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## Ultrasound features of sole of foot pathology: a review

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adventitial bursa

### Abstract

Foot pain is a common problem among adults, with approximately 19% of men and 25% of women describing significant daily foot pain that limits their ability to function. Older adults, the obese, and active adults participating in sports involving running and jumping are at increased risk of developing pathology. Problems affecting the sole of the foot are often the cause of pain. Ultrasound is an extremely useful method of quickly and accurately localizing and characterizing pathology of the foot. The wide availability of ultrasound combined with its low cost, lack of ionizing radiation, high spatial resolution, multiplanar capability and excellent patient tolerance makes it an ideal technique for assessing the superficial structures in the sole of the foot. Ultrasound has the advantage of dynamic assessment over other imaging modalities. Furthermore, Doppler interrogation allows a real-time assessment of vascularity, not possible using other techniques. The ability to perform extended field of view images allows improved image presentation, which has increased clinicians' acceptance of the technique. Finally, ultrasound can be used to guide interventional procedures. This review article will consider the ultrasound features of pathology commonly affecting the sole of the foot, and will describe MRI correlates that can be expected.

## Introduction

This review aims to provide an overview of common pathologies affecting the sole and their ultrasound and MRI correlates. Specifically, it will consider abnormalities of the plantar fascia, including plantar fasciitis, plantar fascia tears and plantar fibromatosis, in addition to Baxter's neuropathy, epidermal inclusion cysts, foreign bodies and adventitial bursitis. Together, these encompass significant sources of foot pain<sup>(1)</sup>. Familiarity with these pathologies and their appearance on ultrasound and MRI is vital for accurate diagnosis by a radiologist.

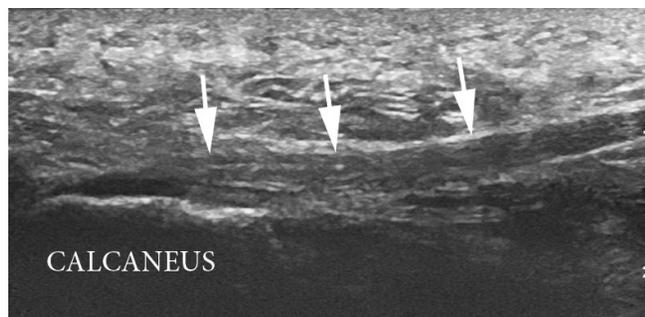
## Anatomy of the plantar fascia

The plantar fascia (PF) is the most superficial structure in the sole of the foot, originating from the plantar surface of the calcaneus at the medial calcaneal tubercle and attaching to the plantar surfaces of the five metatarsal

heads and proximal phalanges of the toes. It consists of a central, medial and lateral part. The central part is thickest and adheres to the underlying flexor digitorum brevis muscle; as it extends towards the forefoot, it divides into five separate bundles, which radiate towards and attach at the plantar plates of the proximal phalanges and metatarsophalangeal joint capsules. Acting as a major stabilizer, all five bundles contribute to maintaining the longitudinal arch of the foot and the congruity of the relationship between the calcaneus and metatarsal heads. The medial and lateral parts attach to the abductor hallucis and the abductor digiti minimi, respectively. Distally, the lateral part inserts at the fifth metatarsal joint capsule, whereas the thinner medial part inserts at the first metatarsal joint.

## Plantar fasciitis

Plantar fasciitis is the most common cause of heel pain, affecting the PF at its proximal calcaneal attachment<sup>(2)</sup>.

