MR Imaging of normal ankle anatomy: What the radiologists need to know

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Purpose

Musculoskeletal diseases are increasingly being recognized due to the widespread use of magnetic resonance (MR) imaging. Its high soft-tissue contrast resolution, noninvasive nature and multiplanar capabilities have made MR imaging an indispensable tool in the study of musculoskeletal lesions, and orthopedic surgeons are relying on its information for many therapeutic decisions.

One of the most common reasons to perform an MR imaging examination of the ankle is to examine the soft- tissue structures around it, such as tendons and ligaments, and for detecting occult bone injuries before they became evident at other imaging modalities. Therefore, understanding the anatomy of the ankle is necessary to make a correct diagnosis. But the anatomic complexity of this area has made ankle MR imaging became a challenge for radiologists.

The purpose of this poster is to review the anatomy of the ankle seen with MR imaging, particularly structures that can be affected by disease (ligaments and tendons), and to discuss the radiological findings of common pathologic conditions around this area.
Methods and Materials

MR imaging is performed at our institution on a 1.5-T scanner (Signa Horizon LX, GE Healthcare) with an extremity surface coil.

Ankle MR imaging standard protocol is performed in the axial, coronal, and sagittal planes and includes: sagittal T1-weighted spin-echo (repetition time msec /echo time msec = 440/13), axial T2-weighted fast-spin-echo (3540/110.1), axial proton-density-weighted (PDW) fat-suppressed (2500/9.44), coronal PDW fat-suppressed (4000/ 9.616) and sagittal short inversion time inversion recovery (STIR) (4220/47.88) sequences. T1-weighted fat-suppressed sequences before and after gadolinium administration are used only in specific situations, as differentiating between a cystic or a solid mass and in inflammatory or tumoral processes.

The patient is in supine position with the foot in neutral position (20° of plantar flexion). Plantar flexion is useful for three reasons: it decreases the magic angle effect, accentuates the fat plane between the peroneal tendons, and allows better visualization of the calcaneofibular ligament.

T1-Weighted sequences are especially useful for anatomic study. T2-Weighted sequences provide information of fluid, edema, and hemorrhage, being very useful for detecting pathology. Marrow abnormalities are best evaluated with fat-suppression techniques such as PDW fat-suppressed or STIR sequences.

The "magic angle phenomenon" is an MR imaging artifact that occurs on sequences with a short TE. It consists in an intrasubstance signal increase in normal tendons passing around the ankle, mimicking tendinopathy. It happens when the orientation of the tendons is off axis relative to the main magnetic field. A typical situation is in the peroneal tendons as they hook around the lateral malleolus. To avoid this problem, the study can be repeated with the foot in a different position, as prone position with plantar flexion.
Results

ANKLE LIGAMENTS:

1) NORMAL LIGAMENTOUS ANATOMY:

Ligaments around the ankle can be divided into three groups: syndesmotic ligamentous complex, lateral collateral ligament and medial collateral ligament or deltoid ligament. Fig. 1 on page 18

Ligaments appear at MR images as thin, linear, low-signal-intensity structures joining adjacent bones and are usually delineated by contiguous high signal intensity fat. Some ligaments have a striated appearance because interpose fat between its fibers, what is normal and should not be confused with partial tears.

Axial and coronal images are recommended to allow visualization of the ligaments in their entirety. Ligaments can be seen in one image or must be followed on contiguous images.

- Syndesmotic ligamentous complex: Fig. 2 on page 18

The syndesmotic ligamentous complex is composed of the anterior and posterior tibiofibular, and interosseous ligaments. They join the distal epiphyses of the tibia and fibula, giving stability to resist the axial, rotational, and translational forces.

The anterior and posterior tibiofibular ligaments are seen at the level of the tibial plafond and talar dome on usually two or more sequential axial and coronal MR images. The most useful plane for the evaluation of the syndesmotic ligamentous complex is the axial one.

- The anterior tibiofibular ligament originates in the anterior tubercle of the tibia (5 mm in average above the articular surface), and its fibers extend in a distal and lateral direction to the anterior margin of the lateral malleolus. Functionally is the most important ligament. On axial images, it often appears striated and discontinuous owing to fat interposed between the fascicles of the ligament.

- The posterior tibiofibular ligament is found on the most distal sections through the tibia. Originates at the posterior edge of the lateral malleolus and directs proximally and
medially to insert in the posterior tibial tubercle. This component would be homologous to the anterior tibiofibular ligament. The inferior part is called the \textit{transverse ligament}. Sagittally it is seen as a signal void structure, which should not be mistaken for a loose body. \textbf{Fig. 3 on page 19}

- The \textit{intermalleolar ligament} is a common normal variant. It runs distal to the inferior transverse ligament, and inserts laterally near the posterior talofibular ligament, and medially on the posterior tibia or medial malleolus.

- The \textit{interosseous tibiofibular ligament} is considered a distal continuation of the interosseous membrane at the level of the tibiofibular syndesmosis.

\begin{itemize}
  \item \textbf{Lateral collateral ligament complex: Fig. 4 on page 20, Fig. 5 on page 21}
\end{itemize}

The lateral collateral ligament complex is subdivided into the anterior talofibular, calcaneofibular, and posterior talofibular ligaments. The anterior and posterior talofibular ligaments are usually seen on a single axial image obtained slightly distal to the tibiofibular ligaments.

