Magnetic Resonance Imaging of Ligamentous Injuries in Ankle Sprain

PY Chu, WSW Chan, HC Lee, YW Hon, JCS Chan, KKL Lo
Department of Radiology and Organ Imaging, United Christian Hospital, Kwun Tong, Hong Kong

ABSTRACT
Ankle sprains are common. Injury to the ankle ligaments is increasingly diagnosed by magnetic resonance imaging (MRI). In this review, 3-dimensional MRI sequence is discussed, the normal and injured MRI appearance of various components of the ankle ligaments is illustrated, and associated complications of ankle sprain are briefly presented.

Key Words: Ankle injuries; Ligament; Magnetic resonance imaging

INTRODUCTION
Ligamentous injury caused by excessive range of motion at the joint in the absence of fracture or dislocation is called a sprain. Ankle sprain is common and accounts for >90% of ankle injuries sustained in football, hockey, basketball, martial arts, and indoor volleyball. Subsequent re-injury can result in chronic instability and disability. Treatment of acute ligament injuries is based on clinical history and physical examination. With its multiplanar capability and superb soft tissue contrast, magnetic resonance imaging (MRI) is the tool of choice to evaluate the extent of ligament injuries in ankle sprain. MRI helps differentiate ligament injuries from other causes of ankle pain such as fracture, osteochondral injury, and tendon injury.

We review the MRI technique for the ankle, describe the normal and injured MRI features of various components of the ankle ligaments, the associated complication of sinus tarsi syndrome, and discuss the management of ligament injuries.

IMAGING TECHNIQUE
In our institution, routine MRI of the ankle is performed...
by experienced radiologists using a 1.5-T magnetic resonance scanner (MAGNETOM Aera; Siemens Medical Solutions, Erlangen, Germany). Axial, coronal, and sagittal planes are obtained. The ankle is imaged in the oblique axial plane parallel to the talar dome, the oblique coronal plane perpendicular to the long axis of the calcaneus, and the oblique sagittal plane parallel to bilateral malleoli and perpendicular to the talar dome. The patient is positioned supine with the foot in slight plantar flexion. Plantar flexion can decrease the magic angle effect, accentuate the fat plane between the peroneal tendons, and better visualise the calcaneofibular ligament (CFL). A dedicated extremity surface coil (Foot/Ankle 16-Channel Coil; Siemens Medical Solution) is used to enhance spatial resolution. The standard MRI protocol for evaluation of ankle ligamentous injury is summarised in the Table.

### Three-dimensional Magnetic Resonance Imaging Pulse Sequences

Three-dimensional (3D) MRI sequences have the advantage of acquiring thin continuous slices that reduce the effects of partial volume averaging. 3D MRI sequences with isotropic resolution enable high-quality multiplanar reformat images to be obtained following a single acquisition. Preliminary results for the diagnostic performance of 3D isotropic resolution sequences are encouraging. 3D MRI sequences have been reported to have 94% accuracy in detecting anterior talofibular ligament (ATFL) and CFL tears, and 92% sensitivity and 100% specificity in diagnosing ATFL and CFL rupture.

A variety of 3D MRI pulse sequences have been used to detect internal derangement of joints. These include gradient-echo and fast spin-echo (FSE) 3D acquisition sequences. Potential disadvantages of gradient-echo 3D MRI techniques include the relatively long acquisition time and inherent sensitivity to intravoxel dephasing and susceptibility artefacts. FSE 3D pulse sequences use parallel imaging, long-echo trains, and large turbo factors to reduce imaging time. The contrast characteristics in FSE 3D pulse sequence images are similar to those of FSE sequences and are a more attractive option than gradient-echo 3D pulse sequences. Such 3D FSE pulse sequences include sampling perfection with application-optimised contrasts with different flip-angle evolutions (SPACE) by Siemens Healthcare and extended echo-train acquisition and FSE-Cube acquisition by GE Healthcare.

At our institution, 3D MRI pulse sequences are incorporated into ankle MRI protocols. We use FSE proton density (PD)-weighted 3D pulse sequence SPACE. It is particularly important in the evaluation of ankle ligaments as they are often obliquely oriented to the standard anatomic orthogonal imaging planes. 3D isotropic pulse sequences enable generation of multiple high-quality post-processing reformatted images from an original isotropic data acquisition along any user-defined imaging plane (Figure 1) using picture archiving and communication system station (IMPAX; Agfa Healthcare, NV, Belgium).