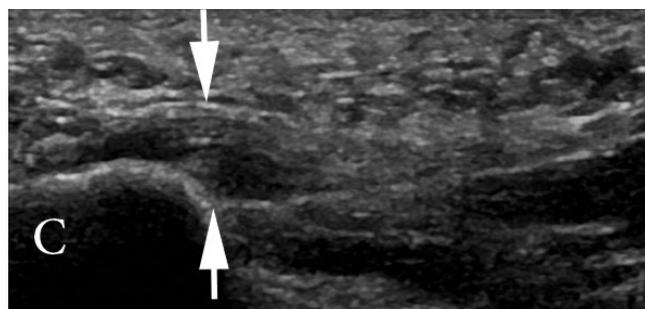


**Fig. 1.** Longitudinal US of normal plantar fascia. The arrows indicate the position of the central bundle of the plantar fascia which has a fibrillar pattern

Typically, it involves the central bundle. The most common cause is considered to be excessive biomechanical stress of the PF and its entheses of the calcaneal tuberosity, leading to degenerative microtrauma and tears<sup>(3,4)</sup>. Thus the term plantar “fasciopathy” or PF enthesopathy may be preferable to plantar “fasciitis”. Pain on the under surface of the heel on weight bearing is the principal complaint and is usually worse in the morning after a prolonged period of rest before easing with activity. Passive dorsiflexion of the toes may also exacerbate discomfort<sup>(4)</sup>.

Plantar fasciitis is thought to account for around 80% of sole of foot complaints, with a lifetime prevalence of 10%. In clinical practice, plantar fasciitis is encountered in three main groups: in middle aged patients, athletes, and in association with inflammatory spondyloarthritis. It is most common in people aged 40–60 years, with a predilection for women over men. People who exercise regularly are more at risk, as are those who are overweight. Athletes who compete or run on hard surfaces or grass. As plantar fasciitis can be seen in association with spondyloarthropathies, such as ankylosis spondylitis, reactive spondyloarthritis and psoriatic arthritis, it is prudent, as part of the ultrasound examination, to additionally examine the Achilles tendon for an insertional enthesopathy in order to exclude or confirm seronegative arthritides as a cause for plantar pain.

Plain radiographs in patients with plantar fasciitis often demonstrate PF thickening, cortical erosions or



**Fig. 2.** Plantar fasciitis on US. The arrows indicate fusiform thickening of the plantar fascia at the insertion of the calcaneus (C)

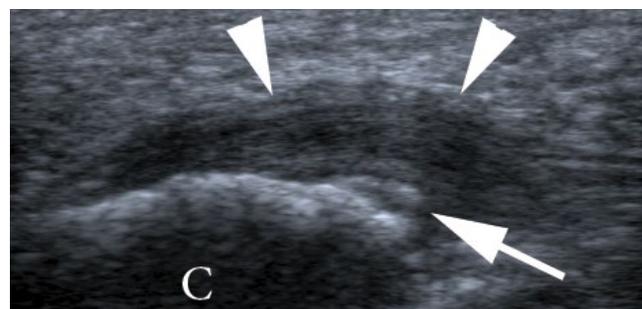
irregularities and abnormalities in the soft tissue or fat pad deep to the PF. Additionally, they may demonstrate an inferior bony heel spur; which although common, is not considered to be the cause of PF degeneration and pain and are thus a non-specific finding. Its presence may reflect chronic enthesopathy of plantar fasciitis of at least six months, in spite of whether the patient has been symptomatic.

Sonographically, the PF is best visualized longitudinally as a fibrillar structure with hyperechoic lines of collagen fibre bundles (Fig. 1), with inter-fascicular matrix producing anechoic lines between them<sup>(3)</sup>. The normal plantar fascia has a relatively uniform thickness and measures less than 5 mm in thickness. In plantar fasciitis, there is increased, fusiform thickness of the fascia, typically greater than 5 mm or a 25% relative increase in thickness compared to the asymptomatic foot. The lesions are observed at the heel attachment, and in more advanced or chronic cases may embrace a more distal part. There is loss of the fibrillar structure, diffuse low echogenicity or hypoechoic foci, and edema within the fascia and around the site of its insertion (Fig. 2, Fig. 3). The PF is poorly vascularized, and thus hyperemia is rarely demonstrated on Doppler interrogation.

