

MRI OF THE ANKLE AND HINDFOOT

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INTRODUCTION

Traumatic injuries of the ankle and hindfoot are the most common musculoskeletal injuries and account for approximately 10% of all visits to emergency departments. Most patients are managed conservatively, and conventional radiographs are the appropriate initial imaging modality. Treatment is usually nonsurgical, and specific advanced imaging definition of the exact extent of soft tissue injuries is usually not required. Elite or high performance athletes may be an exception. Patients referred to MRI are typically those who have failed conservative treatment and have nondiagnostic conventional radiographs. The number of patients referred for MRI of the ankle and hindfoot is less than the more routine examinations of the knee and shoulder. The anatomy is complex and less familiar than more routine studies.

MRI TECHNIQUE

Imaging technique and protocols are as individualized as great gourmet recipes! There are many different ways to create great meals. Here is my favorite ankle recipe. At our institution we utilize 1.5 Tesla or occasionally 3.0 Tesla magnet systems for ankle and hindfoot imaging. We currently use a dedicated foot and ankle high-resolution coil with excellent SNR (Medical Advances QEXTREM, transmit-receive, quadrature coil) which completely encloses the ankle and foot. An extremity coil with an open superior surface, allowing clearance for the forefoot, is an alternative. All of our examinations are performed with the foot and ankle in a neutral position. Some prefer a plantar-flexed position when specifically imaging the tendons which cross the ankle. This straightens the course of the tendons and diminishes “magic angle” artifact. However, ankle ligaments and the Achilles’ tendon are best imaged in a neutral position. Maximal anatomic detail and spatial resolution are best obtained with small FOV and narrow slice thickness. This limits available signal strength since SNR is directly proportional to voxel volume. I find the most useful sequences are high resolution proton density-weighted FSE (w/o fat sat) paired with fluid sensitive T2-weighted, or Intermediate-weighted FSE (with fat sat) images in the axial and coronal planes. I prefer viewing tendon and ligament pathology with the paired PD and fat-suppressed T2-weighted sequences. I utilize the coronal and sagittal fat-suppressed T2 or Intermediate-weighted FSE sequences for evaluation of chondral or osteochondral injuries. This provides an arthrographic appearance with excellent contrast between joint fluid and cartilage. I include a high-resolution T1-weighted FSE sequence in the sagittal plane for better evaluation of bone marrow, osseous fractures, osteonecrosis and characterization of soft tissue or osseous masses if present. I do not feel the T1-weighted sequences provide enough contrast when evaluating tendon and ligament pathology. On rare occasions I will include comparison axial views of the asymptomatic ankle (ie, question of subtle syndesmotic injuries or anterolateral impingement). Chem-sat fat suppression technique utilized with the Intermediate or T2-weighted FSE sequences improves lesion conspicuity. When using standard extremity or surface coils, fat suppression may be incomplete at curved air-soft tissue interfaces such as the heel. There are commercially available “sat pads” which can help minimize this inhomogeneity (this is not necessary with the QEXTREM coil). Also, FSE-IR or two-point Dixon chemical shift MR imaging may be utilized for improved fat suppression. I rarely use intravenous gadolinium when imaging sports or chronic over-use injuries. It may be helpful in distinguishing between simple peritendinous fluid collections vs. stenosing tenosynovitis. Very rarely, intra-articular gadolinium may be used to assess stability of Type III osteochondral lesions of the talar dome (looking for the presence of gadolinium collecting deep to the osteochondral fragment). Hemosiderin-sensitive GRE sequences may be helpful when evaluating cases of giant cell tumor of the tendon sheath, intra-articular PVNS or chronic hemarthrosis. There are many different ways to set up your parameters! Pick what works best at your institution.

