Review

MRI in acute ligamentous injuries of the ankle

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Summary. Ankle sprains are the most common lower limb injuries and affect more frequently young athletes; imaging is needed for an accurate diagnosis of such traumatic injuries. The purpose of this review is to analyse the magnetic resonance (MR) findings of both normal and pathological ankle's ligaments; indeed, MRI is the gold standard for the diagnosis of acute traumatic injuries and is useful for differentiation of the causes of ankle instability as well as for pre-operative planning. (www.actabiomedica.it)

Key words: MRI, acute ligamentus injuries, ankle

Introduction

Ankle sprains are the most common lower limb injuries (incidence between 5-7 per 1000 persons/year in Europe), affecting more frequently young athletes (1); the most common mechanism of injury is represented by inversion of the foot (less frequently eversion). Therapeutic and rehabilitative strategies are planned after a precise radiological evaluation of the ligamentous injury.

The purpose of this review is to analyse the magnetic resonance (MR) findings of both normal and pathological ankle's ligaments.

Imaging

Ankle x-ray is the first imaging method used to detect fractures and bone gaps, although it cannot efficiently evaluate occult fractures and soft tissue alterations.

CT allows an excellent assessment of skeletal fractures; nevertheless it shows low accuracy in soft tissue evaluation and presents an higher radiation exposition compared to x-ray.

Ultrasound imaging is a powerful diagnostic tool to evaluate both superficial ligaments and tendons; indeed, through dynamic manoeuvres US allows a functional evaluation, too.

MRI is the most accurate diagnostic procedure for the evaluation of traumatic ligamentous injuries, given its high contrast resolution and accuracy in the detection of bone oedema; it is not indicated for acute injury (with the exception of professional athletes). At MRI imaging the ligaments appear as thin structures, with linear low signal intensity in T1W- and T2W-sequences; they are highlighted by the adjacent adipose tissue, the latter showing high signal intensity.

Injured ligaments are identified as either disrupted or thickened and irregular structures, associated with signal's alterations. Fluid-sensitive sequences are helpful in identifying these injuries.

Anatomical and pathological findings

Ankle's ligamentous structures can be grouped into five different complexes:

1. Lateral collateral ligament complex (LCL)

Sprains in inversion and plantar flexion cause injuries of the lateral complex; they represent more than 20% of all sportive traumatic disorders (2-4). Depending on the intensity of trauma, ligaments are consecutively affected (Tab. 1 and Fig. 1).

Anterior talo-fibular ligament (ATF)

ATF originates from the anterior margin of the lateral malleolus and lies anterior-medially to fit the lateral tubercle of the talus; it limits both the anterior displacement of the talus and the plantar flexion of the ankle. ATF is best viewed in axial plane, and it may present more than one component (5-7) (Fig. 1 D). Injuries of the ATF can be suspected according to the before mentioned morphological and signal alterations; moreover, the "bright rim sign" (Fig. 2) - reflecting a cortical defect with bright dot like or curvilinear high-signal-intensity lesions on T2W-sequences - can suggest a ligamentous alteration too (8).

Calcaneo-fibular ligament (CF)

CF originates from the anterior region of the lateral malleolus and lies obliquely and posteriorly to fit in on the postero-lateral region of the calcaneus. PC is best viewed in oblique coronal plane (2) (Fig. 1 and Fig. 3).

Posterior Talofibular ligament (PTF)

It originates from the malleolar pit of the medial surface of the lateral malleolus and lies horizontally to fit on the postero-lateral tubercle of the talus. PTF is best viewed in oblique coronal plane (Fig. 3) but can also be detected in the axial plane (9, 10) (Fig. 1).

