Differential Diagnosis of common causes of foot pain in adults

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Learning objectives

1) In this pictorial poster, we show different causes of foot pain.
2) Review image modalities used to assess foot.
3) Understand important imaging features that aid in correct diagnosis of the given pathology.
Background

It is worthwhile for a radiologist to have some knowledge of the potential causes of foot pain and their imaging features.

These can be broadly divided as follows:

- **Trauma**: radiographically occult fracture, sesamoiditis-AVN, stress fracture, plantar plate disruption.
- **Infection**: osteomyelitis, septic arthritis.
- **Joint disorders**: osteoarthritis, gout, rheumatoid arthritis, neuropathic osteoarthropathy.
- **Tendon disorders**: tendinosis, tenosynovitis, tendon rupture.
- **Non-neoplastic soft-tissue masses**: Morton neuroma, plantar fibromatosis, ganglia, bursitis, haemangioma.
- **Neoplastic masses**: bone tumours, benign soft-tissue tumours, malignant soft-tissue tumours.
Imaging findings OR Procedure Details

Multimodality imaging is used for different purposes such as:

- Plain radiograph for osseous lesions.
- Ultrasound for preliminary evaluation of the soft tissue such as fascia, muscles, tendons, ligaments and bursa.
- CT has great value in evaluation of osseous lesions and trauma.
- MRI has superior soft tissue contrast resolution and therefore remains the modality of choice for foot investigation.

We discuss the spectrum of pathologies that can occur in the foot region and their imaging characteristics to aid in the diagnosis.

Morton Neuromas

Morton neuromas are not true neoplasms; rather, they are masses composed of interdigital perineural fibrosis and nerve degeneration.

Morton neuroma is more common in women, and high-heeled shoes have been implicated as a causative factor.

The mass is most commonly found between the 3rd and 4th metatarsal heads.

Pain at the metatarsal head, often radiating to the toes, is characteristic.

Morton neuroma is isointense to slightly hyperintense relative to muscle on T1-weighted MR images (Fig 1).

It is iso- or hypointense relative to fat on T2-weighted images, resulting in poor lesion conspicuity. The use of gadolinium is helpful because intense enhancement typically occurs on fat-suppressed T1-weighted images, increasing the conspicuity of the lesion (Fig 2).

Tenosynovitis

Tenosynovitis is inflammation of the tendon sheath and may be due to synovial inflammatory disease, infection, or mechanical irritation. Tenosynovitis may affect the flexor hallucis longus tendon between the sesamoid bones, where it is subject to repetitive impact, and under the base of the first metatarsal bone, where the flexor digitorum longus crosses under the flexor hallucis longus.

MR imaging findings in stenosing tenosynovitis include thickening of the tendon or
tendon sheath, increased fluid within the tendon sheath, and enhancement of the tendon sheath following intravenous administration of gadolinium (Fig 3,4,5).

**Plantar fibromatosis**

Plantar fibromatosis, or Ledderhose disease, refers to a benign fibroblastic proliferation of the plantar fascia. Nodules or masses of plantar fibromatosis are typically located in the middle to the medial aspect of the plantar arch and may extend to involve the skin or deep structures of the foot.

Lesions have low to intermediate signal intensity on T1-weighted MR images and usually demonstrate low to intermediate signal compared with muscle signal intensity on T2-weighted images (Fig 6,7,8). Contrast enhancement is variable.

**Myositis ossificans**

Myositis ossificans (MO) is a benign process characterised by heterotopic ossification usually within large muscles. Its importance stems in large part from its ability to mimic more aggressive pathological processes. Myositis ossificans is one of the skeletal "don't touch" lesions.

Typically presents as a painful, tender, enlarging mass, which in 80% of cases is located in large muscles of the extremities, often following recognised local trauma, although a definite traumatic event is not always recalled.

In general, histologic stage correlated well with duration of symptoms, which usually were pain and/or soft tissue mass. Early lesions were associated with 3-6 weeks of symptoms, intermediate lesions with symptoms of 6-8 weeks' duration and late lesions with symptoms of up to 10 years' duration.

Plain radiograph: Calcification usually begins to become apparent on plain radiographs within 2-6 weeks, and the lesion reaches the classic well circumscribed peripherally calcified appearance by two months. Over the following 4 or so months, they typically become smaller and denser.