AXIAL and CORONAL PLANES

PD-FSE-XL TR-3000; TE-33; ETL-8; BW-32; Matrix-256x256; NEX-2; FOV- (12-14cm); Slice/Space-4mm/.5mm; TRF, VB, Zip 512

Fat-suppressed Intermediate-FSE-XL TR-3000; TE-45; ETL-12; BW-31; Matrix-256x256; NEX-2; FOV- (12-14cm); Slice/Space-4mm/.5mm; TRF, VB, Zip 512

SAGITTAL PLANE

TI-FSE-XL TR-600; TE-min full; ETL-2; BW-32; Matrix-256x256; NEX-2; FOV-(12-14cm); Slice/Space-3mm/.5mm; TRF, VB, Zip 512

Fat-suppressed Intermediate-FSE-XL TR-3000; TE-45; ETL-12; BW-31; Matrix-256x256; NEX-2; FOV-(12-14cm); Slice/Space-3mm/.5mm; TRF, VB, Zip 512

OPTIONAL SEQUENCE

Post-gadolinium 2D Fast SPGR TR-150-250; TE-min full; flip angle 70; BW-32; Matrix-256x224; NEX-2; FOV-(12-14cm); Slice/Space-3mm/.5mm; npw

ANATOMY

The soft tissue anatomy of the ankle and hindfoot is quite complex and can be intimidating. It is easiest to partition the anatomy into groups of ligaments and tendons. Although it is certainly important to know all of the anatomic structures, I have placed an asterisk by those which you most likely will be assessing directly at the request of the referral clinician. As a recommendation, all cases should be reviewed dynamically at an interactive work station, scrolling through images. Findings should be confirmed in all three image planes. Realize that the Anterior Inferior Tibiofibular Ligament (AiTbFL) of the syndesmotic complex has an oblique course beginning more superiorly at its tibial attachment and extending inferolaterally to its fibular attachment. The continuity of that structure is established by dynamically scrolling through the axial images. Also, on occasion the Anterior Talofibular Ligament (ATFL) can be difficult to completely visualize on the axial images alone. Viewing this structure on the coronal images can be extremely helpful, especially in detecting subtle avulsions of the ligament from its lateral malleolar attachment. The Calcaneofibular Ligament (CFL) has an oblique course, best seen on the axial AND coronal images, immediately deep to the peroneal tendons. Some recommend oblique images parallel to this structure, although I do not find that necessary. The Deltoid Ligament, and the Posterior Talofibular Ligaments (PTFL) have a striated "ACL-like" appearance normally.

Ligaments

- Lateral complex ATFL*, CFL, PTFL
- Medial complex Deltoid Ligament (deep and superficial)
- Syndesmotic complex AiTbFL*, PiTbFL, IM, ITL
- Spring Ligament Plantar calcaneonavicular

Tendons

- Anterior compartment TA*, EHL, EDL, PTr
- Medial compartment PT*, FDL, FHL*
- Posterior compartment AT*
- Lateral compartment PB*, PL

Osseous

- Bones Tibia, fibula, talus, calcaneus
- Accessory bones Os trigonum*, Os peroneum, Navicular

Other

- Sinus tarsi conical space of lateral hindfoot*

- Tarsal tunnel medial fibro-osseous tunnel*

On occasion accessory muscles may be noted on MR. These are usually asymptomatic, but occasionally present as a mass or with pain. The two most common are the accessory soleus muscle and the peroneus quartus muscle. The accessory soleus frequently presents as an asymptomatic mass or area of fullness within the pre-achilles space. The peroneus quartus is usually asymptomatic but can be associated with peroneal tendon pathology.

ANKLE AND HINDFOOT PATHOLOGY

The clinical differential for patients with persistent ankle pain following a period of conservative therapy with negative conventional radiographs includes osseous pathology such as osteochondral fractures of the talar dome and tibial articular surface, occult traumatic and stress fractures and bone marrow edema syndromes. Soft tissue injuries typically presenting in this group of patients include syndesmotic injuries, impingement syndromes, chronic ligamentous instability and synovitis, peroneal tendon tears or dislocation, and sinus tarsi syndrome.