Table 1. According to biomechanical studies, the ATF is the weakest lateral ankle ligament, therefore is the firstly involved in inversion/plantar flexion sprains, consequently the CF, CL and PTF. The pure inversion sprains which affect only the CF are extremely rare

Phase 1	ATF
Phase 2	ATF + CF
Phase 3	ATF + CF + CL
Phase 4	ATF + CF + CL + PTF

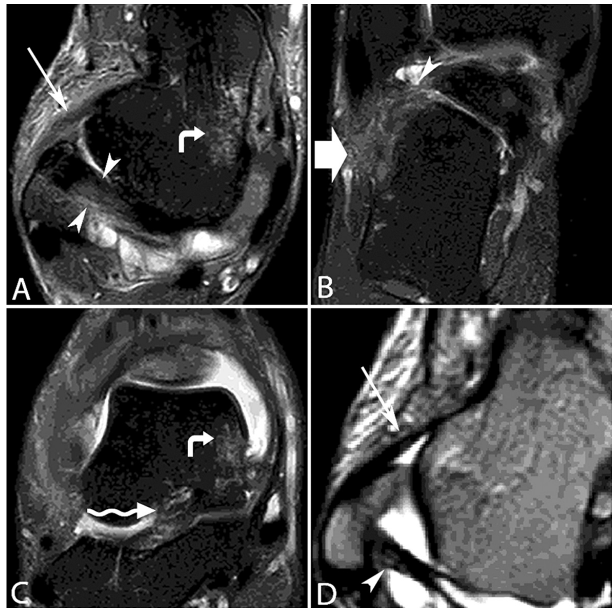

Figure 1. MRI DP-SPAIR images (A, B, C) of a young male obtained after traumatic inversion ankle sprain; image A (axial view) shows the lesion of the ATF (arrow) and of the PTF (arrowheads); Image B (coronal view) shows the lesion of FC (thick arrow) and of the PTF (arrowhead); image C (coronal view) shows the lesion of the CL (corrugated arrow). Image A and C shows the spongious oedema of the medial area of the taluls (curved arrow) caused by the impaction with the tibial malleulus. TSE T2w- axial view image (D) shows normal anatomy of ATF (arrow) and PTF (arrow head), highlighted by the presence of a intraarticular hyperintense effusion

Anatomic variations

Posterior intermalleolar ligament **(**PIML), known as "marsupial meniscus", is located between the posterior tibio-fibular ligament (PITFL) and the anterior talo-fibular ligament (AITFL) and lies from the fibular malleolar pit to the posteromedial area of the tibia (2).

Lateral talo-calcanear ligament and *Posterior talo-calcanear ligament*

2. Tibiofibular syndesmosis (distal)

The lesions of the tibio-fibular syndesmosis represent about 7% of ankle injuries, commonly after exter-

Figure 2. TSE T2-w axial image shows the lesion of the ATF (arrowhead) associated with a cortical defect with curvilinear high-signal-intensity (“bright rim sign” - arrow)

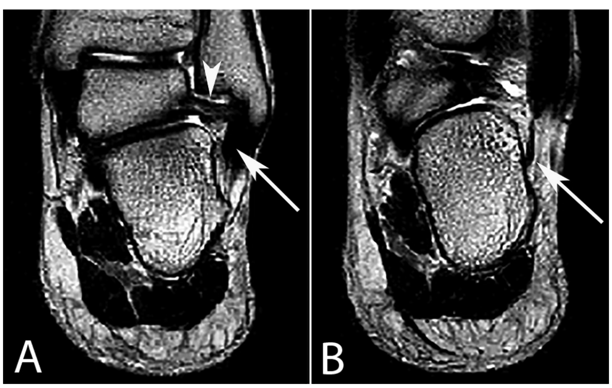

Figure 3. (A) TSE T2-w coronal images showing the normal anatomy of FC, that in its proximal portion it is slightly differentiable because of its course below the peroneal tendons (arrow); PFA ligament is normal (arrowhead). (B) FC ligament is clearly visible in its distal portion before the calcaneal insertion (arrow)

nal rotation and iperdorsiflexion. An isolated external rotation may cause a lesion of the anterior part of the deltoid ligament or a fracture of the medial malleolus.

The tibio-fibular syndesmosis is best viewed in axial and oblique coronal planes (10-13).

