REVIEW ARTICLE

MRI ROAD MAP FOR ANKLE LIGAMENTS IN CHRONIC FOOT PAIN

Ummara Siddique Umer, Aman nawaz Khan, Hadia Abid, Shahjehan Alam, Syed Ghulam Ghaus, Mahwish Jabeen, Abdullah Safi, Aliya Sharif, Karishma Israr, Fouzia Wazir

Department of Radiology, Rehman Medical Institute (RMI), Peshawar, Pakistan.

PJR April - June 2021; 31(2): 100-107

Purpose or Learning Objective

- To describe the imaging technique, planning and ideal sequences to assess MRI ankle in patients with chronic ankle pain.
- To describe imaging details of normal appearance of ankle ligaments.
- To describe the imaging findings of abnormal and torn ligaments.

Introduction

Ankle trauma is most often a ligamentous sprain injury and accurate in-time diagnosis for appropriate treatment is required. Magnetic resonance imaging (MRI) is the imaging modality of choice for diagnosing ligament pathologies because of its multiplanar capability and high soft tissue contrast. Accurate diagnosis on MRI depends on knowledge of ligamentous anatomy of ankle and the spectrum of ligament appearances from normal to disrupted to scarred. With MRI, it is possible to triage the cause of post traumatic ankle pain to bone, ligament or tendon pathologies.[1,2] This educational review aims to provide an overview of the MRI features of normal and abnormal appearances of the ankle ligaments.

Findings

To understand the anatomy and diagnose the pathologies in ankle ligaments, the first step is to start with understanding the ideal imaging plane and technique.

Imaging technique includes proper planning and ideal selection of required sequences.

Planning: Ankle joint assessment requires atleast a 1.5 tesla strength MRI machine. MRI is performed with dedicated foot coil or surface coil covering the ankle and foot.

Considering complex anatomy and curved course of majority ligaments in ankle joint, it is crucial to obtain MR images with proper planning. Axial, coronal and Sagittal images are acquired as shown in (Fig.1).

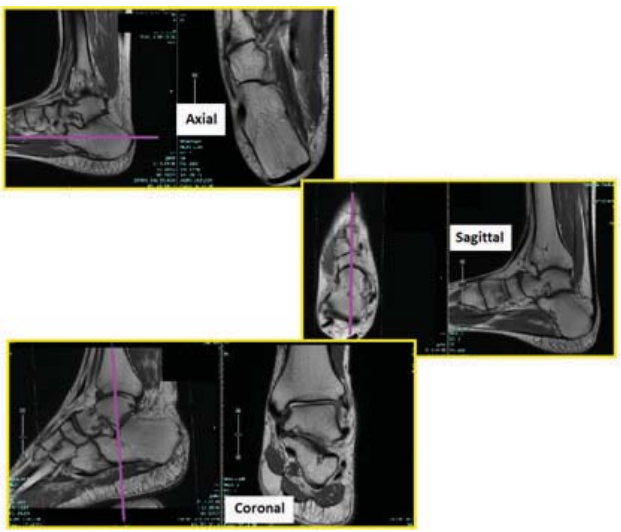

Figure 1: Planning for axial, coronal and sagittal images.

Correspondence : Dr. Ummara Siddique Umer
Department of Radiology,
Rehman Medical Institute,
Peshawar, Pakistan.
Email: ummara_81@hotmail.com

Submitted 14 March 2021, Accepted 3 May 2021

Imaging Sequences: MRI joints has been done with varying protocols. There is a difference in opinion among different authors. The catch is to first assess the indication of joint imaging. In cases of suspected mass, infective or infiltrative process, the protocol includes T1, T2, T2 FATSAT and post contrast images in all planes.

In cases with trauma, chronic joint pain, internal derangement, PD and PD FATSAT images in all planes is the protocol of choice. PD sequence with a long TR and a short TE has the ability to characterize pathologies in ligaments, menisci, cartilage, cortex and marrow when PD FATSAT is acquired.

To assess joint ligaments, cartilage, muscles, tendons and bones, the ideal sequence is a PD weighted sequence or intermediate sequence. Its high TR and A short TE gives image the beauty to assess both the ligaments and cartilage at the same time. Initially, the literature review and even experience of our senior radiology colleague has shown that there were different sequences required for assessment of certain structures, e.g. a short TE sequence like T1 or GRE has been shown better assessment for cartilage and a long TR sequence was found better for ligaments e.g. T2 weight image. But the PD sequence has the qualities of both giving the assessment of cartilage and ligaments both in a single sequence. This not only saves patient's time but also time of the technician. A FATSAT sequence, preferably PD FATSAT is requires to look for bone marrow or abnormal fluid within the joint and regional soft tissues (Fig.2).

