive modality. High STIR signal and corresponding low

Figure 1. Dorsoplantar view plain radiograph of the right foot demonstrating periosteal reaction and callus formation as a result of a stress fracture in the distal second toe metatarsal (arrow).

T1 signal in a metatarsal mid-shaft is likely to indicate a stress fracture. Stress fractures involving the sesamoid bones of the hallux may cause metatarsalgia that may be difficult to identify on plain film, thus magnetic resonance imaging could be used to identify subtle stress fractures and those in unusual sites (Oloff and Schulhofer, 1996).

Metatarsophalangeal joint instability

Metatarsophalangeal joint instability is seen when the base of the proximal phalanx dorsally subluxes or dislocates from the metatarsal head (Maas et al, 2016). This can occur in an acute trauma setting but there are often chronic attritional changes to the stabilising soft tissue structures of the metatarsophalangeal joint which ultimately results in their failure (Doty and Coughlin, 2014). The plantar plate and the collateral ligaments fail with these structures undergoing initially elongation, then attenuation followed by rupture (Maas et al, 2016).

Attritional mechanical overload of the lateral plantar plate leads to a tear, most commonly at the proximal phalanx attachment, which propagates medially (Linklater and Bird, 2016). Plantar plate tears have been described in 40% of patients with metatarsalgia, with 90% of those occurring at the second metatarsophalangeal joint (Umans et al, 2014).

The plantar plate is a complex fibrocartilaginous structure, containing fibres organised in a longitudinal fashion that attach to the plantar fascia. It is most often disrupted in the distal lateral aspect of the plantar plate, which often causes a medial displacement of the associated phalanx. Dynamic ultrasound can provide a clear diagnosis with the ability to perform live manoeuvres on such small structures with excellent resolution to demonstrate discontinuity of the normal plantar plate.

Magnetic resonance imaging of plantar plate tears may demonstrate high T2 signal intensity around the plantar plate (Figure 2), persistent hyperextension of the proximal phalanx with discontinuity of the plantar plate, metatarsophalangeal joint synovitis, flexor sheath tenosynovitis, or some combination of these (Yao et al, 1994). Retraction of the torn plantar plate may not be apparent and is difficult to appreciate in chronic tears in patients with low signal intensity scarring. Oedema can sometimes be seen at the base of the proximal phalanx (Linklater and Bird, 2016).

Magnetic resonance imaging allows easier identification of partial-thickness tears, which will appear as focal increased T2 signal change of the plantar plate (Yao et al, 1996), suggesting a low-grade sprain or tear, without complete discontinuity. Magnetic resonance imaging can also give important information such as the degree of proximal retraction, subsequent joint deformity and metatarsophalangeal joint synovitis. Although magnetic resonance imaging is more specific than ultrasound, they have similar sensitivities and ultrasound is more cost efficient (Klein et al, 2012; Carlson et al, 2013).

Magnetic resonance arthrography further improves visualisation of the fibrous capsule, plantar plate and collateral ligament complex of the lesser metatarsophalangeal joints, allowing better delineation of anatomy and pathology (Mohana-Borges et al, 2003).

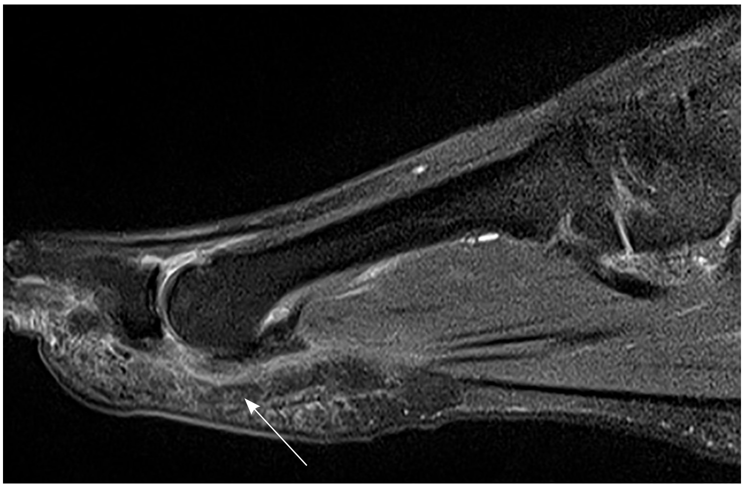

Figure 2. Sagittal image through the forefoot in a magnetic resonance imaging STIR sequence demonstrates a plantar plate tear with high signal in the plantar plate (arrow).

Figure 3. a. Axial STIR sequence of the forefoot, shows flattening of the second and third metatarsal head with mild adjoining oedema. b. Axial T1 sequence of the forefoot, shows flattening of the second and third metatarsal head. The findings are consistent with Frieberg's disease. c. Plain radiograph of a different patient with Frieberg's disease, demonstrating sclerosis and flattening of the third metatarsal head.

Freiberg's disease

Freiberg's disease describes avascular necrosis of the metatarsal head, which is most commonly seen in the second metatarsal (Biz et al, 2017). This avascular necrosis alters the metatarsophalangeal joint, causing flattening and collapse of the metatarsal head, subsequently causing arthritis of the joint (Cerrato, 2011). The aetiology is believed to be multifactorial, with the main theories being trauma and vascular insufficiency.

Changes are seen on magnetic resonance imaging before they are seen on radiography. Early magnetic resonance imaging findings include low signal intensity changes in the metatarsal head on T1-weighted images, with increased signal intensity on corresponding T2-weighted and STIR images (Figures 3a and b). With disease progression, flattening of the metatarsal head occurs, and low signal intensity changes develop on T2-weighted images as the bone becomes sclerotic.