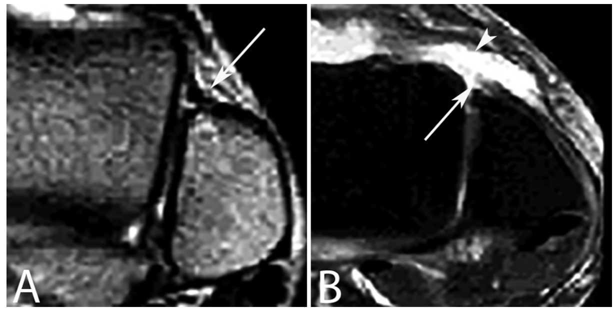

Figure 4. (A) TSE T2-W MR axial image shows the integrity of tibiofibular syndesmosis; particularly, ATFL appears as a thin linear low signal intensity structure (arrow). (B) DP-SPAIR MR axial image demostrates the lesion of ATFL (arrow), characterized by interruption and presence of joint fluid (arrowhead)

Anterior Tibio-fibular ligament (ATFL)

AITFL originates from the anterior tubercle of the tibia, lies lateral-caudally and fits on the front edge of the lateral malleolus (Fig. 4). An anatomic variant - Bassett’s ligament - is separated with the main component of the AITFL through a fibro-adipose septum; the latter should not be misdiagnosed as a ligamentous tear (6, 7, 14).

Posterior tibio-fibular ligament (PTFL)

PITFL originates from the rear edge of the lateral malleolus and heads skull-medially to insert on the posterior tibial tubercle (Fig. 5).

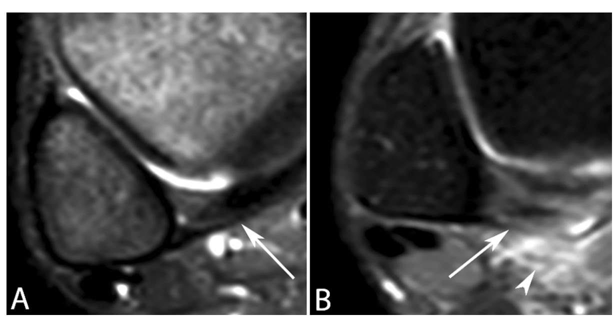

Figure 5. DP-SPAIR MR axial images. (A) Shows the normal appearance of the PTFL as a low signal intensity structure (arrow). (B) Shows the lesion of the PTFL, which is characterized by a thickened structure, disomogeneus signal intensity and soft tissue oedema (arrowhead)

Transverse tibio-fibular ligament (TTFL)

TTFL originates from the proximal portion of the malleolar pit to fit on tibial rear edge.

Interosseous ligament (IOL)

IOL connects tibia and fibula about 0.5-2 cm above the articular surface of the tibiotalus joint and can be considered as a continuation of the distal interosseous membrane.

3. Medial collateral ligament complex (MCLC)

MCLC is composed of two different layers, namely superficial and deep, hardly distinguishable both pathologically and radiologically; also, given its shape it is defined as "deltoid"(Fig. 6 A).

The lesions of the medial complex are rare (Fig. 6 B); indeed, they represent approximately only 5% of sprains ankle.

In more than 10% of the cases lesions of the medial complex are associated with injury of the distal tibio-fibular syndesmosis (10, 13, 15).

Superficial component

The superficial component originates from the anterior tubercle of the medial malleolus directed posteriorly.

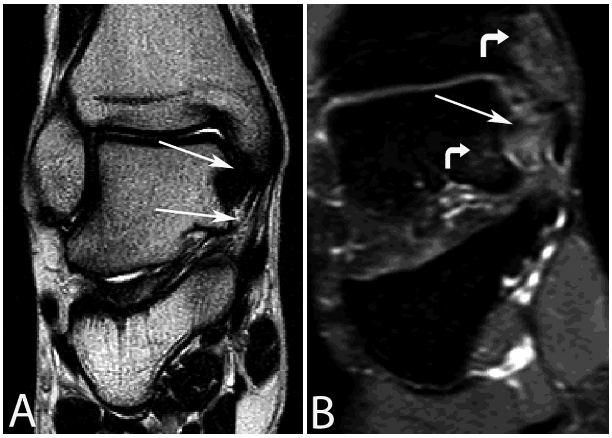

Figure 6. (A) TSE T2w MR coronal image shows the normal appearance of the deltoid ligament (arrows). (B) DP-SPAIR MR coronal image demonstrates the lesion of the deltoid ligament (arrow) associated with bone oedema of tibial melleolus and the medial area of the talus (curved arrow)

The *tibio-navicular ligament (TNL)*is always present; it fits on the navicular and shares the upper portion with the spring ligament.