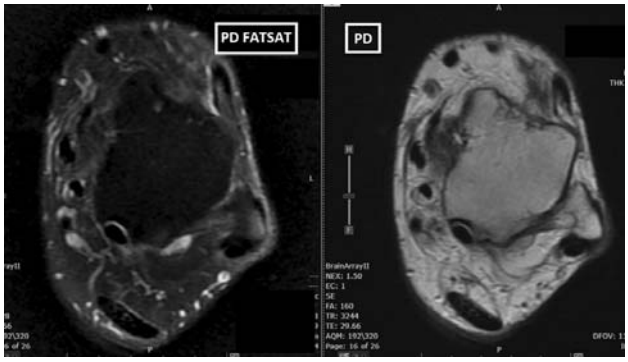

Figure 2: PD and PD FATSAT images in axial plane at level of talofibular joint.

MRI assessment in chronic ankle pain:

The guide to assessing ankle joint in patients with chronic ankle pain, should cover following:

1. Joint articulation including the syndesmosis.
2. Ligaments integrity
3. Impingement signs.
4. Synovium assessment.
5. Marrow and cortical abnormalities.
6. Muscles, tendons and fascia.

This review will only focus on the ligament assessment on MRI.

Ankle ligaments on MRI

MRI can depict ligament injuries and has been traditionally used to differentiate ligament tears from other causes of ankle pain, such as fracture, osteochondral injury or tendon injury. The appropriate treatment following an ankle injury requires differentiation between various types of ligament injury as well as the age of injury. To assess ligament injury, let's start with understanding the normal location and normal appearance of ankle ligaments. For this, the ideal roadmap includes dividing the ligaments into different compartments. Although the division is anatomical, the mechanics of ligaments is such that one compartment old injury can lead to a later life injury to other compartment ligaments. So, assessment of each compartment ligaments should be done individually.

Anatomical compartments of Ankle Ligaments:

Ankle ligaments are divided into three sections:

1. Medial ligaments.
2. Lateral ligaments.
3. Syndesmotic ligaments, the Distal tibiofibular ligaments, also called the Inferior Tibiofibular ligaments (iTFL).

MRI characteristics of Ankle Ligaments

Normal appearance: It is a known MRI fact that ligaments are uniformly hypointense on all sequences with exception of few ligaments like the anterior cruciate ligament of knee (ACL) and few ligaments in ankle. These exceptions have intrinsic T2 or PD high signals, which are normal. The assessment of ligament integrity should therefore be done keeping this in mind. Limiting ourselves to discussion of imaging appearances of ligaments in the ankle, the normal ligaments on MRI can have following appearance:

- Linear thin slip like hypointense fibers.
- Thick band like fibers with striated signals.

Anterior ligaments: In ankle joint, the anterior ligaments (medial, lateral and syndesmotic compartments) have diffusely hypointense signals on all sequences so they appear intensely hypointense on long TR sequences like PD and T2 weighted images (Fig.3). These are thin slip like fibers, the continuity of which should be assessed on axial images. As these are slips with a bit oblique orientation, they should be assessed on more than one axial image.

Posterior ligaments: In ankle joint, the posterior ligaments are of intermediate signal intensity with striated appearance, particularly on PD FATSAT images (Fig.3).This can be mis-reported / falsely reported as a tear or interstitial sprain. As shown in figure, posterior ligaments have a striated appearance with intrinsic linear signals of hypointensity and intermediate to high signals. These high signals are not as bright as fluid. To assess integrity, the continuation of fibers should be assessed on axial as well as coronal planes.

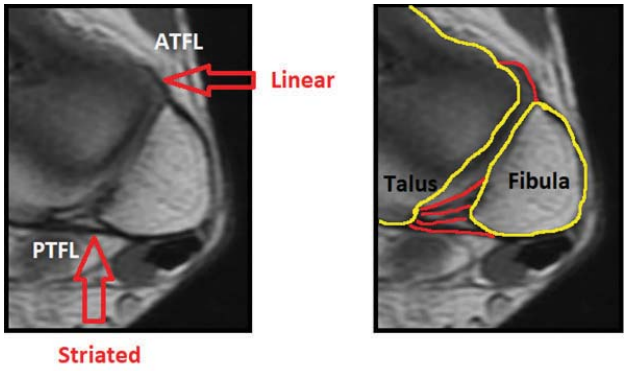

Figure 3: Normal ankle ligament appearance. Anterior tibiofibular ligament (ATFL) seen as linear hypointensity and posterior tibiofibular ligament (PTFL) seen as a thick striated band with mixed signals.

