Magnetic resonance imaging of abnormalities of the nonosseous structures of the forefoot: A pictorial review

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Learning objectives

1. To catalog the wide spectrum of forefoot injuries depicted by MRI using a pictorial review of the findings in abnormalities affecting the tendons, ligaments, nerves, and soft tissues.
2. To provide a comprehensive overview of normal and pathologic findings in the forefoot and discuss the differential diagnosis of forefoot abnormalities.

Background

We studied the forefoot in 848 patients using MRI at 1.0 T over five years. All patients were previously examined with plain films and some with US and CT. We used T1-weighted density and T2-weighted spin-echo or fast spin-echo sequences in the sagittal and coronal planes, together with gradient-echo and occasionally spin-echo T1-weighted sequences in the axial plane. STIR or fat-suppressed T1-weighted sequences were also used in some cases. Intravenous gadolinium contrast was administered when necessary.

Imaging findings OR Procedure details

We divide forefoot injuries into five groups: ligament, musculotendinous, nerve, synovial and soft-tissue abnormalities.

LIGAMENT ABNORMALITIES

Rupture of the medial collateral ligament of the first metatarsophalangeal joint (figure 1) on page 33 is uncommon. It can lead to hallux valgus. Injuries can also occur in sporting activities including football, soccer, and dance, or following trauma to the hallux. The mechanism of injury is typically hyperextension of the metatarsophalangeal joint, but injuries have also been reported secondary to valgus or varus stress.

Osteochondral lesion may rarely accompany rupture of the medial collateral ligament of the first metatarsophalangeal joint (figure 02) on page 35.

Plantar plate disruption (figure 03) on page 35 may be related to acute traumatic events or subacute repetitive traumas (degenerative lesions). Generally, acute traumatic lesions occur because of hyperextension forces placed on joints, the first metatarsophalangeal joint being the most commonly affected. The plantar plate is a fibrocartilaginous structure that reinforces the articular capsule of metatarsophalangeal joints.
MUSCULOTENDINOUS ABNORMALITIES

Tenosynovitis of extensor tendons (figure 04) on page 36 and of flexor tendons (figure 05) on page 37 are uncommon in the forefoot, like in the ankle, and gliding of the tendons through the sheath is restrained as result of thickening of the tendons from acute or repetitive trauma.

Plantar fasciitis (figure 06) on page 38 is a painful inflammatory condition caused by excessive wear to the plantar fascia of the foot. It occurs only very rarely in the forefoot and the pain usually is felt on the underside of the heel.

Plantar fascia tear (figure 07) on page 39 is rare and result from a violent or repetitive trauma over the plantar aponeurosis or fascia. The plantar fascia is a deep span of connective tissue extending from the anteromedial tubercle of the calcaneus to the proximal phalanges of each of the toes. Fibrous septa originate from the medial and lateral borders to attach to the first and fifth metatarsal bones.

NERVE ABNORMALITIES

Schwannoma (figure 08) on page 40 is a benign, encapsulated neoplasm that may originate from a peripheral or sympathetic nerve.

Morton's neuroma (figure 09) on page 41 is a perineural fibrosis and nervous degeneration. It is a type of nerve compression syndrome which involves the common digital nerves of the lesser toes: most often in the third and less often the second interspace. It is a common cause of metatarsalgia. It occurs most often in middle-aged women; patients complain of burning and tingling down the interspace of the involved toes. Pain is usually made worse by walking in high-heeled shoes in which the toes are boxed and is relieved by rest and by removing the shoe; during toe off of ambulation, the interdigital nerve may become compressed by the intermetatarsal ligament. In some case, Morton's neuroma can appear a long time after surgery (figure 10) on page 42.

SYNOVIAL ABNORMALITIES

The initial manifestation of rheumatoid arthritis (figure 11) on page 42 occurs in the foot in 15% of patients. Initially, RA involves the forefoot, then the midtarsal joints, and finally the hindfoot; the forefoot is involved twice as often as the hindfoot. Although forefoot and hindfoot disease can coexist, commonly patients have one or the other. MR can determine the extent of bone edema, the presence of synovitis and identify small bone erosions.

Chronic synovial proliferation (figure 12) on page 43, composed of mononuclear cell infiltration, synovial hypertrophy and pannus formation are observed in pathology. MRI allows early synovial hypertrophy to be detected and the status of the articular cartilage to be examined. The differential diagnosis includes pigmented villonodular synovitis and hemophiliac arthropathy.
SOFT-TISSUE ABNORMALITIES

Ganglia (figure 13) on page 43 are cystic lesions with mucinous content and a fibrous capsule. In the foot, ganglia usually occur on the dorsal region, adjacent to the articular capsule, tendinous sheath, tendon or ligament, and there is usually no apparent connection with the articular space.