CT scan examination is more sensitive than radiography for detecting ossification and may also show a central fatty metaplastic area.

MRI appearances change with the age of the lesion.

Early features can be misleading because the peripheral calcification is not well seen, and oedema in the soft tissues may extend beyond the often inapparent calcific rim.
On MRI scans, an iso- or slight hyperintensity can be observed within the intramuscular mass on T1W and T2W images respectively. On gadolinium-enhanced T1W images, a hyperintense rim is suggestive of the zone phenomenon and may correspond to active hypervascularized osteoid matrix (Fig 9,10,11). This annular enhancement is distinct from the heterogeneous enhancement seen in sarcomatous tumors. Starting in the subacute phase of MO, the rim may be hypointense on all MRI sequences, indicating mineralization. Other important imaging characteristics of MO include the lack of invasion of adjacent tissues and the presence of viable muscle fibers within the lesion, which are often involved in case of tumor.

**Sesamoiditis**

Sesamoiditis is a painful condition affecting the sesamoids and can occur with or without trauma. This may be due to cartilage abnormalities similar to chondromalacia of patellofemoral joint or inflammation of peritendinous structures. MR imaging findings in the marrow of the sesamoid bones include decreased or normal signal intensity on T1-weighted images and increased signal intensity on STIR images (Fig 13,14,15). Sesamoids have a tenuous circulation making them vulnerable to avascular necrosis. In cases of avascular necrosis trauma may be an aetiological factor. Radiographs may show fragmentation with areas of increased bone density. MRI is also helpful in diagnosis (Fig 16).

**Freiberg disease**

Freiberg disease, also known as Freiberg infraction, is osteochondrosis of metatarsal heads. It typically affects the 2nd metatarsal head (the 3rd and 4th may also be affected).

Clinically they present with pain that is increased by weight-bearing, plus swelling and tenderness. Freiberg’s disease is a pathological condition painful forefoot, which usually affects teenage girls who practice dance and ballet. The exact etiology is unknown, but the disease is often associated with alterations in ossification of the second metatarsal head.

Plain radiographs may show sclerosis and varying degrees of flattening of the articular surface involved (Fig 17).

Early MR 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. With disease progression, flattening of the metatarsal head occurs, and low-signal-intensity changes develop on T2-weighted images as the bone becomes sclerotic (Fig 18,19,20).

**Stress Fractures**
Stress fractures in the metatarsal bones are common in runners, ballet dancers, gymnasts, and military recruits.

Stress fractures refer to fractures occurring in bone due to a mismatch of bone strength and chronic mechanical stress placed upon the bone. Fractures can either be:

-fatigue fracture: abnormal stresses on normal bone

-insufficiency fracture: normal stresses on abnormal bone.

During the first few weeks after the onset of symptoms, x-rays of the affected area may look normal. Positive findings include sclerosis, periosteal reaction/elevation, cortical thickening and a fracture line (Fig 21).

CT: The appearances are similar to those on plain radiograph with sclerosis, new bone formation, periosteal reaction and fracture lines in long bones (Fig 22).

MRI: On MRI the low signal fracture line usually extends through the cortex and into the medullary canal and is elucidated with surrounding bone oedema in the surrounding marrow. MRI is also useful to differentiate ligamentous/cartilaginous injury from bone injury (Fig 23,24,25).

**Plantar fasciitis**

Plantar fasciitis refers to inflammation of the plantar fascia of the foot. It is considered the most common cause of heel pain. It is generally a low-grade inflammatory process involving the plantar aponeurosis with or without the involvement of the perifascial structures. Ultrasound and MRI should be considered as first- and second-line modalities for assessment of plantar fascia disorders, respectively. Patients with contraindications for MR and CT may be helpful in evaluation of plantar fascia (Fig 26,27).

**Soft-Tissue Neoplasms**

**Benign Neoplasms**

Although uncommon, lipomas and nerve sheath tumors may occur in the foot. Lipomas are isointense relative to fat with all pulse sequences (Fig 28, 29). Nerve sheath tumors demonstrate a nonspecific appearance. Schwannomas are well encapsulated and well defined.