On MRI, the normal PF appears as a thin, hypointense structure extending anteriorly from the calcaneal tuberosity. MRI correlates of plantar fasciitis include intermediate T1 signal and high T2 signal involving typically the entheses, and in more chronic cases the distal aspects. The STIR (short tau inversion recovery) sequence is sensitive in detection of both fascial and perifascial edema, which appears as a poorly marginated area of high signal intensity (Fig. 4). MRI features also include PF fusiform thickening with increased T2 and STIR signal intensity of the proximal PF, and edema of the adjacent fat pad and underlying soft tissue<sup>(5,6)</sup>.

### Plantar fascia tears

PF tears typically occur following sudden forceful activity, usually in patients with previously diagnosed plantar fasciitis or following steroid injection. Clinical presentation



**Fig. 3.** Plantar fasciitis on US. The calcaneus is indicated by the letter ‘C’. The short arrows indicate fusiform thickening of the plantar fascia with a small enthesopathic spur at the insertion (long arrow)

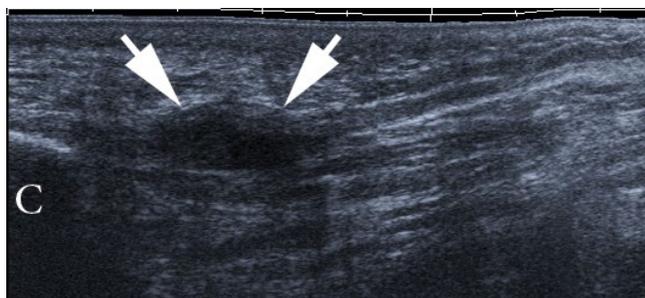


**Fig. 4.** Plantar fasciitis on MRI. A sagittal STIR image shows fusiform swelling (arrow) of the central bundle of the plantar fascia with minor intrinsic signal change, and mild surrounding soft tissue edema. There is mild bone marrow edema at the calcaneal insertion

includes acute pain, often accompanied by a snapping noise or pop, with bruising, swelling, and tenderness to palpation on examination of the medial plantar surface of the affected foot. The most common precipitating events include sudden jumping, running or sprinting causing forced plantar flexion, usually in a non-athlete.

Ultrasound features include either complete or partial interruption of the PF, with disrupted fibers at the site of injury (Fig. 5, Fig. 6). Large tears may have a surrounding hematoma or an inflammatory reaction. In contrast to plantar fibromatosis there is no discrete mass or abnormal vascularity.

MRI demonstrates an absence or partial loss of T1-weighted low signal intensity<sup>(7)</sup> at the site of complete rupture



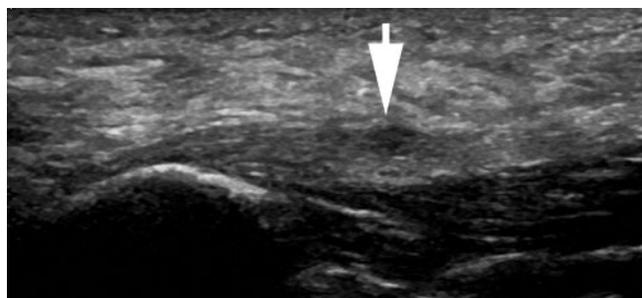
**Fig. 5.** Subacute/healing plantar fascia tear. Longitudinal US image shows focal swelling of the plantar fascia 1.5 cm from the insertion in a typical location for a plantar fascia tear. In contrast to a plantar fibroma there is no discrete mass, and no abnormal vascularity

(Fig. 7). There may also be abnormal thickening of the PF surrounding the site of partial disruption; unlike the more fusiform swelling associated with simple plantar fasciitis, actual PF tears are more diffusely thickened and may show architectural irregularities indicating a loss of the normal fascial tension (Fig. 8).