- The \textit{anterior talofibular ligament} is a band that originates at the anterior margin of the lateral malleolus and runs anteromedially to the insertion on the talar body, anterior to the fibular articular surface. The average width is 6-10mm. Variations in width does not modify ligament's function. In neutral position is horizontal to the ankle, but inclines upward in dorsiflexion and downward in plantar flexion. Because of its horizontal orientation it is better visualized on axial images. Is closely related to the ankle joint capsule. Its function is limiting anterior displacement of the talus and plantar flexion of the ankle.

- The \textit{calcaneofibular ligament} originates from the anterior part of the lateral malleolus and runs obliquely downward and backwards to attach to the posterior region of the lateral calcaneal surface. The ligament is best demonstrated on axial images as a thin band deep to the peroneal tendons, but it is not always identify at MR images. The ligament is homogeneous and rounded and with a diameter of 6-8 mm and its length is about 20 mm. It is separate from the ankle joint capsule, but it is intimately associated with the peroneal tendons sheath. Calcaneofibular ligament is often partially imaged in coronal or axial planes, so multiple images are often needed to visualize its entire course.

- The \textit{posterior talofibular ligament} originates from the malleolar fossa (where the lateral malleolus is concave towards the talus) coursing almost horizontally to insert with broad attachment, as a fan shaped insertion, in the posterolateral talus. It is also best seen in the axial plane and has an inhomogeneous appearance and thickening
that correlates with individual fibers separated by fatty tissue, which should not be misinterpreted as a tear.

The fibers of the anterior and posterior tibiofibular ligaments may be
crossed with those of the anterior and posterior talofibular ligaments at MR imaging. The anterior and posterior tibiofibular ligaments courses above the joint (where the talar dome is seen) and inserts onto the fibula above the malleolar fossa. The anterior and posterior
talofibular ligaments are usually seen on a single axial image obtained just below to the
tibiofibular ligaments (where the talus shape is more oblong) and inserts at the level of
the malleolar fossa.

• Medial collateral ligament or deltoid ligament: Fig. 6 on page 22, Fig. 7 on page 23

The medial collateral ligament, also known as the deltoid ligament, is a strong
ligamentous complex with various components that attach the medial malleolus to
multiple tarsal bones. This components are not easily separated with MR imaging. It is
situated under the medial flexor tendons of the ankle and each component is named
according to their attachments. It is the main stabilizer against valgus and pronation force,
as well as rotational forces on the talus.

It can be divided into a superficial and deep group of fibers:

- The deep layer courses from the tip of medial malleolus to the medial talar surface and
is divided into the anterior and posterior tibiotalar ligaments. They have a fan shaped,
specially the posterior tibiotalar ligament, and normally demonstrate regular striations
giving a heterogeneous appearance. The deep layer is intraarticular and is covered by
sinovium.

- The superficial layer courses from the medial malleolus to the navicular bone
(tibionavicular ligament), to the calcaneus (tibiocalcaneal ligament) and the
tibiospring ligament. The tibiocalcaneal runs vertically, deep to the flexor retinacula and
superficially to the tibiotalar ligaments. The tibiospring ligament is the only component
without a distal bone attachment, because it joins the spring ligament. It is a secondary
stabilizer of the medial plantar arch, being the posterior tibialis tendon the first one.

The various components of the deltoid ligament are well visualized on both axial
and coronal images, but coronal plane is recommended to differentiate the deep and
superficial layers.
The posterior tibiotalar ligament and the tibiospring are always visible on MR images of the ankle, tibiocalcaneal ligament usually is visible, but the anterior tibiotalar and tibionavicular ligament are less frequently well demonstrated on MRI imaging.

2) LIGAMENTS INJURIES:

Ankle ligament injury is the most frequent cause of acute ankle pain. The lateral collateral ligament complex is the most commonly injured group of ankle. The anterior talofibular ligament is the weakest ligament and therefore the most frequently torn. It can be a single lesion, or can affect sequentially from anterior to posterior the rest of ligaments. Involvement of the posterior talofibular ligament is rare even with sever trauma.

- Acute ligament injuries are generically classified as grade I sprain (stretching/periligamentous edema), grade II sprain (partial tear), or grade III sprain (complete disruption).