OSSEOUS ABNORMALITIES

Fractures

MRI may be very helpful in identifying a variety of traumatic osseous injuries that are not obvious on conventional radiographs. Both T1W and T2W images are sensitive in demonstrating band like areas of signal abnormality, which are consistent with occult fractures. Fat-suppressed T2W images typically show bright signal marrow edema bordering a dark signaling fracture line. Similar to the “kissing contusion” patterns seen with ligamentous injuries of the knee, there are analogous bone contusion patterns seen with soft tissue ankle injuries. Unsuspected post-traumatic chondral, or osteochondral fractures may be seen. Also, displaced intra-articular loose bodies may be demonstrated.

- Traumatic (osseous, osteochondral or chondral)
- Stress (fatigue and insufficiency type)
- Contusions (acute injury w/o fracture line)
- Stress reaction (chronic/overuse injury w/o fracture line)

Types of fractures which are notoriously missed on conventional radiographs and are subsequently detected with advanced imaging include; anterior process fractures of the calcaneus, lateral tubercle of the posterior process of the calcaneus (“*Shepherd's fracture*”), lateral process fractures of the talus (“*Snow boarders fracture*”), occult stress fractures of the distal tibia, talus, calcaneus and navicular, and osteochondral injuries.

Bone Marrow Edema

The appearance of bone marrow edema (dark on T1 and bright on T2) is nonspecific and may overlap with other entities. The differential diagnosis for bone marrow edema pattern in our generic post-traumatic patient would include RSD (realize that disuse osteoporosis occurs in most patient’s who have been splinted or casted and can cause very similar radiographic and MR features), altered weight bearing, stress reaction or post-traumatic degenerative arthritis with subchondral edema.

Bone Infarcts

Bone infarcts are usually demonstrated as dark serpiginous lines surrounding fat signaling areas on T1W images and “double line sign” on T2W images. These occur at typical locations in patients at risk. Smaller infarcts may be primarily sclerotic.

Osteochondral lesions of the Talus (OLT)

OLT is an accepted term for a variety of disorders including osteochondritis dissecans, transchondral and osteochondral fractures. All are due to direct or repetitive microtrauma to the talar dome (torsional or rotary sheering). In osteochondritis dissecans this leads to osteonecrosis, subchondral fracture and collapse. MRI aids

OLT detection and may be useful in predicting lesion stability and treatment stratification. In general, linear fluid signal or cystic change deep to the osteochondral lesion correlates with instability at arthroscopy. Lesions are typically located at the posteromedial or anterolateral talar dome. Osteochondral lesions may also occur at the tibial articular surface. There are several classification systems for describing OLTs, including specific MRI or arthroscopic categorization. The most commonly used classification system is the Berndt and Harty clinical description listed below.

- **STAGE I:** **Compression fracture**
- **STAGE II:** **Partially detached**
- **STAGE III:** **Completely detached in situ (stable vs. unstable)**
- **STAGE IV:** **Completely detached and migrated**

Berndt AL, Harty M: Transchondral fractures (osteochondritis dissecans) of the talus. J Bone Joint Surg [Am] 1959; 41:988

Accessory Ossicles

There are many accessory ossicles located around the foot and ankle. Most are of no clinical significance. A few have been shown to cause clinical symptoms.