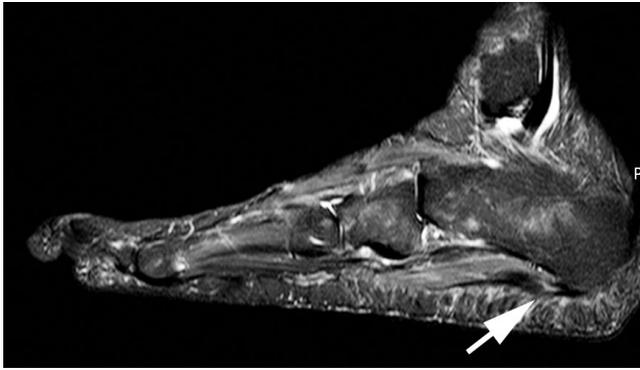
### Plantar fibromatosis

Classified as a superficial fibromatosis, and also referred to as Ledderhose disease, plantar fibromatosis refers to a benign fibroblastic proliferation of the PF. Although a benign neoplasm, it is non-encapsulated and thus can be locally aggressive with a high recurrence rate. It is less common than its palmar fibromatosis counterpart, with an incidence of 0.23%<sup>(8)</sup>. The etiology of plantar fibromatosis remains controversial, with prior trauma considered the most likely cause. Incidence increases with age, and there is a recognized male predilection. Well-defined nodules, typically smaller than 1 cm in diameter, are located in the central portion of the medial PF and may extend to involve the skin or deep structures of the foot. Nodules may be symptomatic due to the mass effect or invasion of adjacent muscles or neurovascular structures; these patients typically complain of aching pain after walking or standing for prolonged periods. Typically, flexion deformities do not occur, though nodules may lead to eventual shrinkage and sclerosis of the entire PF. There is often association with other fibroproliferative disorders including Dupuytren's disease, keloid scarring and Peyronie disease. Bilateral nodules occur in 20–50% of cases<sup>(8)</sup>.

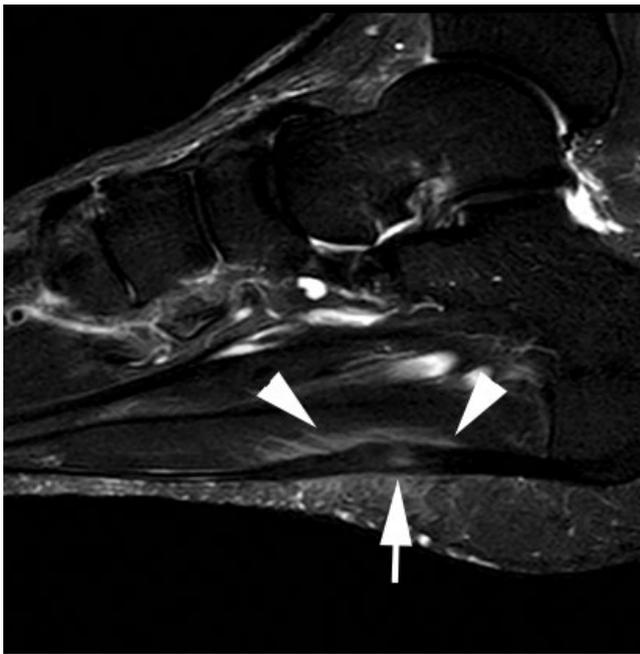
On ultrasound, plantar fibromatosis is often seen as a single hypo- to mixed echogenicity nodular thickening of the PF located separately to the calcaneal insertion, and thus differing from fasciitis affecting the enthesis<sup>(9)</sup>. Also, contrary to fasciitis, the lesions are well-defined (Fig. 9, Fig. 10). Typically, they demonstrate a heterogeneous internal structure that may include visible septa. There are no calcifications or fluid collections, which differentiates them further from acute or traumatic overuse injuries. Doppler generally shows an absence of vascularity inside the lesion<sup>(4)</sup>.