  • Direct signs of ligament injuries at MR images are: disruption, thickening, non-visualization, and alteration in signal intensity or abnormality in contour. Increased intraligamentous signal is indicative of edema or hemorrhage in acute injuries Fig. 8 on page 24. Deltoid ligament contusions are manifested as a lost of the tibiotalar regular striations, and having a high signal intensity in T1 and T2 weighted images. Fig. 9 on page 25

  • Indirect signs of ligamentous lesions can be obliteration of the surrounding fat planes, bone contusions Fig. 10 on page 26 and presence of reactive fluid within tendon sheaths: fluid within the peroneal tendon sheath in calcaneofibular ligament injury, and fluid within the posterior tibial tendon in deltoid lesions. The anterior talofibular ligament is closely related to the ankle joint capsule, so extravasation of joint fluid into the adjacent soft tissues is indicative of rupture. Fig. 11 on page 27

- Chronic injury or scarring of the ligament leads to an intact but irregular, thickened or thinned ligament. Fig. 12 on page 28

Streaky increased signal within the ligament mimicking a tear is typically seen in the anterior tibiofibular ligament, the tibiotalar components of the deltoid ligament, and the posterior talofibular ligament due to the interposition of fat between the ligamentous fibers. It should not be confused as a partial tear.
ANKLE TENDONS:

1) NORMAL TENDONS ANATOMY:

Tendons around the ankle joint insert into the foot and allow movement of the foot and ankle. They can be divided into four compartments: the extensor group anterally, flexor group medially, peroneus group laterally and Achilles tendon posteriorly. Fig. 13 on page 29

Tendons appear as low-signal-intensity structures on both T1- and T2- weighted on MR images. They are surrounded by a sheath, excepting the Achilles tendon.

a) ANTERIOR COMPARTMENT:

The anterior compartment includes the extensor group: the tibialis anterior, extensor hallucis longus and extensor digitorum longus tendons. Their function is to extend toes and dorsiflex the foot and ankle joint.

The location of the tendons can be remembered as "Tom, Harry and Dick" referring to the Tibialis anterior, extensor Hallucis longus and extensor Digitorum longus tendons. Their sheaths rarely contain fluid. They are rarely injured.

- Anterior tibialis tendon: It is the thickest tendon of the anterior compartment. It is located in the anteromedial aspect of the ankle (in the 12’oclock position in the axial planes) and inserts distally into the first cuneiform and the base of the first metatarsal bones of the foot.
- Extensor hallucis longus tendon: situated between the tibialis anterior and the extensor digitorum longus. It is inserted into the base of the distal phalanx of the great toe.
- Extensor digitorum longus tendon: it is located in the lateral part of the anterior compartment. It is divided into four slips, which run forward on the dorsum of the foot, and are inserted into the second and third phalanges of the four lesser toes.

b) MEDIAL COMPARTMENT: Fig. 14 on page 30

The medial compartment includes the flexor group of tendons. A useful way to remember the order of the medial ankle tendons, starting anteromedially is: "Tom, Dick and Harry"
referring to the **Tibialis posterior, flexor Digitorum longus and flexor Halluces longus tendons. And** stands for artery and vein, along with the tibial nerve. A mucous sheath surrounds every tendon. The posterior tibialis tendon and the flexor digitorum longus passes behind the medial malleolus, in a groove, but are separated from by a fibrous septum. **Fig. 14 on page 30**

- **Posterior tibialis tendon**: It descends posterior to the medial malleolus and inserts onto the navicular bone with components also extending onto the cuneiforms and the second to fourth metatarsal bones. The insertion in the navicular bone is the only one identified on MR imaging. Signal elevation and thickening at this insertion are normal and should not be confused with a partial tear. It has an oval shape and is the thickest tendon of the medial compartment, twice as thick as the adjacent flexor tendons. A decrease in diameter suggests tendon injury. Effusion around the tendon is rare, even with a complete tear. It supports the arch of the foot and rupture leads to a flat foot.
- **Flexor digitorum longus**: inserted into the bases of the last phalanges of the second, third, fourth, and fifth toes.
- **Flexor hallucis longus**: runs in a groove between the lateral and medial talar tuberosities and then passes inferior to the sustentaculum tali into the sole of the foot. Here it crosses the flexor digitorum tendon and continues to the big toe. Its sheath communicates with the ankle joint, so fluid within the sheath may be normal.

c) **LATERAL COMPARTMENT**:

The lateral compartment includes: the peroneus longus and peroneus brevis tendons. Their function is plantar flexion and eversion of the foot.

Both tendons are located posterior to the lateral malleolus passing through a fibro-osseous tunnel called the retromalleolar groove, above the lateral ankle joint. A retinaculum maintains the tendons behind the lateral malleolus. They share a common sheath at this level but the have independent sheaths distally. They pass over the lateral aspect of the calcaneus and are often separated by the peroneal tubercle of calcaneus, although both tendons may also pass anterior to it. **Fig. 15 on page 31**

- **Peroneus brevis tendon**: inserts at the lateral aspect of the base of the fifth metatarsal bone. It has a flat shape at the retro- malleolar groove level.
- **Peroneus longus tendon**: passes inferior to the cuboid bone in a bone tunnel called the cuboid tunnel and inserts onto the plantar surface of the first cuneiform bone laterally and the proximal first metatarsal bone. It has a globular configuration at the retro- malleolar groove level.
d) POSTERIOR COMPARTMENT:

The posterior compartment includes the Achilles tendon. It is formed by the junction of the two heads of the gastrocnemius muscles and the soleus muscle and inserts distally on the calcaneus. It’s the largest tendon in the human body.

The normal average thickness of the Achilles tendon is 7 mm. On axial images the anterior margin is concave or flat, and the posterior convex. On sagittal images, anterior and posterior margins are parallel and the tendon widens as it extends distally at the insertion. The fat seen anterior to the tendon is named Kager’s fat pad.