**Malignant Neoplasms**

The most common primary malignant soft-tissue neoplasm of the foot in persons under 45 years old is synovial sarcoma. Synovial sarcomas are relatively common intermediate-
to-high grade malignant soft tissue tumours, often with an initial indolent course, and involving the soft tissue surrounding the knees.

MR imaging often reveals a heterogeneous mass with fluid levels and lobulated margins (Fig. 30,31,32).

**Bone Neoplasms**

Bone tumors rarely affect the feet but commonly produce pain and swelling. With both benign and malignant primary tumors, the metatarsal bones were most commonly affected, followed by the calcaneus. The most common benign tumor was giant cell tumor, followed by chondromyxoid fibroma and osteochondroma.

Intraosseous lipomas are rare benign lesions that account for about 0.1-2.5% of all bone tumours (Fig 33,34,35).

The most common malignant primary bone tumors were (in decreasing order) chondrosarcoma(Fig 36,37,38), osteosarcoma, and Ewing sarcoma.

MR imaging is useful for tumor detection and staging.

Computed tomography (CT) can evaluate the osseous architecture for endosteal scalloping, cortical thickening, or disruption. In addition, CT is helpful in identifying the pattern and extent of calcifications.
Fig. 1: Morton neuroma in a patient with pain at the level of the third MTP joint radiating into the toe. Coronal T1-weighted MR image shows a large, teardrop-shaped mass with intermediate signal intensity at the third MTP interspace.

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Fig. 2: Morton neuroma. On a coronal gadolinium-enhanced T1-weighted MR image, the lesion demonstrates diffuse enhancement.

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Fig. 3: Flexor hallucis longus tenosynovitis: T2 axial image of forefoot shows hyper intense fluid signal surrounding the flexor tendon. The flexor tendon itself appears swollen on comparison to subjacent tendon.

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**Fig. 4:** Flexor hallucis longus tenosynovitis: Coronal PDFS image of forefoot shows hyper intense fluid signal surrounding the flexor tendon. The flexor tendon itself appears swollen on comparison to subjacent tendon.

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**Fig. 5:** Flexor hallucis longus tenosynovitis: Sagittal STIR image of forefoot shows hyper intense fluid signal surrounding the flexor tendon.

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**Fig. 6:** Plantar fibromatosis in a 27-year-old man with a painful nodule in the foot. (a) Axial T2-weighted MR image demonstrates a mass with intermediate to low signal intensity in the region of the plantar fascia at metatarsal level.

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Fig. 7: Plantar fibromatosis in a 27-year-old man with a painful nodule in the foot.  
b) Gadolinium-enhanced fat-suppressed T1-weighted MR image shows the lesion with marked enhancement.

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Fig. 8: Plantar fibromatosis in a 27-year-old man with a painful nodule in the foot. c) A nodular soft tissue mass in the distal plantar fascia, adjacent to the muscles, with high-intermediate signal on STIR sequences.

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Fig. 9: Early myositis ossificans in the dorsum of the foot in the region of diaphysis IV metatarsal bone below the extensor digitorum tendon of 33-year-old woman with pain for 3-4 weeks. Axial T2-weighted MR image shows inhomogeneous, relatively well-defined mass surrounded by diffuse edema in adjacent subcutaneous fat of dorsum of the foot. Mineralization was not apparent on radiograph (not shown).

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Fig. 10: Early myositis ossificans in the dorsum of the foot in the region of diaphysis IV metatarsal bone below the extensor digitorum tendon of 33-year-old woman with pain for 3-4 weeks. Sagital Gadolinium-enhanced fat-suppressed T1-weighted MR image and corresponding sagital PD image show the lesion with moderate inhomogeneous enhancement. Surrounding edema is seen enhancing around the lesion. There was no history of trauma.

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**Fig. 11:** Early myositis ossificans in the dorsum of the foot in the region of diaphysis IV metatarsal bone below the extensor digitorum tendon of 33-year-old woman with pain for 3-4 weeks. Sagital Gadolinium-enhanced fat-suppressed T1-weighted MR image and corresponding sagital PD image show the lesion with moderate inhomogeneous enhancement. Surrounding edema is seen enhancing around the lesion. There was no history of trauma.