### Anatomy of Ankle Ligaments

The ankle joint is supported by three groups of ligaments: lateral collateral ligaments, medial collateral ligaments, and the syndesmotic ligament complex. Ligaments that generally appear homogeneously hypointense on all imaging sequences may include the ATFL, CFL, and superficial deltoid ligament. Other ankle ligaments may show a mixed or striated signal intensity pattern; these include the posterior talofibular ligament (PTFL), posterior tibiofibular ligament, and deep deltoid ligament. Nonetheless, there are exceptions to typical appearances. Awareness of the normal and atypical MRI characteristics of ankle ligaments may improve diagnostic accuracy.

### Table. Routine magnetic resonance imaging protocols for the ankle.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>FOV (mm)</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>Matrix</th>
<th>Slice thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial PDW TSE, FS</td>
<td>150</td>
<td>3500</td>
<td>31</td>
<td>256 x 256</td>
<td>3</td>
</tr>
<tr>
<td>Axial T2-weighted TSE, FS</td>
<td>150</td>
<td>4190</td>
<td>77</td>
<td>256 x 256</td>
<td>3</td>
</tr>
<tr>
<td>Coronal PDW TSE, FS</td>
<td>160</td>
<td>3500</td>
<td>36</td>
<td>162 x 320</td>
<td>3</td>
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<tr>
<td>Sagittal T1-weighted, no FS</td>
<td>150</td>
<td>400</td>
<td>11</td>
<td>240 x 320</td>
<td>3</td>
</tr>
<tr>
<td>Sagittal T2-weighted TSE, FS</td>
<td>150</td>
<td>3000</td>
<td>73</td>
<td>256 x 256</td>
<td>3</td>
</tr>
<tr>
<td>Coronal 3D PDW SPACE TSE, no FS</td>
<td>23</td>
<td>1100</td>
<td>23</td>
<td>156 x 256</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Abbreviations: 3D = 3-dimensional; FOV = field of view; FS = fat saturation; PDW = proton density-weighted; SPACE = sampling perfection with application-optimised contrast with different flip-angle evolutions; TE = echo time; TR = repetition time; TSE = turbo spin-echo.
The lateral collateral ligament complex includes the ATFL, PTFL, and CFL. The ATFL extends from the anterior aspect of the lateral malleolus and courses anteromedially downward to attach onto the talar neck (Figure 2). It is best demonstrated on axial T1-weighted or high-resolution PD-weighted MRI. It usually appears as a thin, flat, and straight low-signal-intensity band in a single axial image. In most cases, ATFL actually consists of two separate fascicles, and occasionally of one or more fascicles. The fascicles may not be differentiated in the axial plane, although may be depicted with high-resolution images (Figure 2). The ATFL may also appear striated with mildly increased intra-ligamentous signal intensity on T2-weighted and PD-weighted images.

The PTFL has a broad, fan-shaped appearance extending from the fibular fossa of the distal fibula, running horizontally and attaching to the posterior talar process (Figure 2). It is the strongest component of the lateral collateral ligament complex. It is best demonstrated on axial and coronal images, appearing striated due to the presence of interspersed fat. It often has marked heterogeneity and thickening, with high-signal elements on fat-suppressed sequences, which is normal and should not be interpreted as a tear. The PTFL and the posterior intermalleolar ligament course transversely behind the tibiotalar joint and are typically seen as punctate low-signal-intensity structures posteriorly in the sagittal plane, potentially mimicking intraarticular bodies in the posterior ankle. It is important to track each of these ligaments from their origin to their insertion on orthogonal imaging planes to avoid misdiagnosis. In addition, the pseudodefect of the...
talus represents a normal groove containing the PTFL.\textsuperscript{17}

The ATFL and PTFL can be distinguished from the anterior and posterior inferior tibiofibular ligament (AiTFL and PiTFL) by the morphological appearance of the talus and the distal fibula on axial MRI.\textsuperscript{18} The ATFL and PTFL are located inferior to the AiTFL and PiTFL, respectively, where the talus is oblong and the fibula demonstrates a medial indentation representing the malleolar fossa (Figures 1 and 2). AiTFL and PiTFL are detected in the talar dome that is somewhat square. In addition, these ligaments insert onto the fibula above the malleolar fossa, where the fibula is round with a flat medial border.