However, plain radiography (Figure 3c) is often obtained first because of its low cost and ease of imaging, and five stages of Freiberg disease have been described based on the radiographic appearance. Stage 1 appears as flattening and fissuring of the epiphysis and stage 2 as subchondral collapse secondary to central bone resorption in the metatarsal head with appearance of joint widening. This is followed by progressive collapse of the articular surface and peripheral irregularities (stage 3). Osteochondral loose bodies appear in stage 4 and flattening of the head with advanced arthrosis in stage 5.

Equivocal or early-stage disease on radiographs can be used to justify further magnetic resonance imaging in patients with strong clinical suspicion of pathology.

Morton's neuroma

Morton's neuromas are not true neuromas; rather, they are masses composed of perineural fibrosis and nerve degeneration involving the plantar digital nerves supplying the toes (Resch et al, 1994).

Morton's neuroma commonly involves the plantar digital nerve in the third webspace, where the nerve is thicker than other sites and so prone to neuroma formation. They often present with metatarsalgia between the third and fourth rays that radiates to the toes (Terk et al, 1993). Ultrasonography and magnetic resonance imaging can both be used to help identify Morton's neuromas but clinical identification remains key (Briggs, 2006). Magnetic resonance imaging is useful because it allows three-dimensional assessment of the forefoot, including the bones. However, ultrasound allows dynamic assessment of the neuroma and also helps with guided injections that are commonly used for initial treatment.

Morton's neuroma appears mildly hyperintense relative to muscle on T1-weighted magnetic resonance images and hypointense relative to fat on T2-weighted magnetic resonance images (Figures 4a and b) (Zanetti et al, 1997; Ashman et al, 2001). Asymptomatic lesions that are visible on magnetic resonance imaging are often smaller than their symptomatic counterparts (Zanetti et al, 1997). Ultrasound has a good specificity and

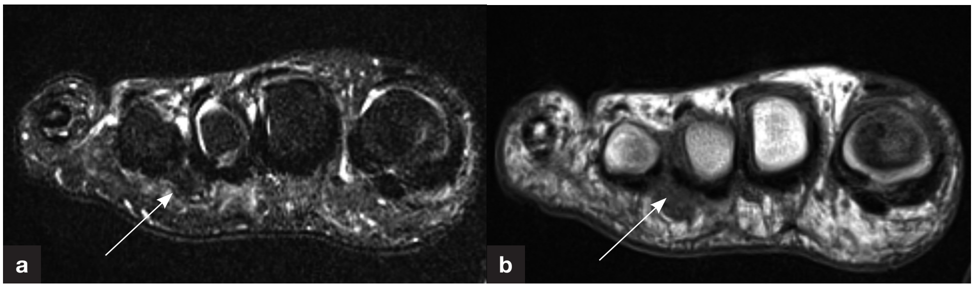

Figure 4. a. STIR magnetic resonance sequence of the forefoot with dumbbell shaped low signal Morton's neuroma between the third and fourth metatarsal heads (arrow). b. T1 magnetic resonance sequence of the forefoot with dumbbell shaped intermediate signal Morton's neuroma between the third and fourth metatarsal heads (arrow).

sensitivity (0.65 and 0.98) for Morton's neuroma despite being user dependent (Shapiro and Shapiro, 1995).

Systemic conditions: most commonly rheumatoid arthritis

Metatarsalgia is one of the most common presentations of rheumatoid arthritis (Chalmers et al, 2000) and often the earliest changes in rheumatoid arthritis are seen in the metatarsophalangeal joints. Commonly changes caused by rheumatoid arthritis are recognised as bone erosion, synovitis and bone oedema and are easily detectable on magnetic resonance imaging of the foot, with erosive changes and high T2/STIR signal in the synovium and adjacent bone respectively (Siddle et al, 2012). The plantar plate has also been demonstrated to be torn or absent in patients with rheumatoid arthritis, but this has still to be correlated with metatarsalgia itself (Siddle et al, 2012). Plain radiography monitoring of disease with sequential radiographic assessment of the hands and feet is common (Kgoebane et al, 2018) and easily accessible. Ultrasound and magnetic resonance imaging can be used to better delineate the soft tissue structures (Siddle et al, 2012). These principles can be applied to other systemic conditions such as psoriatic arthritis, which may demonstrate changes such as synovitis, erosions and submetatarsal bursae (Figure 5) (Turner et al, 2014).

Figure 5. Coronal magnetic resonance imaging STIR sequence of the forefoot demonstrates periarticular erosions and synovial thickening and bony oedema in the third and fifth metatarsophalangeal joints (arrows), in a patient with rheumatoid arthritis.

Key points

- Clinical assessment with relevant radiographs is often sufficient to make a diagnosis and formulate a management plan.
- Consider the anatomical source of the pathology and this will help guide the differential diagnosis.
- Identifying a differential before requesting imaging can help guide the most appropriate test, providing a faster path to diagnosis and subsequent treatment.
- Specific magnetic resonance imaging sequences may provide more accurate information regarding the patient's current clinical status.
- Ultrasound assessment can be useful for the dynamic assessment of metatarsalgia.

Conclusions

Patients with metatarsalgia commonly present to the foot and ankle clinic. Careful clinical assessment with accurate selection of appropriate imaging can facilitate optimal diagnosis and management.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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