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Fig. 12: Sesamoiditis; X-ray_2013; 17 years-old-female presenting with pain over 1st metatarsal head of left foot when standing and walking. Tenderness of the plantar MTP I joint. Medial sesamoid of left foot is slightly sclerotic and irregular in shape.

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**Fig. 13:** Sesamoiditis; 17 years-old-female presenting with pain over 1st metatarsal head of left foot when standing and walking. Tenderness of the plantar MTP I joint. 2013. The medial sesamoid shows low signal at T1 WI and high signal STIR WI and intermediate at T2 WI.

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**Fig. 14:** Sesamoiditis; 17 years-old-female presenting with pain over 1st metatarsal head of left foot when standing and walking. Tenderness of the plantar MTP I joint. 2013. The medial sesamoid shows low signal at T1 WI and high signal STIR WI and intermediate at T2.

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Fig. 15: Sesamoiditis; 17 years-old-female presenting with pain over 1st metatarsal head of left foot when standing and walking. Tenderness of the plantar MTP I joint. 2013_The medial sesamoid shows low signal at T1 WI and high signal STIR WI and intermediate at T2.

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**Fig. 16:** Sesamoiditis/AVN; The MR after one year shows a collapsed, fragmented medial sesamoid bone corresponding to AVN or osteonecrosis of the bone. 2014. The medial sesamoid shows low signal at PD WI.

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**Fig. 17:** Freiberg infraction; 16 yo female patient with persistent pain and swelling of the metatarsal phalangeal joint of the second toe. Radiograph demonstrating sclerosis and collapse of the 2nd metatarsal head.

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**Fig. 18:** Freiberg infraction; 16 yo female patient with persistent pain and swelling of the metatarsal phalangeal joint of the second toe. MRI examination shows bone marrow edema of the 2nd metatarsal with evidence of small cortical defect at the level of the head. (Cor PD, Cor STIR, Sag T2W MRI).

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Fig. 19: Freiberg infraction; 16 yo female patient with persistent pain and swelling of the metatarsal phalangeal joint of the second toe. MRI examination shows bone marrow edema of the 2nd metatarsal with evidence of small cortical defect at the level of the head. (Cor PD, Cor STIR, Sag T2W MRI).

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**Fig. 20:** Freiberg infraction; 16 yo female patient with persistent pain and swelling of the metatarsal phalangeal joint of the second toe. MRI examination shows bone marrow edema of the 2nd metatarsal with evidence of small cortical defect at the level of the head. (Cor PD, Cor STIR, Sag T2W MRI).

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Fig. 21: Stress fracture of the 3rd metatarsal. Three weeks later there is periosteal reaction at the site of a stress fracture of the shaft of the 3rd metatarsal. The fracture itself is not visible but the periosteal reaction (callus formation) is.

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Fig. 22: Stress fracture of the 3rd metatarsal shaft in a 40-year-old female. The patient had no history of acute trauma. CT scans depict fractures that are not visualized on plain radiographs.

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**Fig. 23:** Stress fracture of the 3rd metatarsal shaft in a 40-year-old female. The patient had no history of acute trauma. (a) Axial T2FS-weighted MR image shows increased signal intensity within the marrow and adjacent soft tissues. (b) Coronal T1-weighted MR image shows cortical thickening, a low-signal intensity horizontal band representing a fracture line spanning the width of the bone, and adjacent low-signal-intensity changes within the marrow. (c) On a gadolinium-enhanced T1-weighted MR image, the fracture line is more conspicuous. Note the intense contrast enhancement of the adjacent bone marrow and soft tissues.

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Fig. 24: Stress fracture of the 3rd metatarsal shaft in a 40-year-old female. The patient had no history of acute trauma. (a) Axial T2FS-weighted MR image shows increased signal intensity within the marrow and adjacent soft tissues. (b) Coronal T1-weighted MR image shows cortical thickening, a low-signal intensity horizontal band representing a fracture line spanning the width of the bone, and adjacent low-signal-intensity changes within the marrow. (c) On a gadolinium-enhanced T1-weighted MR image, the fracture line is more conspicuous. Note the intense contrast enhancement of the adjacent bone marrow and soft tissues.