Ligament fibers integrity on MRI: The intact normal ankle ligaments should have:

1. Normal fiber orientation.
2. No interruption in any fiber.
3. No abnormal intrinsic fluid signal intensity.
4. No abnormal thickening.
5. No associated bone or synovial abnormality.

Ligament Tear: Ligament tear is disruption of full or partial thickness of fibers. The term used is ligament tear, either partial or complete.

Partial tear: This is graded according to the severity of injured ligament fibers ranging from mild to severe.

On MRI one of the following features in ankle ligaments suggests partial tear (Fig.4):

1. Increased intrinsic signal intensity.
2. Ill-definition of fibers.
3. Mushy appearance of fibers (like they have been crushed).
4. Thickened fibers.
5. Thinning of fibers (full length or partial).
6. Loss of fibers.
7. Fluid signals replacing the torn fibers.

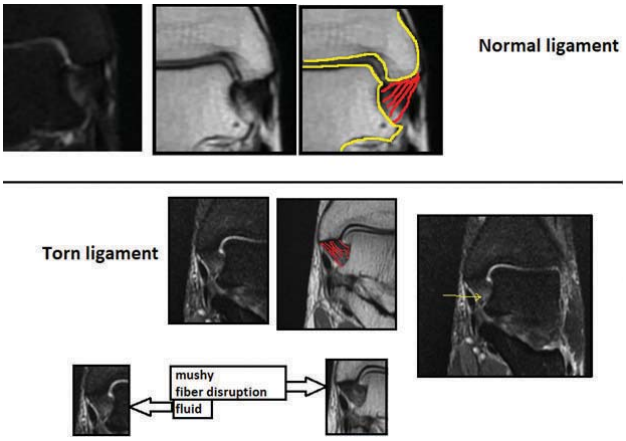

Figure 4: Coronal PD and PD FATSAT images of posterior tibiotalar ligament showing normal appearance (upper images) and partial tear (lower images).

Complete Tear: As the name indicates, there is full thickness tear of the ligament (Fig.5). On MRI, it is seen as absenceof fibers or non-visualization of any of the full thickness ligament segment between the attachment sites. It must be assessed on more than one planes. It is important to look at multiple slices

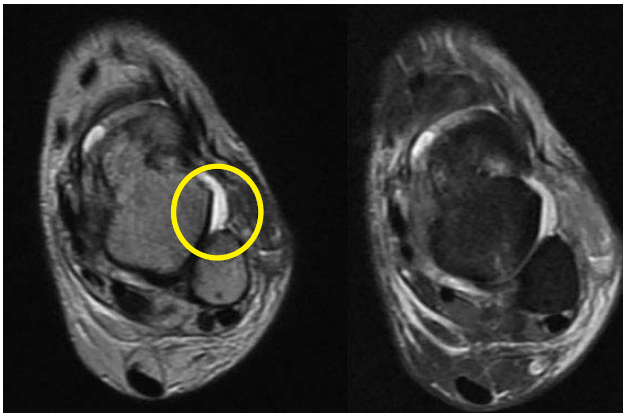

Figure 5: Axial PD and PD FATSAT images showing complete tear of anterior talofibular ligament (circle). No fibers seen at the talar attachment site. Note the soft tissue hematoma along the injury site. Also a small cortical fracture seen in posterior talus, better evident on PD FATSAT images.

to make sure not to miss any residual attachment fibers, which would then be apartial tear instead of a complete one. It is important to mention the associated findings in surrounding soft tissues like hematoma, fluid collection, marrow or cortical abnormalities.

Other findings associated with ligament tear:

Cortical disruption: Cortex should be assessed on a non-FATSAT image, preferably axial or coronal plane. Normal cortex is signal void, so any altered signals in its signal void appearance would suggest a cortical injury. Cortical interruption or absence at ligament attachment site with background of ligament tear suggests cortical avulsion or an avulsion fracture (Fig.6). The avulsed bone fragment might be a tiny fragment and always not visible on MRI as could be masked by the ongoing soft tissue reaction, hematoma etc.

Figure 6: Coronal images of a patient with tear of PTTL (curved arrow). Associated injury seen as Cortical avulsion injury (labeled images). Note the interruption in normal cortex and marrow edema (on PD FATSAT image) as associated findings with partial tear of PTTL.

Marrow edema: When suspecting a ligament injury, after assessing the ligament integrity and the cortex at ligament attachment site, the next step is to assess the attachment site of ligaments for marrow edema. If there is cortical disruption, then the cause of marrow edema is self-explanatory, contusion / trabecular fracture. It however can be a reactive edema seen at or near attachment site of torn ligament, when the overlying cortex is present in its whole extent.