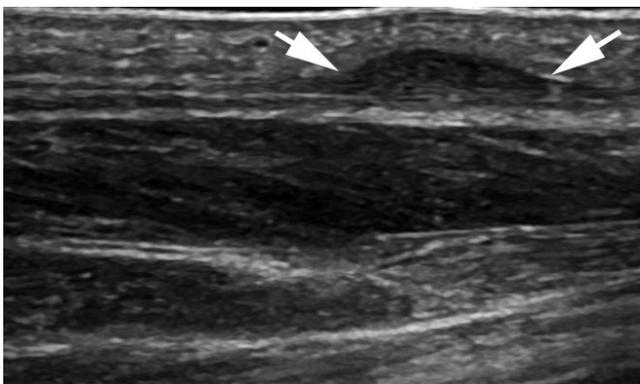
**Fig. 6.** Partial plantar fascia tear. Longitudinal US image shows disruption of the normal fibrillar structure of the superficial fibers of the plantar fascia (arrow) with a small hypoechoic focus consistent with a partial tear



**Fig. 7.** Full-thickness plantar fascia tear on MRI. Sagittal T1-weighted images show discontinuity of the fibers of the central bundle of the plantar fascia (arrow)



**Fig. 8.** Partial-thickness plantar fascia tear on MRI. Sagittal STIR sequence showing a focal high T2 signal lesion in the thickened plantar fascia (arrow), with thickening and intrinsic high T2 signal of the plantar fascia with surrounding soft tissue edema (arrowheads)



**Fig. 9.** Plantar fibromatosis. Longitudinal US image shows a fusiform hypoechoic mass arising from the plantar fascia

On MRI, fibromatosis is identified as a well-defined region of nodular thickening at the inferior margin of the PF, with iso- to low T1 signal intensity compared with muscle<sup>(6)</sup> and heterogeneous T2 signal (Fig. 11, Fig. 12). On fluid sensitive sequences, the lesion may be of low or heterogeneous signal with high and low signal areas. The well-defined nodular configuration assists in differentiating them from plantar fasciitis, although scarring in the cases of chronic partial tears of the PF can lead to a nodular appearance which mimics plantar fibromatosis; in this case there may be additional evidence of enthesopathy at the medial calcaneal tuberosity.

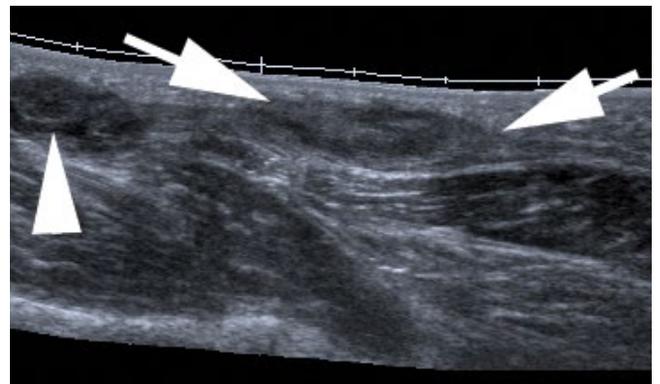
### Baxter's neuropathy

Localized nerve entrapment of the inferior calcaneal nerve is described as Baxter's neuropathy. Clinically, this presents with heel pain radiating to the plantar medial aspect of the foot and anterior to the medial aspect of the calcaneus. There is no associated sensory loss, but there may be motor weakness of abductor digiti minimi. Predisposing factors include plantar fasciitis, plantar calcaneal spurs, muscle hypertrophy and obesity.