It is low intensity signal in all sequences, but small punctate areas of high signal intensity seen at its insertion are normal. They correspond to interfascicular membranes. Fig. 16 on page 32

It has no tendon sheath, being enclosed almost completely within a connective tissue named paratendon.

A focal convexity of the Achilles tendon can be caused by insertion of soleus fibers; it should not be confused with a pathologic thickening that should be broader. Fig. 17 on page 33

There are two bursas surrounding the tendon: the retrocalcaneal bursa (true bursa) located between calcaneus and the distal Achilles tendon to prevent friction between these two structures, and the retro-Achilles bursa (acquired bursa) posterior to the tendon, in the subcutaneous tissue. Retrocalcaneal bursa has a tear shape and measures should be less than: 6 x 3 x 2 mm (superior to inferior, medial to lateral, anterior to posterior). Fluid may normally be seen in the retrocalcaneal bursa. Clinical significance increases with bursa size.

2) TENDONS INJURIES:

The ankle tendons are predisposed to a wide spectrum of acute and chronic injuries because they are all involved in the movements that allow daily activities.
Tendons should be analyzed in axial images, optimal for assessing morphologic features, longitudinal splits, tendon sheath fluid, and adjacent soft-tissue abnormalities. Sagittal images are most useful for evaluating the Achilles tendon. Coronal images are the least useful for assessing tendon disease.

Tendons appear as low signal intensity structures in all MR imaging sequences. Heterogeneity and increased signal intensity on T2-weighted images are usually indicative of disease.

Synovial sheath is only seen when there is synovial fluid inside. A minimal amount of fluid can be noted within the tendon sheath what is clinically insignificant.

Tendon injuries can be grouped into five categories: tendinosis, rupture (partial or complete), peritendinosis, tenosynovitis, and dislocation. **Fig. 18 on page 34**

A) Tendinosis consists in intrasubstance degeneration. Its manifested as thickening, heterogenicity and increased signal intensity areas within the tendon on T1-weighted and PDW images.

B) Tendon rupture may be acute or chronic. Acute rupture is often noted in the middle-aged men in the Achilles tendon after a trauma antecedent. Chronic ruptures are usually a degenerative process with no acute trauma.

1. **Partial rupture** manifests as thickening and heterogeneous signal intensity within the tendon on T2-weighted images, without complete interruption. Signal intensity may be similar to that seen in advanced tendinosis, so differentiation between partial tear and severe chronic tendinosis may be difficult.

2. **Complete rupture** is manifests as complete disruption of the tendon with fibers retraction of the torn edges of the tendon.

The most injured tendons are the Achilles tendon first, and the tibialis posterior tendon second.

**Achilles tendon injuries** can be insertional or non insertional.

• **Insertional tendinopathy** occurs at the insertion on the calcaneus and can be associated with Haglunds syndrome. MR imaging findings include thickening and increased signal intensity at the insertion site representing partial tears.
Fig. 19 on page 35. In Haglund syndrome we should also see bone marrow edema in the posterior calcaneus and distended retrocalcaneal and Achilles bursitis Fig. 20 on page 36.

- **Non-insertional tendinopathy** typically occurs anteromedially in the middle third of the tendon (2 - 6cm above the insertion). Tendinosis typically associates tendon thickening and a loss of the anterior concave surface, becoming diffusely convex Fig. 21 on page 37. Sever tendinosis may be difficult to differentiate from partial tears. High signal intensity on T2W images representing intratendinous hemorrhage and inflammatory changes in the Kager fat pad are typically associated with partial tears Fig. 22 on page 38. Focal discontinuity of fibers without complete interruption represents a partial tear Fig. 23 on page 39. Complete ruptures demonstrate a gap between tendon edges.

**Chronic tendinopathy of the tibialis posterior tendon** is more frequent than acute ruptures. It develops in women during the 5th and 6th decades of life and is associated with progressive flat foot deformity (tibialis posterior insufficiency). Usually occurs at the medial malleolus level where the tendon is subjected to a significant amount of friction.

Tears of the tibialis tendon can be divided into three types:

- **Type I tear** consists in an incomplete tear seen as enlargement, intrasubstance degeneration, and high signal intensity intratendon foci representing longitudinal splits. Radiologic findings are similar to those of severe tendinosis. Fig. 24 on page 40

- **Type II tear** consists in stretching and elongation of the tendon, with a decrease in the diameter of the tendon (less than adjacent flexor digitorum longus tendon) and usually without signal intensity alterations. Fig. 25 on page 41

- **Type III** tear is complete disruption of the tendon.

**Peroneus tendons ruptures** can be transverse or more commonly, longitudinal splits. There can be insolated, or appear in both tendons.