- Accessory navicular (marrow edema and PTT dysfunction)
- Os trigonum (posterior impingement syndrome)
- Os peroneum (injury of Peroneus Longus)

Hindfoot Coalition

Hindfoot coalitions may be osseous, fibrous or cartilaginous and are found in 1-5% of the population and may be bilateral in 20% of patients. They typically become symptomatic in 2nd and 3rd decades when they ossify. The two most common types are talocalcaneal and calcaneonavicular, which account for greater than 90% of cases. Oblique conventional radiographs usually are diagnostic of osseous calcaneonavicular coalitions. Indirect plain film findings of talonavicular coalitions (sustentacular type) include anterior talar beaking, broadening of the lateral process of the talus, narrowing of the posterior subtalar facet joint and a ball and socket type tibiotalar joint. MR and CT are both useful in osseous type coalitions; however CT is faster and provides better spatial resolution and bone detail. Sagittal images are best for calcaneonavicular. Coronal are best for talocalcaneal. Findings may be more subtle in nonosseous types. MRI is usually ordered if the diagnosis has not been made, or if the clinical differential diagnosis is broad.

LIGAMENTS

MRI is not indicated for imaging of routine ankle sprains in the immediate post-injury period. MR should be reserved for chronic ligamentous instability and pain or specific ligamentous pathology or problem solving. ATFL injuries are common and infrequently imaged. Acute injuries may demonstrate a thickened, attenuated or disrupted ligament with fluid signal. Chronic ATFL injuries are demonstrated by thickened (>3mm) structures which may cause lateral impingement symptoms. More likely clinical presentations to be referred to MR include anterolateral impingement, sinus tarsi syndrome, deltoid ligament injury, and syndesmotic injuries “high sprains.”

Anterolateral Impingement

Entity first described in 1950 which represents a cause of chronic ankle pain following multiple inversion sprains of the lateral ligament complex. Patients present clinically with pain and limitation of tibiotalar motion. Causes include post-traumatic anterolateral ligamentous hypertrophy, nodular synovitis and hemorrhage leading to a “meniscoid lesion.” Also, patients with accessory fascicles of the AiTbFL and those with loose bodies and exostoses in the region of the anterolateral gutter may develop impingement. Clinically, patients are typically diagnosed and treated with ankle arthroscopy with debridement of hypertrophied scar tissue. MRI may exclude

other entities and show some diagnostic features. It may be helpful to consider intra-articular gadolinium to better demonstrate nodular synovial scarring and meniscoid lesions, although this is not necessary in most cases.

Sinus Tarsi Syndrome

The sinus tarsi is a cone-shaped space opening to the lateral aspect of the hindfoot with the apex of the cone located between the middle and posterior subtalar facet joints. The space is normally filled with fat, ligaments and neurovascular structures. This space may become filled with post-traumatic fibrosis, scar tissue or edema or occupied by masses which are typically benign (ganglion cysts, venous varicosities). Patients present clinically with chronic lateral hind and midfoot pain. MRI may show replacement of the normal fat with decreased T1SI and increased or decreased T2SI. *Imaging findings alone may be nonspecific. Diagnosis requires classic clinical features in conjunction with typical imaging appearance.*

Deltoid Ligament Injury

The deltoid ligament is a strong medial ligament with deep and superficial components which is rarely injured without associated fractures. The mechanism of injury is typically eversion and external rotation. The normal ligament has a striated ACL-like appearance. With ligamentous sprain, the striated fibers become indistinct, with increased T2 signal. Clinicians do not typically refer patients to specifically define the injury. More typically, MRI is ordered to evaluate a broader differential diagnosis, which may include osteochondral injuries, occult fractures or additional soft tissue injuries.

Syndesmotic Complex Ligamentous Injuries

These ligamentous injuries are also referred to as “high sprains” and often occur in athletes with presumptive clinical diagnoses of routine lateral ankle sprains. As many as 10% of patients with presumptive routine lateral ankle sprains may in actuality have syndesmotic sprains. These patients have continued chronic ankle pain and instability despite conservative management and may require prolonged rehabilitation, closed casting, arthroscopic intervention or internal fixation depending on the severity of the injury. It is important to assess the stability of the distal tibiofibular joint, which can be difficult to evaluate with a non-weightbearing MR study. This is best accomplished by assessing the width of the tibiofibular clear space on weightbearing AP standing radiographs. This space should normally be less than 6mm, and it is helpful to compare to the asymptomatic ankle. Orthopedic surgeons may perform dynamic stress imaging under fluoroscopy to determine whether a syndesmotic screw may be necessary to stabilize the joint. The AiTbFL is the most common ligament to be torn. Typical MR appearance is a thickened and indistinct ligament with increased T2 signal in the acute injury phase. More chronically, focal disruption of the AiTbFL may be appreciated and heterotopic ossification may develop in the interosseous membrane.