When an abscess (figure 14) on page 45 affects the foot, predominantly the forefoot, the patient is most likely to be diabetic. Abscesses are significantly more frequent in patients with osteomyelitis and in feet that have been treated surgically (figure 15) on page . Therefore, MRI is useful for evaluating the location, size, and extension of pedal abscesses. In Europe, recent immigration has led to abscesses are becoming increasingly common amongst non-diabetic patients.

Bursitis (figure 16) on page 45 is the inflammation of one or more bursae, or small sacs of synovial fluid, in the body. Bursitis may be present in cases of trauma, infection, rheumatoid arthritis, gout. Besides affecting intermetatarsal bursae, it may occur in adventitious bursae (localized under the metatarsal heads). Small collections with 3 mm or less in transverse diameter in the three first intermetatarsal bursae may be physiological.

Reparative fibrosis (figure 17) on page 46 represents an excessive growth and deposition of collagen in the tissues characterized by keloids and hypertrophic scars after surgery.

Epidermal inclusion granuloma (figure 18) on page 48 and foreign body granuloma formation are a common result of retained foreign bodies. The subsequent rupture of an inclusion cyst will result in abscess formation along with ulceration.

Tophaceous gout (figure 19) on page 48 represents the chronic form of the disease. Tophi may produce bone erosions and occur at intraarticular or periarticular locations or at a distance, manifesting as a soft-tissue mass. Most commonly, gout affects the first metatarsophalangeal joint. Findings in the acute phase are non-specific and include joint effusion and synovial thickening.

Soft-tissue tumors in the forefoot mostly are benign lesions representing a variety of histologic types. In some cases, it may be difficult if not impossible to identify the lesion; however, careful analysis of the MRI findings and correlation of these findings with the patient's clinical history can usually suggest a more specific diagnosis, particularly in the most common benign tumors of the foot (e.g., fibromatosis, cavernous hemangioma) and in nonneoplastic soft-tissue lesions, such as Morton's neuroma, ganglion cyst, and plantar fasciitis. The primary goal is to determine whether the mass is benign or malignant. Prior to biopsy, it is important to determine whether the mass is above or below the fascia, because deep lesions are more often malignant.
This is a series of soft-tissue masses which were studied and confirmed at pathology and divided into pathological subgroups according to World Health Organization classification of soft tissue tumors:

- **Vascular tumors**

  - **Hemangioma** (figure 20) on page 49 is a benign congenital tumor of mature blood vessels. It may be composed of capillaries, as with a strawberry or mulberry birthmark. Or it may be composed of larger vessels, for example, cavernous hemangioma.

  - **Arteriovenous malformation** (figure 21) on page 50 can develop in many different sites of the body, albeit rarely in the forefoot.

- **Fibroblastic tumors**

  - **Ledderhose disease** (figure 22) on page 51, also known as plantar fibromatosis, is a non-malignant thickening of the fascia, characterized by a fibrous proliferation.

- **Fibrohistiocytic tumors**

  - **Giant cell tumor** (figure 23) on page 52 is a nodule, possibly inflammatory, that usually develops from the flexor sheath of the toes and is composed of fibrous tissue, multinucleated giant cells, and lipid- and hemosiderin-containing macrophages. Also called localized nodular tenosynovitis. Sometimes the tumor erodes or destructs the neighbor bone (figure 24) on page 53.

- **Adipocytic tumors**

  - **Lipoma** (figure 25) on page 54, a benign, soft, rubbery, encapsulated tumor of adipose tissue, usually composed of mature fat cells.

- **Pericytic tumors**

  - **Glomus tumor** (figure 26) on page 55 arises from the arterial portion of the glomus body, or the Sucquet-Hoyer canal, which is an arteriovenous shunt in the dermis that contributes to temperature regulation. The most common location for these tumors is the distal extremities, especially in subungual areas.

- **Chondro-osseous tumors**

  - **Chondroid metaplasia** (figure 27) on page 57. Apparently, tumors never affect the chondroid bone exclusively. It seems to be involved mainly as a transitional region between cartilage and bone or (often in tumors) osteoid.

- **Tumors of uncertain differentiation**

  - **Angiomyxolipoma** (figure 28) on page 57 is a benign tumor composed of adipose tissue, muscle cells, and vascular structures.
Fibromyxoma (figure 29) on page 58 is a benign tumor of fibrous connective tissue in which focal or diffuse degenerative changes result in portions that resemble primitive mesenchymal tissue.
**Fig.:** Female 50-year-old. Axial echo-gradient image demonstrates disrupted medial collateral ligament (arrow), in a patient affected of valgus hallux.