- **Peroneus brevis tendon** tears are usually partial and longitudinal within the fibular groove, where the tendon is entrapped between the peroneus longus tendon and the lateral malleolus. The tendon assumes a C-shaped configuration that partially envelops the peroneus longus tendon with a thin central portion. Fig. 26 on page 42

- **Peroneus longus tendon tears** can occur in three locations: at the lateral malleolus (associated with peroneus brevis tendon tears), at the peroneal tubercle of the calcaneus Fig. 27 on page 43 or in the cuboid tunnel.
A hypertrophic peroneal tubercle may irritate the peroneus longus tendon sheath leading to tenosynovitis and tear. **Fig. 28 on page 44**

The anterior tibialis tendon tears are very uncommon and normally manifest as a mass or a suspect of tumor in the anterior ankle. **Fig. 29 on page 45**

C) Tenosynovitis and peritendinosis are caused by inflammation or mechanical irritation of the tendon sheath and peritenon. On MR images manifests with fluid accumulation within the tendon sheath or adjacent soft tissues. The low signal intensity ring around the fluid represents the synovial sheath. **Fig. 30 on page 46**

Fluid within the tendon sheaths should only be considered significant if symptoms are present. The flexor hallucis longus tendon sheath communicates with the ankle joint, so fluid within the sheath may be normal.

The distribution of the fluid should be homogeneous and free of septa. If not, stenosing tenosynovitis should be considered.

Peritendinosis occurs in the Achilles tendon and it presents as irregular areas of high signal in the pre-Achilles tendon fat pad indicating the presence of edema, with a normal tendon.

D) Dislocation:

Peroneal tendons dislocation is the most frequently. It is associated with rupture of the retinaculum, or a hypoplastic (flat or convex) retromalleolar groove. When peroneal tendons dislocation occurs, tendons are located anterior and lateral to the distal fibula. It is best demonstrated on axial images. **Fig. 31 on page 47**

Pseudosubluxation of the peroneus longus tendon is a normal variant that occurs when the peroneus brevis tendon is medial to the medial edge of the fibular groove on axial plane, and peroneus longus tendon is in the retromalleolar groove. It should not be confused with a medial subluxation of the tendon. **Fig. 32 on page 48**

**OSSEUS ABNORMALITIES:**

- Accessory ossicles:
There are many accessory ossicles in the ankle. They are normal variants but may became symptomatic if inflammation or fracture.

Accessory navicular bone is important because is a risk factor of tearing or tendinopathy of the tibialis posterior tendon. It can be divided into three types:

1. **Type 1:** small, entirely within the tibialis posterior tendon and asymptomatic.
2. **Type 2:** Unfused secondary ossification center of the navicular bone. It may associate stress reaction at the synchondrosis, manifesting as bone edema, hyperintensity of the adjacent soft tissues and chronic tendinopathy of the tibialis posterior insertion. **Fig. 33 on page 49**
3. **Type 3:** As type 2 but partial synostosis, less symptomatic.

- **Os trigonum:**

The os trigonum is similarly to a secondary ossification center that appears between the ages of 7 and 13 years connected to the talus by a cartilaginous synchondrosis. It normally fuses with the talus in 1 year after its appearance, forming the trigonal or Stieda process. But in 7-14% of patients it remains as a separate ossicle (unfused os trigonum). **Fig. 34 on page 50**

Forced plantar flexion of the foot may cause talar compression between the posterior tibial and the calcaneus. The os trigonum syndrome or posterior ankle impingement may result from an acute or chronic trauma that leads to an injury of the synchondrosis or a fracture.

Radiological findings on MR images are: bone marrow edema within the os trigonum or posterior talus, posterior synovitis and adjacent soft-tissue edema **Fig. 35 on page 51**. A fracture in the synchondrosis is represented as a high lineal intensity between the os trigonum and the posterior aspect of the talus. It can also be associated with pathology of the flexor hallucis longus tendon.

- **Prominent vascular remnants:**

This is a very common normal variant. It consists on cystic changes from penetrating vessels in the calcaneus bone marrow, adjacent to the ligament insertions. On MR images are manifested as high intensity areas on T2W images and decreased intensity on T1W images, representing vascular remnants. Sometimes may be quite extensive. **Fig. 36 on page 52**

- **Tarsal coalition:**
Consists of an osseous, cartilaginous or fibrous connection between two bones. The most frequent types are: Talocalcaneal (between calcaneus and talus) or calcaneonavicular (between the anterolateral process of the calcaneus and dorsolateral margin of navicular bone). They are bilateral in 50% of cases. If symptomatic, patients refer vague hind foot pain. The more ossified the coalition is, the more likely it is to be symptomatic.

Sagittal and axial images are indicated in the evaluation of calcaneonavicular coalitions, and coronal images for assessing talocalcaneal coalitions. MR imaging findings in cartilaginous or fibrous connections are narrowing and irregularity of joint space. In osseous coalitions a continuous bone bridge is seen. Fig. 37 on page 53

- **Bone marrow edema:**

  Bone marrow edema is a common and sometimes confusing finding on MR imaging studies of the ankle. It is represented as ill-defined areas of hypointensity on T1W images and hyperintensity on T2W fat-suppressed or STIR images. Its etiology is unclear, and may include fluid, hemorrhage, fibrosis, and necrosis.

  There are many causes of bone marrow edema in the ankle that manifest with the same appearance making the diagnosis a real challenge for the radiologist. We describe different causes of bone marrow edema, excluding obvious fractures, infection or tumors.