The CFL extends from the tip of the lateral malleolus posteroinferiorly to attach to a small tubercle on the lateral aspect of the calcaneus. It is best demonstrated on coronal and axial images. It appears as a thin low-signal-intensity band deep to the peroneal tendons and is often incompletely visualised due to its oblique orientation (Figure 3).\textsuperscript{12} The complete course of the CFL can usually be depicted using multiplanar reconstruction from thin-section 3D MRI sequences (Figure 3).

The medial collateral ligament complex, also known as the deltoid ligament, consists of deep and superficial layers (Figure 4). The deep ligaments have talar attachment and cross one joint, and consist of anterior and posterior tibiotalar ligaments. The superficial ligaments have variable attachments and cross two joints. The three components of the superficial layer are
the tibiocalcaneal ligament, tibionavicular ligament, and tibiospring ligament. These components are variably present.\textsuperscript{19} On standard MRI, the tibionavicular ligament and anterior tibiotalar ligament may not always be visible.\textsuperscript{20} The mostly present components include the tibiocalcaneal ligament and tibiospring ligament in the superficial layer, and the posterior tibiotalar ligament in the deep layer.\textsuperscript{20} The various components of the deltoid ligament are usually best demonstrated on axial and coronal images. The posterior tibiotalar component is the strongest and the most readily visualised component. It extends between the tip of the medial malleolus to the medial talar surface. It is a thick structure comprising multiple fascicles and has a striated appearance due to the presence of intervening fat between its fibres. It should not be confused with injury.\textsuperscript{19}

The syndesmotic ligaments consist of the AiTFL, PiTFL, inferior transverse tibiobibular ligament, and inferior interosseous ligament or membrane. These ligaments are best demonstrated on axial and coronal MRI with low-to-intermediate signal intensity.\textsuperscript{4} The AiTFL and PiTFL are usually seen on two or more sequential axial and coronal MR images at the level of the tibial plafond and talar dome (Figure 5). The AiTFL is the weakest and the most commonly torn syndesmotic ligament.\textsuperscript{51} The AiTFL often appears striated and discontinuous due to interposition of fat between
Figure 4. Normal deltoid ligament: (a) coronal turbo spin-echo proton density-weighted 3D SPACE image showing a normal anterior tibiotalar ligament (arrow), tibiospring ligament (thin arrow), and tibialis posterior tendon (curved arrow). Coronal SPACE images showing (b) a normal posterior tibiotalar ligament (arrow), with a striated appearance, and the flexor retinaculum (curved arrow), (c) a normal tibiocalcaneal ligament (arrow), and (d) a normal tibionavicular ligament (arrow).
Abbreviation: SPACE = sampling perfection with application-optimised contrasts using different flip angle evolutions.

Figure 5. Normal syndesmotic ligaments: (a) axial proton density (PD)-weighted image with fat saturation showing the anterior inferior tibiofibular ligament (AITFL) (arrow) and posterior inferior tibiofibular ligament (PIFIL) (thin arrow). (b) Axial turbo spin-echo PD-weighted 3D SPACE image showing the normal AITFL (arrow) and PIFIL (thin arrow) as low-signal-intensity bands. They are detected in the talar dome, which is somewhat square. They insert onto the fibula above the malleolar fossa, where the fibula is oval with a flat medial border.
Abbreviation: SPACE = sampling perfection with application-optimised contrasts using different flip angle evolutions.
fascicles and the downward oblique course of the ligaments from the anterior tubercle of the distal tibia to the anterior tubercle of the distal fibula. It can result in depiction of a partly interrupted ligament, leading to a false-positive diagnosis of a rupture.\textsuperscript{16}