The sites of possible nerve entrapment are as follows:

1. Deep to or adjacent to the fascial edge of the abductor hallucis muscle
2. Along the medial edge of the quadratus plantae muscle
3. Adjacent to the medial calcaneal tuberosity

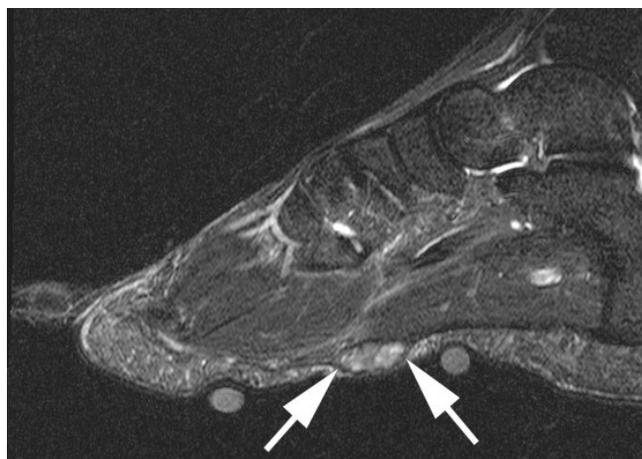
In early and subacute cases of nerve entrapment there is edema and swelling of the abductor digiti minimi muscle belly with high T2 signal seen on a fluid-sensitive MRI sequences (Fig. 13). In more established cases of muscle denervation, there is fatty infiltration of the abductor digiti minimi muscle (Fig. 14). The condition may be very difficult to appreciate on US, but fatty infiltration of the abductor digiti minimi muscle belly may manifest as increased echogenicity relative to surrounding musculature.



**Fig. 10.** Plantar fibromatosis. Longitudinal US extended field of view image shows a fusiform heterogeneous mass arising from the substance of the plantar fascia (arrows)



**Fig. 11.** Plantar fibromatosis, same patient as in figure 10. Sagittal T1-weighted image shows an intermediate/low signal fusiform mass arising from the plantar fascia



**Fig. 12.** Plantar fibromatosis, same patient as in figure 10. Sagittal proton-density fat-saturated image shows a heterogeneous high T2 signal mass

### Epidermal inclusion cyst

These are common cutaneous lesions representing a proliferation of squamous epithelium within the confined space of the dermis or subdermis. They are often the result of a penetrating injury that drives keratinizing epithelium into subcutaneous tissue or bone. They often occur in the sole due to the pressure of weight-bearing. They are different from sebaceous cysts, which originate in the sebaceous glands. Epidermal cysts may be found incidentally, or present as a firm, non-tender lump. They are more common in men than women, and usually occur in the third to fourth decade. They may rupture, in which case a local inflammatory response may mimic infection.

Ultrasound shows a well circumscribed hypoechoic mass (Fig. 15) in the subcutaneous fat of the foot (in contrast to a plantar fibromatosis, which is located within the PF). Most commonly, they are ovoid or spherical, but may be lobulated, or more rarely, tubular<sup>(10)</sup>. If they are small, they may mimic a typical simple cyst. Whilst cysts tend to be hypoechoic, larger lesions may be more heterogeneous due to the presence of fat, calcification or pus. There may be

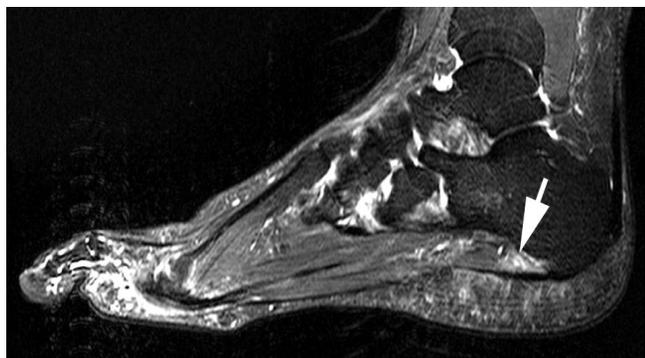
occasional linear echogenic reflections, increased through-transmission and hypoechoic rims<sup>(11)</sup>. There is no Doppler flow as they do not have associated vascularity.