  **Contusions:**

  Bone marrow edema secondary to contusions is the result of trabecular microfractures, edema, hemorrhage, or reaction after stress. Normally resolves within 8-12 weeks. Typically, there is not a fracture line within the bone edema. Fig. 38 on page 54

  **Stress fracture:**

  There are two forms of stress fractures: fatigue and insufficiency fractures.

  Fatigue fractures are due to repeated abnormal stresses in normal bone; while insufficiency fractures result when normal stress is applied to abnormal bones (such as bones with osteoporosis).

  A stress fracture appears as an irregular and hypointense line within an area of bone marrow edema. Bone marrow edema occurs before the fracture develops, and represents the stress response of the bone against chronic trauma.

  They typically occur in the calcaneus Fig. 39 on page 55, and less frequently in the navicular bone and talus. Fig. 40 on page 56
Osteochondral fractures / Osteochondrosis dissecans

The term osteochondral lesion is preferred to the term osteochondritis dissecans because it better describes the traumatic nature of these lesions.

Acute traumatic osteochondral lesions of the ankle are usually seen anterosuperiorly on the lateral margin of the talar dome.

Osteochondral talar lesions are classified into four stages based on the integrity of the articular cartilage and the displacement of the osteochondral fragment. Fig. 41 on page 57

1. **Stage I:** Trabecular fractures of the subchondral bone that manifests as abnormal signal intensity of the subchondral bone. Overlying articular cartilage is intact.

2. **Stage II:** Subchondral cyst with overlying articular cartilage integrity, or fissuring of articular cartilage, not extended to subchondral bone.

3. **Stage III:** Complete osteochondral fracture without displacement of the detached fragment.

4. **Stage IV:** Completely detached osteochondral fragment located in a joint recess away from the fracture site.

Fluid between the osteochondral fragment and the underlying bone, displacement of the fragment, and a fragment size >1 cm are signs of an unstable osteochondral fragment.

**Cartilage damage:**

Degenerative (osteoarthritis) or inflammatory diseases can produce periarticular subchondral bone marrow edema affecting multiple bones in ankle. It is associated with osteophytes in osteoarthritis and periarticular soft-tissue edema, synovitis, and marginal erosions in inflammatory arthritis. Fig. 42 on page 58

**High turnover in children:**

The conversion from red to yellow marrow is largely complete by the age of 5 years, but islands of red marrow may persist up to the age of 15, particularly in the tarsal bones and the tibia. These changes have a point-shaped appearance (multiple high intensity focus of bone marrow edema) called "spotty bone marrow" affecting to the tarsal bones and tibia. It is self-limited process and asymptomatic. Fig. 43 on page 59

**Transient regional or migratory osteoporosis:**

Transient regional or migratory osteoporosis is a rare condition of unknown etiology that is more appropriately termed 'transient bone marrow edema syndrome'. It is usually seen
in the femoral head and neck (transient osteoporosis of the hip) but can also involve the tarsal bones.

Patients refer an abrupt onset of pain over the affected area without a history of trauma or trophic soft tissue changes. Bone marrow edema in one, predominantly affecting the talus, or in multiple bones appears 48 h after onset of symptoms and typically takes 6-8 months to resolve.

**Reflex Sympathetic Dystrophy Syndrome (RSDS):**

Bone marrow edema in multiple bones in the ankle with a history of preceding injury, immobilization and trophic soft tissue changes suggest RSDS [Fig. 44 on page 60](#). MRI abnormalities can also include synovial hypertrophy, joint effusions and soft tissue edema. However, normal MRI does not rule out RSDS of the ankle.
ANKE LIGAMENTS

a) SYNDENSMOTIC LIGAMENTOUS COMPLEX

Anterior tibiofibular ligament
Posterior tibiofibular ligament

b) LATERAL COLLATERAL LIGAMENT COMPLEX:

Anterior talofibular ligament
Calcaneofibular ligament
Posterior talofibular ligament

c) MEDIAL COLLATERAL LIGAMENT COMPLEX OR DELTOID LIGAMENT

DEEP LAYER:
Anterior tibiotalar ligament
Posterior tibiotalar ligament

SUPERFICIAL LAYER:
Tibionavicular ligament
Tibiocalcaneal ligament
Tibiospring ligament

Fig. 1

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<table>
<thead>
<tr>
<th>LIGAMENT</th>
<th>BEST IMAGING PLANE</th>
<th>WIDTH</th>
<th>MULTIPLE FASCICLES</th>
<th>SIGNAL INTENSITY PATTERN</th>
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<td>Anterior Tibiofibular</td>
<td>Axial Sequential Images Talar dome level</td>
<td>Thick</td>
<td>Yes</td>
<td>Heterogeneous</td>
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<tr>
<td>Posterior Tibiofibular</td>
<td>Axial Sequential Images Talar dome level</td>
<td>Thin</td>
<td>No</td>
<td>Homogeneous Hypointense in T1W/T2W sequences</td>
</tr>
</tbody>
</table>

**Fig. 2**

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Fig. 3

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## LATERAL COLLATERAL LIGAMENT