**Fig.:** Female 56-year-old. Coronal echo-gradient image demonstrates a desinsertion of the medial collateral ligament with osteochondral lesion (arrow) at the first metatarsal head and adjacent soft-tissue edema.
**Fig.:** Male 40-year-old. Sagittal T2-weighted plane over the third toe (a) and over the fourth toe (b) show a lesion in the plantar plate of the metatarsophalangeal joints with morphological alteration of the plantar plate insertion (yellow arrows), hyperextension of the third proximal phalanx, luxation of the fourth proximal phalanx (red arrow) and subchondral marrow edema in the fourth metatarsal head (asterisk) in a patient with negative rheumatoid test and non-traumatic antecedent. The patient has generalized degenerative lesions in joints of the foot and hands.
Fig.: Female 73-year-old. Sagittal (a) and axial T2-weighted (b) images show a large lobulated collection of synovial fluid within the extensor tendon sheath of the big toe (arrows).
**Fig.** Female 44-year-old. Coronal T2-weighted image shows synovial fluid within the short flexor tendon sheath of the second toe (yellow arrow). Note osseous of the second metatarsal and soft-tissue edema surrounding it (red arrow), because of a repetitive trauma.
**Fig.** Female 52-year-old. Coronal echo-gradient image demonstrates a painful focalized lesion with adjacent soft-tissue edema at the distal plantar aponeurosis (arrows), indicating fascitis.
**Fig.**: Female 46-year-old. Axial echo-gradient (a) and sagittal T2*-weighted (b) images show a disruption of the medial septum of the plantar aponeurosis under the first head metatarsal (yellow arrow), surrounded of the edema soft-tissue. Note the plantar fascia retraction (red arrow).
Fig.: Female 28-year-old. Sagittal non-contrast (a) and contrast T1-weighted (b) images demonstrate an encapsulated mass (arrows) without contact with the plantar fascia, which no-homogenously enhanced after intravenous administration, on the medial side of the first metatarsal base.
Fig.: Female 38-year-old. Coronal T1-weighted image shows a solid mass (arrow) at the third intermetatarsal space, confirming the clinical highly suspect of Morton's neuroma.

Fig.: Female 51-year-old. Coronal T1-weighted image shows a reappeared solid mass at the plantar second intermetatarsal space, six year after the surgical exeresis of the Morton's neuroma.

Fig.: Male 47-year-old. Coronal T2-weighted (a) and axial fat-suppressed T1-weighted (b) images show metatarsal bone edema (red asterisks), tenosynovitis of the flexors
tendons (red arrows), synovitis (yellow arrows) and osseous erosions (white arrow), constituting the initial phase of rheumatoid arthritis affecting the hands and the feet of the patient, with three years of evolution.

Fig.: Female 56-year-old. Sagittal (a) and coronal (b) T2-weighted images show multiples osteochondral lesions (red arrows) in the first metatarsophalangeal joint with a surrounded heterogeneous soft-tissue structure (yellow arrows), corresponding to the chronic synovial proliferative, eight years after valgus hallux surgery.
**Fig.:** Female 44-year-old. Axial T1-weighted fat-suppressed demonstrates a well delimited with lobulated aspect and signal hyperintensive cyst lesion on the dorsal region of the forefoot (arrows).

![Image](image1.png)

**Fig.:** Male 62-year-old. Coronal (a) and sagittal (b) T2-weighted images show a large fluid collection (yellow arrows) that affect the plantar aponeurosis extending from the tarsal canal to the metatarsal heads with skin defect representing perforation plantar (red arrow), directly below flexors tendons and, for the time being, respecting the adjacent bones of a diabetic patient.
Fig.: Male 32-year-old. Axial T2*-weighted (a) and coronal echo-gradient (b) show a plantar abscess (arrows) affecting the fifth metatarsal with signal hypointensity area in its marrow bone (asterisk) and lateral part of the cuboids, indicating osteomyelitis in the diabetic patient with amputee fourth and fifth metatarsals.
**Fig.** Female 38-year-old. Coronal fat-suppressed T1-weighted image shows a fluid collection in the fourth intermetatarsal bursa (arrow) with a transverse diameter of more than 3 mm, ruling out the preliminary clinical diagnosis of Morton neuroma.
Fig.: Female 21-year-old. Axial T2*-weighted image shows an heterogeneous low signal intensity growing structure (arrow) on the medial side of the first metatarsophalangeal joint, three years after juvenile valgus hallux surgery, corresponding to reactive reparative fibrosis.