**ANKLE LIGAMENTOUS INJURIES**

The MRI characteristics of acute injuries to the ankle ligaments include morphological and signal intensity alterations within and around the ligaments.\textsuperscript{4,22} Morphological alterations may include abnormal thinning, thickening, irregularity, discontinuity, or detachment. Signal intensity alterations can be heterogeneous with increased intra-ligamentous signal intensity on fluid-sensitive MRI sequences, which indicate intra-ligamentous oedema or haemorrhage. Other associated features include obliteration of the fat planes around the ligament, extravasation of joint fluid into the adjacent spaces, and bone marrow oedema or contusion. Acute ligamentous injuries are rarely treated surgically. Concomitant injuries such as fracture, osteochondral injury, or tendon injury are common (Figures 6 to 8). These concomitant injuries are often more crucial in determining treatment and prognosis than the ligamentous injuries themselves.\textsuperscript{4,18,19} The MRI manifestations of chronic ligamentous tear of ankle ligaments may be similar to acute injuries, which could be thickening, thinning, or irregular appearance of the...
Figure 7. Subacute right ankle sprain in a middle-aged man: (a) coronal T2-weighted image with fat saturation showing full-thickness tear of the tibiospring ligament of the superficial component of the deltoid ligament (arrow). Bone marrow oedema is seen in the medial malleolus (arrowhead) with adjacent mild soft tissue swelling. There is also bone marrow oedema in the lateral malleolus (asterisk) with adjacent mild soft tissue swelling. Concomitant osteochondral injury (curved arrow) in the talar dome is seen. (b) Slightly posteriorly image showing partial tear of the deep layer of the deltoid ligament (arrow). Bone marrow oedema in the medial malleolus (arrowhead) and lateral malleolus (asterisk) with adjacent mild soft tissue swelling. Concomitant osteochondral injury (curved arrow) in the talar dome is again seen.

Figure 8. Left ankle sprain 3 months previously in a 44-year-old female: (a) plain radiography showing oblique fracture of the low shaft of the fibula suggestive of Weber type B transsyndesmotic fracture (arrow), with no diastasis of the distal tibiofibular joint. (b) Axial proton density (PD)-weighted image with fat saturation showing complete tear of the anterior inferior tibiofibular ligament (arrow). The posterior inferior tibiofibular ligament (curved arrow) appears striated, which could be normal or due to strain / partial tear. (c) Axial PD-weighted image with fat saturation showing thickening of the anterior talofibular ligament (arrow), also evident on magnetic resonance images 2 years previously and suggestive of a chronic partial tear. (d) Coronal T2-weighted image with fat saturation showing avulsion fracture of the tip of the medial malleolus (curved arrow) and partial tear of the deep layer of the deltoid ligament (arrow).
ligaments. Nonetheless, there is usually no residual soft tissue oedema or haemorrhage. Scarring or synovial proliferation may be encountered surrounding the ligaments with decreased signal intensity in all pulse sequences.

Lateral ankle sprains represent 16% to 21% of all sports-related traumatic lesions, and typically occur during forced plantar flexion and inversion. The ATFL is the weakest ligament and therefore the most frequently torn (Figure 6). The lateral collateral ligamentous complex usually demonstrates a predictable pattern of injury depending on the severity of ankle inversion. The ATFL is injured first, followed by the CFL and then the PTFL (Figure 6). The ATFL is injured in 83% of cases, the CFL in 67%, and the PTFL in 34%. Avulsion fractures of the lateral ankle ligaments are not infrequent and can be seen in up to 26% of severe inversion injuries. A three-point MRI grading system is used to describe acute ankle ligament injuries. Grade I injury is defined as mild sprain with superficial soft tissue oedema around the ligament. Grade II injury is a partial thickness tear and is seen as thickening / oedema and internal signal alteration within the substance of the ligament on MRI. Grade III injury is a complete tear, and MRI shows complete disruption or avulsion of the ligament. In chronic injuries of the ATFL, granulation and scar tissue may form within the anterolateral gutter, leading to impingement from entrapment of the synovial membrane between the anterior talus and the adjacent tibia or fibula. This has been described as a meniscoid lesion due to its similar morphology to a meniscus in the knee. This anterolateral impingement is the most common form of ankle impingement, and patients often

Figure 9. Right ankle pain after sprain several years ago in a 63-year-old male: (a) sagittal T1-weighted image showing loss of normal hyperintense fat signal in the sinus tarsi (arrow). (b) Sagittal T2-weighted image with fat saturation showing bright signal intensity with indistinct ligaments (arrow). A small subchondral cyst (curved arrow) is seen in the distal tibia likely due to degenerative changes. (c) Axial proton density-weighted image with fat saturation showing thin anterior talofibular ligament (arrow), likely due to prior sprain or partial tear. (d) Coronal T2-weighted image with fat saturation showing disruption of the deltoid ligament (arrow). Degenerative changes with subchondral oedema and cysts are seen (asterisks).
present with persistent lateral ankle pain and instability.