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<tr>
<th>LIGAMENT</th>
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<th>MULTIPLE FASCICLES</th>
<th>SIGNAL INTENSITY PATTERN</th>
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<td>Axial Single image Related to join capsule</td>
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<td>No</td>
<td>Homogeneous Hypointense in T1W/T2W sequences</td>
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<td>Axial / Coronal Sequential Images Associated with the peroneal tendons sheath</td>
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<td>Axial / Coronal Single image Malleolar fossa level</td>
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<td>Yes</td>
<td>Heterogeneous Striated appearance</td>
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</table>

Fig. 4

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**Figure 5:** Normal lateral collateral ligament complex. a,d) Schematic drawing. b) T2W axial MR image. Anterior talofibular ligament (blue arrow) extends from anterolateral malleolar tip to talar body. It is uniformly hypointense in all sequences. Posterior talofibular ligament (yellow arrow) originates from the malleolar fossa and inserts with broad attachment, as a fan shaped insertion, in the posterolateral talus. It has an inhomogeneous appearance. c) Axial T2W MR images. Calcaneofibular ligament (blue arrow) lies deep in relation to peroneal tendons (red arrow) and extends from lateral malleolar tip to the posterior region of the lateral calcaneal surface. Multiple images are often needed to visualize its entire course. e) Coronal PDW fatsuppressed MR image shows normal posterior talofibular ligament (yellow arrow) with striated appearance.
Fig. 6

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**Figure 9**

**Deltoid ligament partial tear:** a) Coronal PDW fat-saturated MR image shows loss of normal striations in the deep deltoid ligament (blue arrow) and medial malleolar and talus contusions (orange arrow). b) Axial PDW fat-saturated MR image shows abnormal hyperintensity and thickening of the deep deltoid ligament representing ligamentous hemorrhage and edema (blue arrow). c) Sagittal T1W MR image show loss of normal striations in the deep deltoid ligament (blue arrow).

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Figure 16: Normal Achilles tendon. a) Sagittal T1W MR image shows normal parallel anterior and posterior margins of tendon (blue arrows) and normal volume of fat in Kager’s fat pad anterior to tendon (green star). b) Axial T2W MR image shows normal concave anterior margins of tendon (blue arrow). c) Normal fascicles of Achilles tendon. Axial T2W MR image shows normal fascicular anatomy. Fascicles appear as small punctate areas of high signal intensity intratendon (yellow arrow).
Figure 17: Soleus fibers insertion. 
a, b) Axial PDW fat-suppressed MR images at the distal Achilles tendon show a focal anterior convexity of the Achilles tendon caused by the insertion of soleus fibers (blue arrow). It should not be confused with a pathologic thickening which should be broader. c) Sagittal T1W MR image of the same patient shows normal Achilles Tendon (blue arrow).

Fig. 17

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Figure 21: Achilles Tendon tendinosis. a) Axial PDW fat-suppressed and b) axial T2W MR images show an anteromedially convexity of the Achilles tendon losing its concave form, without signal changes (blue arrow). c) Sagittal STIR MR image of the same patient shows abnormal thickening in the middle third of the tendon (blue arrow).
Figure 22: Achilles Tendon non-insertional interstitial tears. a) Sagittal STIR MR image shows abnormal thickening of middle third of the Achilles tendon with longitudinal hyperintense areas inside (blue arrows) consistent with interstitial tear. Note the inflammatory changes within the Kager fat (red arrow). b) Axial PDW fat-suppressed and c) axial T2W MR image show thickened Achilles tendon with hyperintense signal foci inside the tendon (blue arrows).

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**Figure 23**: Partial tear of the Achilles tendon. a) Sagittal T1W MR image and b) axial T2W MR image demonstrate a thickened Achilles tendon with irregular areas of high signal intensity and focal discontinuity of fibers (blue arrow). There is not a complete interruption of the tendon.
Figure 24: **Type I tear of the posterior tibialis tendon.** a) Axial PDW fat-suppressed MR image shows a thickened tendon with increased intrasubstance signal intensity (blue arrow) at the level of the medial malleolus. b) Sagittal STIR MR image and c) axial T2W MR image demonstrate a thickening of the tendon, homogeneously hypointense in both sequences (blue arrow). Radiologic findings are similar to those of severe tendinosis.

**Fig. 24**

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Figure 25: Type II tear of the posterior tibialis tendon. a, b) Axial PDW fat-suppressed MR image at different levels behind the medial malleolus show a decrease in the diameter of the posterior tibialis tendon (thinner than the adjacent flexor digitorum tendon) without signal intensity alterations (blue arrows) what represents a chronic posterior tibial tendon partial rupture. c) Sagittal STIR MR image demonstrates a thinning of the tendon just behind the medial malleolus (blue arrow).

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Figure 27: Partial tear of the peroneus longus tendon. a, b) Axial PDW fat-suppressed MR images show heterogeneous signal intensity and an irregular contour of the peroneus longus tendon (blue arrow) at the peroneal tubercle of the calcaneus level, with signal fluid in the peroneal sheath (red arrow). Bone marrow edema in the calcaneus is also seen (green arrow). c) Sagittal T1 MR image and d) sagittal STIR MR image demonstrate a partial tear in the tendon (blue arrow) just bellow the lateral malleolus, with tenosynovitis changes (red arrow).