Fig.: Female 37-year-old. Sagittal T2-weighted (a) and fat-suppressed T1-weighted (b) images demonstrate a painful high signal intensity rounded and ill defined plantar lesion. The preliminary clinical diagnosis of the lesion was Lederhosen fibromatosis.
Male 33-year-old. Sagittal T2-weighted (a), axial no-contrast T1-weighted (b) and coronal contrast-enhanced T1-weighted (c) images show a large heterogenous mass (arrows) on the medial side of the first metatarsophalangeal joint, involving the flexor tendons of the big toe. The mass no-homogenously periphery enhanced after intravenous administration. The patient, with a well-known clinical history of gout, also had tophaceous masses in other joints.
Fig.: Female 24-year-old. Coronal echo-gradient (a) and axial fat-suppressed T1-weighted (b) images show a high signal intensity trabecular pattern of the mass (arrows) in the dorsal subcutaneous spot relative to the fifth metatarsal.
**Fig.**: Male 52-year-old. Axial T2-weighted (a) and sagittal fat-suppressed T1-weighted images demonstrate a large high signal intensity tubular, serpinginosed and arrosoniaded structures (arrows) at the forefoot.
Fig.: Male 35-year-old. Coronal T2*-weighted image shows a large lobulated and homogenous soft-tissue mass (arrows) involving the bones and the extensors and flexors tendons of the second and third metatarsals with extension to the base of the first metatarsal head affecting its soft tissues structures and sesamoids. Localized nodular tenosynovitis was confirmed at pathological examination.
**Fig.:** Male 36-year-old. Sagittal T2*-weighted (a) and T2-weighted (b) images demonstrate painful thickened fascia with an ill defined and no-homogeneous nodular mass (arrows) at the plantar fascia, corresponding to a local aggressive plantar fibromatosis.
Fig.: Female 46-year-old. Axial T2*-weighted (a), T2-weighted (b) and coronal contrast T1-weighted images (c) show a lobulated and septed soft-tissue mass (arrows) at the tip of the second toe, involving the flexors tendons and producing erosive the distal two phalanges, which can be visualized on x-ray (red arrow) (d).
**Fig.:** Female 56-year-old. Axial (a) and coronal T2*-weighted images show a high signal intensity soft-tissue mass (arrows) surrounding the first phalange of the big toe, charactering the lipoma.
Fig.: Male 70-year-old. Sagittal fat-suppressed T1-weighted image shows high signal intensity little mass (arrow) at the tip of the big toe.

Fig.: Female 47-year-old. Sagittal T2-weighted (a) and coronal echo-gradient (b) images demonstrate a heterogenous mass (arrows) in the third intermetatarsal space, with extension to the plantar. The mass initially was suspected to the Morton neuroma.
**Fig.**: Female 68-year-old. Coronal T1-weighted (a) and axial STIR (b) images show a lipomatous characteristics of soft-tissue mass (yellow arrows) at the plantar base relative to the first phalange of the big toe, respecting the flexors tendons. Pathological examination depicted this definitive diagnosis. Note valgus hallux and its complications (red arrow).
Fig.: Male 39-year-old. Coronal echo-gradient (a) and sagittal fat-suppressed T1-weighted images show a rather homogenously high signal intensity no-painful solid mass (arrows) in the first metatarsal space with extension to the plantar. The preliminary diagnosis was soft-tissue low-aggressive sarcoma.

Additional images for this section:
**Fig. 1:** Female 50-year-old. Axial echo-gradient image demonstrates disrupted medial collateral ligament (arrow), in a patient affected of valgus hallux.

![Image of axial echo-gradient image demonstrating disrupted medial collateral ligament](image1)

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![Image of coronal echo-gradient image demonstrating desinsertion of medial collateral ligament](image2)
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![Image of a well-delimited cyst lesion on the dorsal region of the forefoot.](image)

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![Image of a large fluid collection affecting the plantar aponeurosis in a diabetic patient.](image)
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Conclusion

MRI can provide high-quality multiplanar images useful in the evaluation of forefoot pathology. MRI has proved especially useful in detecting the numerous soft-tissue and early bone and joint processes occurring the forefoot that are not depicted or as well characterized on other modalities. MRI often enables a specific diagnosis based on the location, signal intensity characteristics, and morphologic features of the abnormality. Consequently, MR imaging is increasingly being used to evaluate patients with forefoot complaints.

Personal Information

References