Deltoid ligament complex injuries account for about 5% of ankle sprains. Pronation-eversion and extreme rotation are known to be the mechanism that leads to deltoid ligament injuries. Recent studies show deltoid ligament injuries may be more frequent than previously thought. Isolated deltoid ligament injuries are infrequent and often associated with lateral ligamentous injuries, syndesmotic injuries, or malleolar fractures particularly in Weber type B fracture (Figures 6 to 8). The deep layer is more commonly injured than the superficial layer, and partial tears are more common than full-thickness tears. Sprains of the deep layer of the deltoid ligament are frequently noted on MRI in patients after inversion injuries (Figure 6).

Syndesmotic ligament injury or high ankle sprain accounts for approximately 7% of ankle sprains. The mechanism of injury is thought to be forced external rotation with ankle dorsiflexion and pronation. The ATFL is the most commonly torn ligament, and is almost always torn before the other syndesmotic ligaments (Figure 8). The injuries can be either ligamentous tear, avulsion fracture, or both. They can be isolated or may occur in conjunction with other ankle ligamentous groups, or associated with Weber B or C ankle fractures. It is associated with a greater risk of chronic ankle dysfunction and persistent pain and usually requires a longer time to recover previous level of function, compared with other ankle sprains of similar severity that do not involve the syndesmosis.

**POST-TRAUMATIC SINUS TARSIS SYNDROME**

The sinus tarsi is a cone-shaped cavity in the lateral aspect of the midfoot between the anterosuperior aspect of the calcaneus and the inferior aspect of the talar neck. It opens laterally anterior to the lateral malleolus and terminates posteromedially behind the sustentaculum tali. The contents of the sinus tarsi include abundant fat surrounding vessels, nerves, and a ligamentous complex that comprises the medial, intermediate, and lateral roots of the inferior extensor retinaculum, lateral cervical ligament, and medial talocalcaneal interosseous ligament. The sinus tarsi ligaments, nerves, and vessels play an important role in the stabilisation and proprioception of the subtalar joint.

Sinus tarsi syndrome is a clinical syndrome characterised by persistent lateral ankle pain and hindfoot instability. It is a common complication of ankle sprains; 70% of cases have a trauma history, and 30% have miscellaneous causes such as ganglion cysts, gout or pigmented villonodular synovitis. Sinus tarsi syndrome is a clinical diagnosis and should not be established solely on MRI findings alone. The sinus tarsi is best evaluated on T1- and T2-weighted sagittal images. In MRI, the normal sinus tarsi is T1-weighted hyperintense due to abundant fat, and the ligamentous structures are clearly outlined by the bright fat signal. In sinus tarsi syndrome, the T1-weighted hyperintense fat signal is replaced with a low signal on T1-weighted images due to fluid or scar tissue, and a bright signal on T2-weighted images, with disruption of or indistinct cervical and interosseous ligaments. Associated MRI findings include osteoarthritis of the subtalar joint with subchondral oedema or cysts of the talus or calcaneus, or contrast enhancement of the hypertrophied synovium.

**TREATMENT**

Non-operative management remains the gold standard for ankle sprains. In acute injuries, conservative treatment in the form of RICE (rest, ice, compression, elevation) is recommended. Functional rehabilitation (e.g. motion restoration and strengthening exercises) remains the cornerstone of conservative treatment and is preferred over immobilisation in low-grade sprains. In severe ankle sprain, treatment is controversial. Several prospective level I studies have compared non-operative treatment and operative treatment for grade III sprains and shown no significant difference in outcome. Surgical repair may be considered in patients with persistent symptoms and instability who are recalcitrant to conservative measures.

**CONCLUSION**

It is important for the radiologist to recognise the complex ligamentous structures in the ankle, including the normal anatomic variants and imaging pitfalls. Better understanding of the MRI appearance of various ligamentous injuries and the associated pathological conditions may help guide clinical decision making for early and appropriate intervention, and thus prevent long-term morbidity.

**REFERENCES**