Fig. 27

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Fig. 28: **Hypertrophic peroneal tubercle. Longitudinal split of the peroneus longus tendon.** a) Axial T2W MR image shows an hypertrophic protuberance in the lateral wall of the calcaneus that corresponds with an abnormal peroneal tubercle (blue arrow). b) Coronal PDW fat-suppressed MR image shows the hypertrophic peroneal tubercle (blue arrow) with bone marrow edema (green star). The peroneus longus tendon located under the peroneal tubercle shows increased signal intensity and a longitudinal split (red arrow).
Figure 29: Partial tear of the anterior tibialis tendon: a) Axial PDW fat-suppressed MR image and b) axial T2W MR image at the level of the ankle joint show thickening and hyperintense internal signal of the tendon (blue arrows). c) Sagittal STIR MR image and d) sagittal T1W MR image show thickening and signal intensity abnormalities (blue arrows) at the distal tibia level.
Figure 30: Tenosynovitis of the flexor hallucis longus tendon. a, b, c) Axial T2W MR images show extensive fluid collections (blue arrows) in the flexor hallucis longus tendon sheath (red arrow) from the muscle belly down to the crossing with the flexor digitorum longus at the sole of the foot. d) Sagittal STIR MR image shows the fluid collections around the tendon (green star).

Fig. 30

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Figure 32: Pseudosubluxation of the peroneus brevis tendon. a) Axial PDW fat-suppressed MR image shows peroneus brevis tendon located partially medial to the medial edge of the fibular groove (blue arrow) and peroneus longus tendon in the retromalleolar groove (red arrow). This is a normal variant and should not be confused with a medial subluxation of the tendon.

Fig. 32

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Figure 33: Accessory navicular bone type 2 with tendinosis of the posterior tibialis tendon insertion. a) Axial T2W MR image shows an ossicle adjacent to the medial side of the navicular bone (blue arrow) which corresponds to an accessory navicular bone. b) Axial PDW fat-suppressed MR image shows a thickening and abnormal signal at the attachment of the tibialis posterior tendon onto the ossicle (red arrow) corresponding to tendinosis changes. Also note the bone marrow edema within the ossicle (blue arrow).

Fig. 33

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**Figure 34:** *Posterior talar impingement.* a) Sagittal T1W MR image shows a enlarged Stieda process (blue arrow). b) Sagittal STIR MR image in the same patient demonstrates bone marrow edema in posterior talus (green arrow) resulting of impingement of the Stieda process against calcaneus. There is also synovitis and soft-tissue edema (red arrow). c) Coronal PDW fat-suppressed demonstrate inflammatory changes in the soft tissues of the posterior ankle (red arrow).

**Fig. 35**

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Figure 36: **Prominent vascular remnants:** Sagittal STIR MR image (a) and coronal DPW fat-suppressed MR image (b) show cystic changes (blue arrow) from penetrating vessel at the calcaneus, close to the ligaments insertions. This is a normal variant, very common and sometimes may be quite extensive.
Fig. 37

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**Figure 38**: Bone contusion. a) Sagittal STIR and b) axial DPW fat-suppressed MR images demonstrate increased signal intensity in the posterior distal tibia (blue arrow). No fracture line is seen in sagittal T1W MR image c). Bone marrow edema is the result of microtrabecular fractures.
Fig. 39

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**Fig. 40**

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*Figure 40: Subchondral talar insufficiency fracture. a) Sagittal STIR MR image shows diffuse talar bone marrow edema (green star) associated with low signal intensity of talar articular surface (blue arrow). b) Sagittal T1W MR image shows an hypointense line parallel to the articular surface representing a subchondral fracture (blue arrow).*
Figure 41: Osteochondral lesions of the talus. a) Coronal DPW fat-suppressed MR image shows a subchondral area of edema in the medial talar dome (blue arrow) corresponding to a stage I osteochondral lesion. b) Sagittal STIR MR image shows a subchondral cyst (red arrow) surrounded by bone edema (green star) corresponding to a stage II osteochondral lesion. c) Coronal DPW fat-suppressed MR image demonstrates a crater in the medial talar dome (yellow arrow) with bone marrow edema within the talus (green star) corresponding to a stage IV osteochondral lesion. Bone osteochondral displaced fragment was not identified.

Fig. 41

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Figure 42: **Subtalar joint arthrosis.** Sagittal T1W (a) and STIR (b) MR images show irregularity of the opposite bone surfaces, subcortical cystic changes (blue arrow) and periarticular bone marrow edema (green star).
Figure 43: High turnover in an asymptomatic 11-year-old girl. Sagittal STIR MR image (a) shows multiple foci of increased bone marrow signal (red arrow) in the tarsal bones and tibia with a point-shaped appearance (spotty bone marrow). Sagittal T1W MR image (b) shows the point-shaped bone marrow abnormalities.

Fig. 43

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Fig. 44

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Conclusion

MR imaging is the modality of choice for assessing the pathological conditions of the ankle. An adequate knowledge of the anatomy of this area is necessary for understanding the basic mechanism of injury and helping accurate diagnosis.
References