To assess marrow, T1 weighted image is the modality of choice, but since we have PD and PD FATSAT as ideal sequences for assessment of internal derangement in joint, PD with a small TE gives a marrow appearance nearly similar to T1WI. Marrow edema is better seen on PD FATSAT images. Some centers also acquire a T2 FATSAT or a STIR image for assessment of pathological marrow signals, which is also helpful.

Scarred Ligament

Old torn ligaments are seen as thickened ligaments with ill definition of fibers, not as sharp as in a normal ligament. So, since anterior ligaments of ankle are linear hypointense, in a case with anterior ligament old injury, the scarred ligament would be hypointense but would be thickened with mostly ill defined irregular fibers.[3,4] **Hypertrophied scar:** An old torn ligament might get thickened to such an extent that it can mimic a lesion and even enhance with contrast. This is very pronounced scarring of ligamentous injury. Rather than just thickening of the ligament, there is marked almost mass like hypertophic scar formation at and around the ligament site which at times can involve adjacent tendons as well.

Compartment-wise MRI assessment of Ankle Ligaments:

Lateral ligaments:

1. Anterior talofibular ligament:
   - o Linear, uniform low signals.
   - o Better visualized on axial images. Hint: Level of fibular notch is the landmark to locate it (Fig.7).
2. Posterior talofibular ligament.
   - o Thick, striated, broad band like.
   - o Visualized on both Coronal and Axial planes.

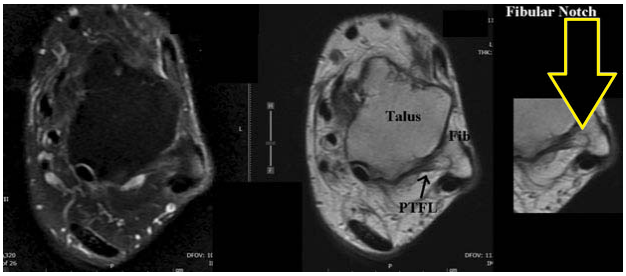

Figure 7: Coronal PD FATSAT and PD images showing Normal appearance of posterior talofibular ligament (PTFL) at the level of fibular notch. Note incidentally finding of tendinopathy in Achilles tendon seen as loss of normal anterior concavity and intra substance latered signals.

3. Calcaneofibular Ligament.
   - o Curved ligament.
   - o Better visualized on Coronal plane (Fig.8).

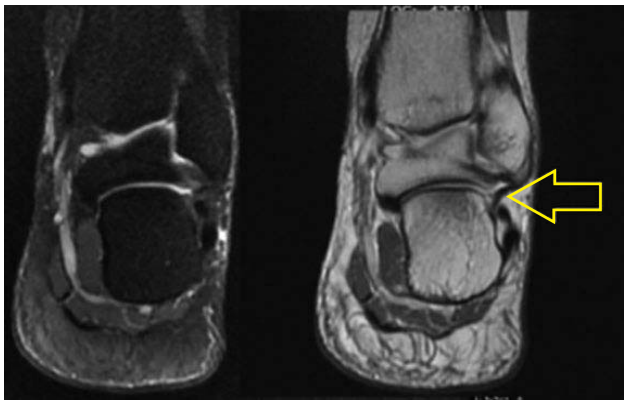

Figure 8: Coronal PD FATSAT and PD images showing Normal Calcaneofibular ligament (arrow. Note its curved course)

Syndesmotic Ligaments at Inferior Tibiofibular joint:

Syndesmotic ligament injury is called the high ankle sprain. Its injury can lead to instability of the tibial / fibular / talar articulations, further compromising the rest of the ligaments. Its diagnosis is crucial since its healing is poor without treatment. Syndesmotic ligaments at Inferior Tibiofibular joint include:

1. Anterior inferior Tibiofibular ligament (AiTFL)
   - o Linear, uniform low signals, may be in the form of multiple strip like insertions (Fig.9).
   - o Better visualized on axial plane.