The *tibial-spring ligament (TSL)* is inserted on the lateral portion of the oblique supero-medial band of the spring ligament (Fig. 9 A).

The *tibio-calcaneal ligament (TCL)* is inserted on the posterior region of sustentaculum tali.

Deep component

The deep component originates from the anterior tubercle of the medial malleolus.

The *anterior tibio-talar ligament (ATTL)* fits on the inner face of the neck of the talus; the *posterior tibio-talar ligament (PTTL)* fits over the medial surface of the talus, below and behind the articular face of the medial malleolus.

4. The tarsal sinus

The tarsal sinus is a cavity between the calcaneus and the talus -filled with adipose tissue -containing vascular structures, nerve endings and five ligamentous bands that serve as stabilizers of the lateral ankle and back-foot.

Those ligaments – best viewed in coronal and sagittal MRI planes (Fig. 7) - are injured in association with trauma of TTP and LCL (Fig. 1) in about 39% of cases (2).

Interosseous talocalcanear ligament (ITCL)

ITCL extends from the sulcus tali to sulcus calcanei; it continues with the medial fibres of the cervical ligament and crosses the medial roots of extensors retinaculum (2) (Fig. 7B).

ITCL controls the talus in the movements of eversion and inversion by maintaining apposition of the talus and calcaneus.

Cervical ligament (CL)

It is a robust beam that connects the neck of the talus with the upper surface of the calcaneus (2) (Fig. 7 A,D) to limit the inversion of the hindfoot.

Extensors retinaculum (ER)

It consists of three beams, namely lateral, intermediate and medial (Fig. 7 C). The extensor retinaculum assists the cervical ligament in limiting inversion of the subtalar joint.

5. Spring ligament

Injuries of the plantar part of the spring ligament occur during major trauma; in young athletes they are caused by direct trauma on the head of the talus.

This hammock-shaped complex is called plantar calcaneus-navicular ligament and plays an important role in the stability of the mid-foot; it consists of three structures (13).

Spring ligament is best viewed in axial and sagittal MRI planes; the medial component can be identified in coronal plane, too (Fig. 8; Fig. 9) (16).

The supermedial band (SM)

SM band originates from the sustentaculum tali and inserts on the navicular bone; it has an average thickness of 3 mm and is separated - through fibrocartilagineous tissue covered with synovium (gliding areas) - from the posterior tibial tendon (PTT).

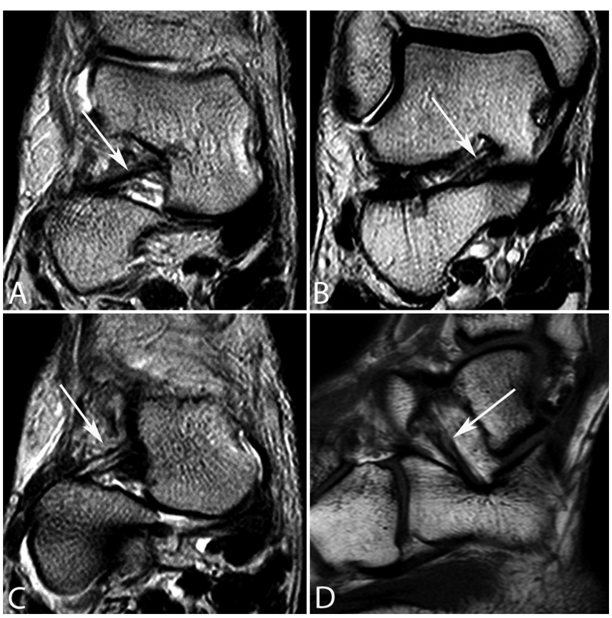

Figure 7. TSE T2-w coronal (A, B, C) and axial (D) MR images show normal findings of sinus tarsi ligaments; in particular, the cervical ligament (arrow in A and D), the Interosseous talocalcanear ligament (arrow in B) and the extensor retinaculum (arrow in C)