On MRI, the content of the cyst is similar to that of water (Fig. 16, Fig. 17). Unruptured cysts typically are of low T1 signal and high T2 signal. There may be a thin low signal rim. Ruptured or mature cysts may have septa or irregular rim enhancement<sup>(12)</sup>.

### Foreign bodies

Most soft tissue foreign bodies consist of glass, metal or splinters from wood. Identification is important before they lead to infection. Whilst radiopaque foreign bodies are easily visualized with conventional radiography, radiolucent foreign bodies are better envisaged with ultrasound.

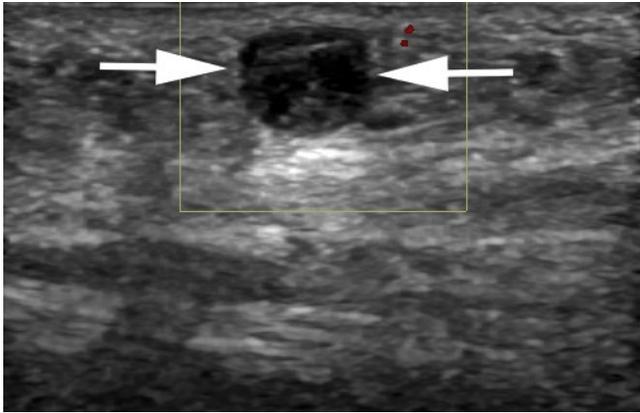
Most foreign bodies are hyperechoic on ultrasound (Fig. 18), typically demonstrated as a small strong reflector surrounded by hypoechoic tissue<sup>(2)</sup>. Posterior acoustic



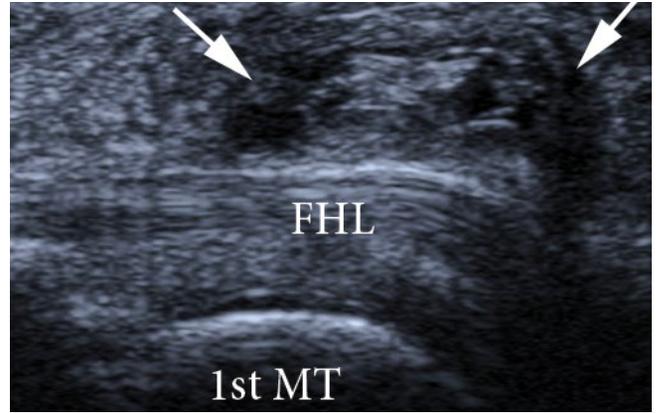
**Fig. 13.** Acute Baxter's neuropathy. Sagittal STIR image shows plantar fasciitis (arrow) with muscle edema of the abductor digiti minimi muscle (arrowhead)



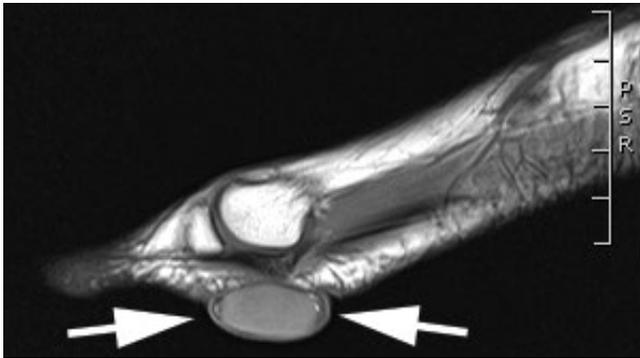
**Fig. 14.** Chronic Baxter's neuropathy. Sagittal T1-weighted image shows fatty infiltration of the abductor digiti minimi muscle (arrowhead) with mild chronic plantar fasciitis (arrow)