TENDONS

There are 10 tendons which cross the ankle. Other than the achilles tendon, the remaining tendons cross the ankle joint in a curved fashion transmitting forces from the muscular compartments of the lower leg to the bones of the foot. This change in course is reinforced by osseous projections or grooves and restraining retinaculi which establish a pulley type mechanism to efficiently distribute the forces. These osseous and retinacular structures can also act as stress points predisposing to segments of tendinopathy and tendon tearing. In addition, these tendons all have hypovascular segments which are common locations for tendon pathology. In regard to imaging, the curved portions of the tendons which are 45° – 65° (55°) to the bore of the magnet are predisposed to magic angle effect. It is important to rely on higher TE sequences (>40ms) to exclude this artifact. Curved segments of the peroneal and posterior tibial tendon are especially prone to this artifact. All ankle tendons other than the achilles tendon are surrounded by a synovial sleeve. The peroneal tendons share a single synovial sleeve proximally. The distal segment of the posterior tibial tendon is not included within the synovial sheath. Asymptomatic volunteers have been shown to have small amounts of synovial fluid surrounding tendons. Therefore, the diagnosis of “tenosynovitis” requires localized imaging findings which match the clinical pain presentation. Abnormal tendons have abnormal signal within them, and/or surrounding them with altered morphology. Simply put, abnormal tendons are too thick, too thin or disrupted. Several tendons may develop longitudinal split tears, especially the peroneus brevis tendon. As previously mentioned, it may be helpful to utilize intravenous gadolinium in cases of

suspected mechanical stenosing tenosynovitis which demonstrates enhancing thickened tenosynovium. I prefer not to use the term “tendinitis” in dictations (although it is commonly used by clinicians) since tendon pathology is not due to an inflammatory process. Rather, I use the same terminology I would for rotator cuff tears of the shoulder: *tendinopathy*>*partial thickness tear*>*full thickness tear*, utilizing similar imaging criteria. Although most tendon tears are seen in degenerated tendons due to overuse, increased risk of tearing is also seen in patients with inflammatory arthropathies, and/or patients on systemic steroids.

Achilles Tendon

The achilles tendon is one of the strongest tendons in the body. It is normally 6mm in maximal thickness with a flat anterior or ventral surface. The tendon is surrounded by a peritenon, but not a synovial sleeve. The fat space anterior to the tendon is referred to as Kager’s fat pad. At the calcaneal insertion, there are two lubricating bursa structures. One is located superficial to the tendon; the other is located deep to the tendon and immediately overlying the adjacent calcaneus “retrocalcaneal bursa.” The achilles tendon is the most frequently torn tendon of the body. Most tears occur in the critical zone of the tendon located 2cm-6cm proximal to the calcaneal insertion. The typical patient is a deconditioned middle aged “weekend warrior” who experiences a characteristic pop with sudden pain during a push-off maneuver during a recreational sporting event. Most experienced orthopedic surgeons and sports physicians are able to accurately diagnosis complete tears without MRI. However, on occasion partially torn tendons, or difficult physical examinations may hinder examination accuracy. MRI may direct treatment triage. Currently, open primary repair is the preferred treatment method for completely torn tendons, although some patients opt for closed management. Insertional tears of the tendon may be seen with rheumatoid arthritis patients, or patients with reactive exostoses of the posterosuperior calcaneus “Haglund’s syndrome.” It may be necessary for surgeons to perform an osteotomy of the osseous protuberance in patients who do not respond to conservative therapy.