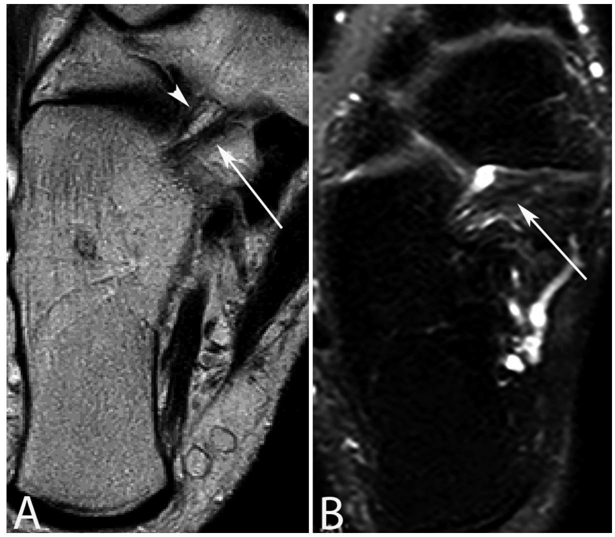

Figure 8. (A) TSE T1w axial MR image shows the IPL band (arrowhead) and the MPO band (arrow). (B) DP-SPAIR axial MR images are of less importance in the detection of such ligament because of the suppression of the adipose tissue, therefore the evaluation of the ligament is difficoult

The Oblique Medioplantar band (MPO) and *Inferoplantar band (IP)*

MPO and IPL are located deeper than the band of the SM. The MPO originates from the coronoid fossa of the calcaneus and inserts on the medial tubercle of the navicular bone; it is generally viewed in the axial and coronal planes.

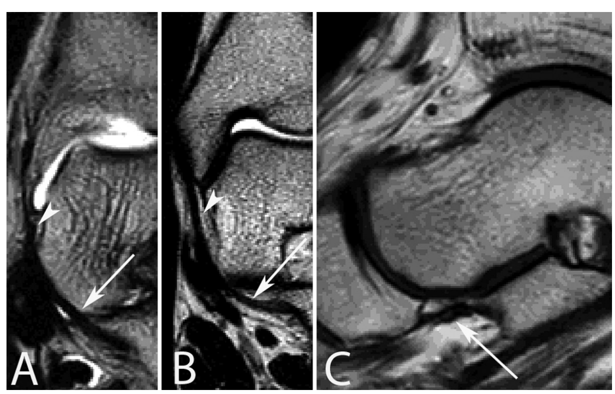

Figure 9. TSE T2-w RM images. (A) normal anatomy of SM band in coronal view (arrow) and of the TS (arrowhead); the gliding zone is circled. B normal anatomy of SM band in axial view (arrow). (C) normal finding of IPL band in sagittal view (arrow)

The IP band is shorter, thicker and originates from the coronoid fossa, more anteriorly than MPO, and fits on the lower portion of the navicular tuberosity; it is best viewed in the sagittal and coronal planes and has an average thickness of 4 mm. The typical MRI findings of the spring ligament injuries - comprising interruptions, ligamentous thickening and inhomogeneous signals – are best detected through fluid sensitive sequences.

Spring ligament's lesions are frequently associated with tendinopathy of the PTT.

The recess of the spring ligament, namely a virtual space communicating with the talus-calcaneo-navicolar articulation through the space between the MPO and IPL, should not be confused with a ligamentous injury (17-21).

Conclusion

Knowledge of ligamentous anatomy is needed to fully understand the basic mechanism of injury, therefore facilitating an accurate and early diagnosis; the latter is made possible through MR imaging, which displays - with high contrast resolution and panoramic view- the whole anatomy of the ankle.

MR is the gold standard for the diagnosis of acute traumatic injuries of ankle ligaments, to differentiate between the various causes of ankle instability and for the pre-operative planning in those cases in which a surgical approach is needed.