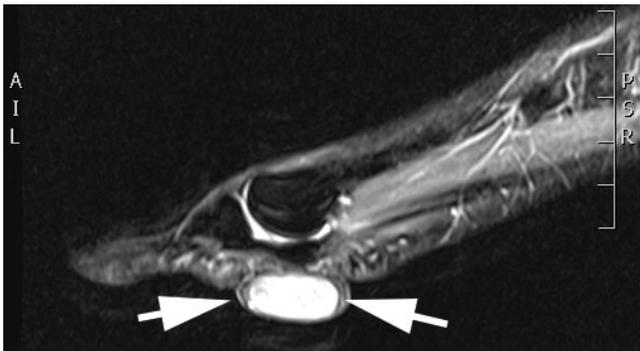
**Fig. 15.** Epidermal cyst. Longitudinal US shows a rounded hypoechoic lesion (arrows) in the subcutaneous tissues of the sole with posterior acoustic enhancement. There is no flow on Doppler interrogation



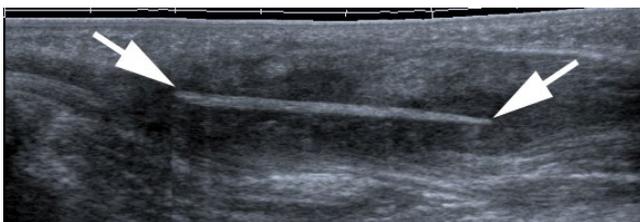
**Fig. 19.** Adventitial bursa. Ultrasound shows a compressible poorly defined heterogeneous region (arrows) in the subcutaneous tissues beneath the 1st metatarsal head (1st MT) and flexor hallucis longus tendon (FHL)



**Fig. 16.** Epidermal cyst. Sagittal T1-weighted image shows an ovoid subcutaneous mass (arrows) with intermediate T1 signal and a low signal rim



**Fig. 17.** Epidermal cyst, same patient as figure 16. Sagittal STIR image shows a high T2 signal lesion with a low signal rim



**Fig. 18.** Foreign body. Ultrasound shows a linear high echogenicity foreign body (splinter) indicated by arrows, with surrounding low-echogenicity granulation tissue

shadowing may be seen; this shadow may be complete or partial depending on the angle of insonation and the composition of the foreign body itself. A hypoechoic halo, representing an inflammatory reaction, may occur in the case of subsequent abscess or granulation tissue formation. Foreign body granulomas appear as a low echogenicity mass surrounding the foreign body itself<sup>(13)</sup>.

### Adventitial bursitis

Adventitial (submetatarsal) bursitis refers to inflammation associated with adventitious bursae; these are not permanent natural bursae, but instead develop in adults in sites where subcutaneous tissue is exposed to high pressure or friction<sup>(14)</sup>. Under such conditions, formation of subcutaneous adventitial bursa begins as a coalescence of small spaces in loose connective tissue; the walls become progressively differentiated from adjacent connective tissue, leading to the formation of a well-defined fluid-filled cavity<sup>(15)</sup>. In the foot, they are normally adjacent to bony prominences, typically at the medial or lateral aspect of the first and fifth metatarsal heads, respectively, forming submetatarsal bursae. Where present in the foot, patients may present with metatarsalgia.

On ultrasound a bursa is characteristically of heterogeneous echogenicity (containing both fluid and synovial hypertrophy), unilocular and compressible<sup>(16)</sup> (Fig. 19). There is typically no Doppler signal.

MRI demonstrates ill-defined lesions located in the subcutaneous fat. Typical signal characteristics are those of fluid (T1 low signal; T2 high signal), with intermediate tissues of thickened synovium.

### Conclusion

Ultrasound is a vital imaging modality for the diagnosis of sole of foot pathologies. Careful analysis of the imaging and correlation with clinical information permits

accurate diagnosis and implementation of the appropriate treatment. An understanding and appreciation of the different ultrasound features of plantar pathology, and their MRI correlates, allow the radiologist to distinguish often subtle pathologies with confidence and thus shape patient management.

### Conflict of interest

*The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.*

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