Medial Tendons

The posterior tibial tendon is the second most commonly torn tendon of the ankle following the achilles tendon. The typical patient is a middle-aged female with acquired pes planus, although it is also seen in athletes with overuse syndromes, in patients with accessory navicular bones, and in patients with a history of rheumatoid arthritis, steroid use or diabetes. The normal tendon should be approximately 2x as large as the adjacent flexor digitorum longus tendon. The distal segment of the tendon leading to its navicular insertion is extrasynovial and may normally have a bulbous and striated appearance. Most tendon pathology occurs in the high stress critical zone at the curved portions of the tendon. The abnormal tendon is too big, attenuated or disrupted with abnormal MR signal within it and/or around it. Occasionally, tears are longitudinal split type. There is frequently associated tenosynovitis and reactive bone marrow edema in adjacent osseous structures.

The flexor hallucis longus tendon is infrequently torn. It is the most likely ankle tendon to have asymptomatic fluid within the tendon sleeve given its close proximity to the ankle joint. It may be symptomatic in cases of posterior impingement or stenosing tenosynovitis which may be associated with an unfused os trigonum. Impingement is most commonly seen in patients with excessive plantar flexion overuse, such as ballet dancers or soccer players.

Peroneal Tendons

The peroneus brevis and longus tendons are the lateral tendons of the ankle which weakly evert and plantar-flex the ankle joint. They share a common synovial sleeve proximally. They are in close contact with the CFL ligament, which is immediately deep to them just below the level of the lateral malleolus. The peroneus brevis tendon (PB) is normally located anterior and medial to the peroneus longus (PL), at and above the lateral malleolus. The PB may normally have a flattened and/or slightly curved configuration at this level, but must be analyzed carefully for longitudinal split tears which can be subtle. These tendons are held in place by soft tissue structures (superior and inferior peroneal retinaculi) and osseous grooves and protuberances (retromalleolar sulcus, lateral malleolus, peroneal tubercle, peroneal groove). Failure of these structures, whether congenital or acquired, may predispose to tendon dislocation. Surgeons may request direct imaging of the superior peroneal retinaculum in cases of peroneal tendon dislocations. Tendinopathy and tendon partial and full thickness tears occur at high stress points. Peroneus brevis tears are frequently split-type. Peroneus longus tears may occur in conjunction with an abnormal os peroneum.

Anterior Tendons

The tibialis anterior tendon is the largest and most medial of the anterior tendon group. It is separated from the other anterior tendons by a septation, and functions as a strong dorsiflexor and invertor of the foot. Tears are infrequent, but typically occur at the level of the inferior edge of the overlying superior extensor retinaculum. Overuse tears occur in downhill hikers and runners. Spontaneous tears occur in patients with RA, DM or steroid use.

SOFT TISSUE DISORDERS

Tarsal Tunnel Syndrome

The tarsal tunnel is a fibro-osseous space at the medial aspect of the ankle beneath the overlying flexor retinaculum and underlying osseous structures which contains the medial tendons and neurovascular structures. It is the ankle equivalent of the carpal tunnel of the wrist. Tarsal tunnel syndrome is a compressive neuropathy of posterior tibial nerve, or its terminal branches within this space typically due to a benign, space-occupying mass. Etiologies include post-traumatic osseous deformity, fibrous scarring, ganglion cysts, venous varicosities, or peripheral nerve sheath tumors

Plantar Fasciitis

Plantar fasciitis is a clinical cause of plantar hindfoot pain typically caused by overuse syndromes or inflammatory arthropathies with associated enthesitis. MR imaging findings characteristically demonstrate fascial thickening with increased T2 signal within and surrounding the plantar fascia and reactive marrow edema in the adjacent bone. On occasion the structure may be focally torn or disrupted due to trauma. More discrete nodularity of the plantar fascia may be seen with plantar fibromatosis.

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