References

1. Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ, Jr. The epidemiology of ankle sprains in the United States. The Journal of bone and joint surgery. American volume. 2010; 92: 2279-84.
2. Golano P, Vega J, de Leeuw PA, et al. Anatomy of the ankle ligaments: a pictorial essay. Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA 2010; 18: 557-69.
3. Burks RT, Morgan J. Anatomy of the lateral ankle ligaments. The American journal of sports medicine 1994; 22: 72-7.
4. Milner CE, Soames RW. Anatomy of the collateral ligaments of the human ankle joint. Foot & ankle international 1998; 19: 757-60.
5. Kanamoto T, Shiozaki Y, Tanaka Y, Yonetani Y, Horibe S. The use of MRI in pre-operative evaluation of anterior talofibular ligament in chronic ankle instability. Bone & joint research 2014; 3: 241-5.
6. Milner CE, Soames RW. Anatomical variations of the anterior talofibular ligament of the human ankle joint. Journal of anatomy 1997; 191 (Pt 3): 457-8.
7. Oae K, Takao M, Uchio Y, Ochi M. Evaluation of anterior talofibular ligament injury with stress radiography, ultrasonography and MR imaging. Skeletal radiology 2010; 39: 41-7.
8. Lee MH, Cha JG, Lee YK, et al. The bright rim sign on MRI for anterior talofibular ligament injury with arthroscopic correlation. AJR. American journal of roentgenology 2012; 198: 885-90.
9. Lee SH, Jacobson J, Trudell D, Resnick D. Ligaments of the ankle: normal anatomy with MR arthrography. Journal of computer assisted tomography 1998; 22: 807-13.
10. Perrich KD, Goodwin DW, Hecht PJ, Cheung Y. Ankle ligaments on MRI: appearance of normal and injured ligaments. AJR. American journal of roentgenology 2009; 193: 687-95.
11. Oae K, Takao M, Naito K, et al. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis. Radiology 2003; 227: 155-61.
12. Takao M, Ochi M, Oae K, Naito K, Uchio Y. Diagnosis of a tear of the tibiofibular syndesmosis. The role of arthroscopy of the ankle. The Journal of bone and joint surgery. British volume 2003; 85: 324-9.
13. Chun KY, Choi YS, Lee SH, et al. Deltoid Ligament and Tibiofibular Syndesmosis Injury in Chronic Lateral Ankle Instability: Magnetic Resonance Imaging Evaluation at 3T and Comparison with Arthroscopy. Korean journal of radiology 2015; 16: 1096-103.
14. Bassett FH, 3rd, Gates HS, 3rd, Billys JB, Morris HB, Nikolaou PK. Talar impingement by the anteroinferior tibiofibular ligament. A cause of chronic pain in the ankle after inversion sprain. The Journal of bone and joint surgery. American volume 1990; 72: 55-9.
15. Mengiardi B, Pfirrmann CW, Vienne P, Hodler J, Zanetti M. Medial collateral ligament complex of the ankle: MR appearance in asymptomatic subjects. Radiology 2007; 242: 817-24.
16. Toye LR, Helms CA, Hoffman BD, Easley M, Nunley JA. MRI of spring ligament tears. AJR. American journal of roentgenology 2005; 184: 1475-80.
17. Desai KR, Beltran LS, Bencardino JT, Rosenberg ZS, Petchprapa C, Steiner G. The spring ligament recess of the talocalcaneonavicular joint: depiction on MR images with cadaveric and histologic correlation. AJR. American journal of roentgenology 2011; 196: 1145-50.
18. De Filippo M, Ingegnoli A, Carloni A, et al. Erdheim-Chester disease: clinical and radiological findings. Radiol Med 2009 Dec; 114(8): 1319-29. doi: 10.1007/s11547-009-0473-8. Epub 2009 Nov 14.
19. Pescarolo M, Sverzellati N, Verduri A, et al. How much

do GOLD stages reflect CT abnormalities in COPD patients? Radiol Med 2008 Sep; 113(6): 817-29. doi: 10.1007/s11547-008-0284-3. Epub 2008 Jul 10.

20. Bertolini L, Vaglio A, Bignardi L, et al. Subclinical interstitial lung abnormalities in stable renal allograft recipients in the era of modern immunosuppression. Transplant Proc 2011 Sep; 43(7): 2617-23. doi:10.1016/j.transproceed.2011.06.033.
21. Cataldi V, Laporta T, Sverzellati N, De Filippo M, Zompatori M. Detection of incidental vertebral fractures on routine lateral chest radiographs. Radiol Med 2008 Oct; 113(7): 968-77. doi: 10.1007/s11547-008-0294-1. Epub 2008 Sep 13.

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