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Fig. 25: Stress fracture of the 3rd metatarsal shaft in a 40-year-old female. The patient had no history of acute trauma. (a) Axial T2FS-weighted MR image shows increased signal intensity within the marrow and adjacent soft tissues. (b) Coronal T1-weighted MR image shows cortical thickening, a low-signal intensity horizontal band representing a fracture line spanning the width of the bone, and adjacent low-signal-intensity changes within the marrow. (c) On a gadolinium-enhanced T1-weighted MR image, the fracture line is more conspicuous. Note the intense contrast enhancement of the adjacent bone marrow and soft tissues.

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Fig. 26: Plantar fascitis; Plantar fascial fusiform thickening which involves its proximal portion and extends to the calcaneal insertion, it elicits hyperdensity at CT after contrast administration, yet with no complete fiber disruption. Oedema of the adjacent fat pad and underlying soft tissues.

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**Fig. 27:** Plantar fasciitis; Plantar fascial fusiform thickening which involves its proximal portion and extends to the calcaneal insertion, it elicits hyperdensity at CT after contrast administration, yet with no complete fiber disruption. Oedema of the adjacent fat pad and underlying soft tissues.

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**Fig. 28:** Lipomas follow subcutaneous fat signal on all sequences: T2W MRI.
Fig. 29: Lipomas follow subcutaneous fat signal on all sequences: T2 with Fat.sat.MRI.

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**Fig. 30:** Synovial sarcoma: 41 yo male patient. Sagittal T2W FS MRI. Markedly heterogeneous appearance of synovial cell sarcomas on fluid-sensitive sequences results in so-called "triple sign" which is due to areas of necrosis and cystic degeneration with very high signal, relatively high signal soft tissue components and areas of low signal intensity due to dystrophic calcifications and fibrotic bands.

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Fig. 31: Synovial sarcoma: 41 yo male patient: MRI was performed depicting a well-defined mass in T1W MRI, isointense to muscle. The lesion is located above the proximal insertion of plantar fascia without involvement of calcaneus.

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Fig. 32: Synovial sarcoma: 41 yo male patient. T1W MRI after gadolinium administration. MR reveals heterogeneous enhancement within the solid component.

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**Fig. 33:** Intraosseous Lipoma of the Calcaneus; X ray demonstrates a classical well-defined lytic lesion in the calcaneus with a sclerotic margin and a central calcification. This appearance resembling the badge generally worn upon a hat and called: Cockade sign.
Fig. 34: Intraosseous Lipoma of the Calcaneus; Sharply delineated lesion with predominant fat density and a central inclusion of soft-tissue density and central calcification. Characteristic finding of a bone lipoma with central degenerative changes (fat necrosis)- Milgram type II.

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**Fig. 35:** Intraosseous Lipoma of the Calcaneus, Sagital T1W MRI; The calcaneal lesion is hyperintense on both T1 and T2 weighted images. There is central hypointensity on T1/T2W within the lesion. STIR and PDFS images reveal fat suppression within the lesion.

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Fig. 36: 49 yo male with histology-proven chondrosarcoma. Axial CT scan shows aggressive metatarsal bone destruction, chondroid matrix mineralization in the intraosseous and extraosseous components, and marked low attenuation of a soft-tissue mass.

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Fig. 37: 49 yo male with histology-proven chondrosarcoma. Axial CT scan shows aggressive metatarsal bone destruction, chondroid matrix mineralization in the intraosseous and extraosseous components, and marked low attenuation of a soft-tissue mass.

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Fig. 38: 49 yo male with histology-proven chondrosarcoma. 3D CT scan shows aggressive metatarsal bone destruction, chondroid matrix mineralization in the intraosseous and extraosseous components, and marked low attenuation of a soft-tissue mass.

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Conclusion

Certain populations appear to be at increased risk of developing foot pain. These include: older adults, the obese, active adults who participate in sports that involve running and jumping, active military personnel, and those engaged in certain occupations.

Foot pain can be produced by a wide range of pathology, which makes it challenging for both clinicians and radiologists to find a correct diagnosis. Musculoskeletal radiologists must therefore be aware of the differential diagnoses a simple foot pain may represent.
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REFERENCE:


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