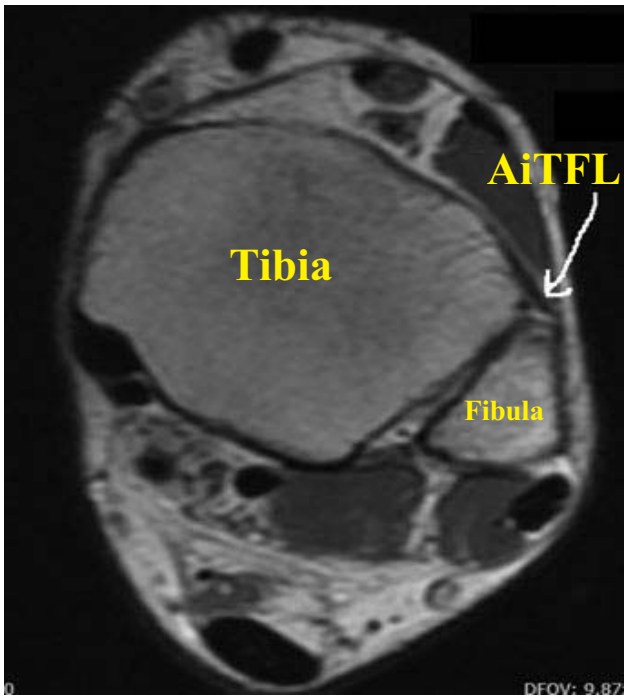

Figure 9: Axial PD image showing Anterior Inferior Tibiofibular ligament (Anterior syndesmotic ligament).

2. Posterior Inferior Tibiofibular ligament (PiTFL)
   - o Thick, striated, broad and band like (Fig.10)
   - o Visualized on coronal and axial planes.

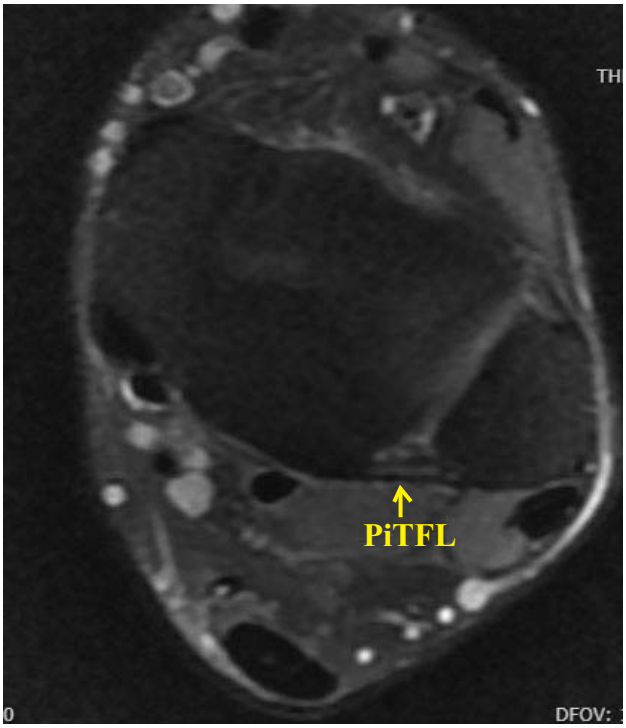

Figure 10: Axial PD FATSAT image showing Normal Posterior Inferior Tibiofibular ligament also called as the Posterior syndesmotic ligament (arrow).The normal anterior tibiofibular ligament is seen as linear hypointensity and posterior tibiofibular ligament seen as a thick striated band with mixed signals. Note tendinopathy in achilles tendon.

3. Interosseous membrane and recess.
   - o Recess is located inferior to the interosseous ligament and has communication with the ankle joint.
   - o Elongation of recess is indirect sign of injury to syndesmosis.
   - o Membrane asessed on coronal and axial planes.
   - o Recess assessed on coronal plane, PD FATSAT preferable.
4. Interosseous ligament:
   - o It is thickening of the inferior most part of the interosseous membrane.
   - o Better visualized on coronal plane (Fig.11).
5. Inferior Transverse Ligament:
   - o It is located inferior to the PiTFL.
   - o Better visualized on coronal plane.

Figure 11: Coronal PD FATSAT and PD images showing Interosseous ligament (arrow) and recess (+)

Medial Ligaments:

These are also called the deltoid collateral ligament complex. It includes the medial deep ligaments, corresponding to the lateral (talofibular) ligaments and a superficial band of ligaments. There is an additional spring ligament at medial ankle having connection with superficial ligament band and has deep insertional fibers giving stability to the medial arch.

1. Medial Deep ligaments.
   - o Anterior TibioTalar Ligament.
   - o Posterior TibioTalar Ligament (Fig.12)

2. Medial Superficial ligaments:For superficial medial ligaments, coronal plane is ideal for assessing integrity. Its advisable to always start from posterior and the first ligament you see attached to sustentaculumtali is Tibiocalcaneal ligament (Fig.13 a&b), followed by anteriorly located tibiospring. The main superficial ligaments are:
   - o Tibiocalcaneal.
   - o Tibiospring.
   - o Tibionavicular.

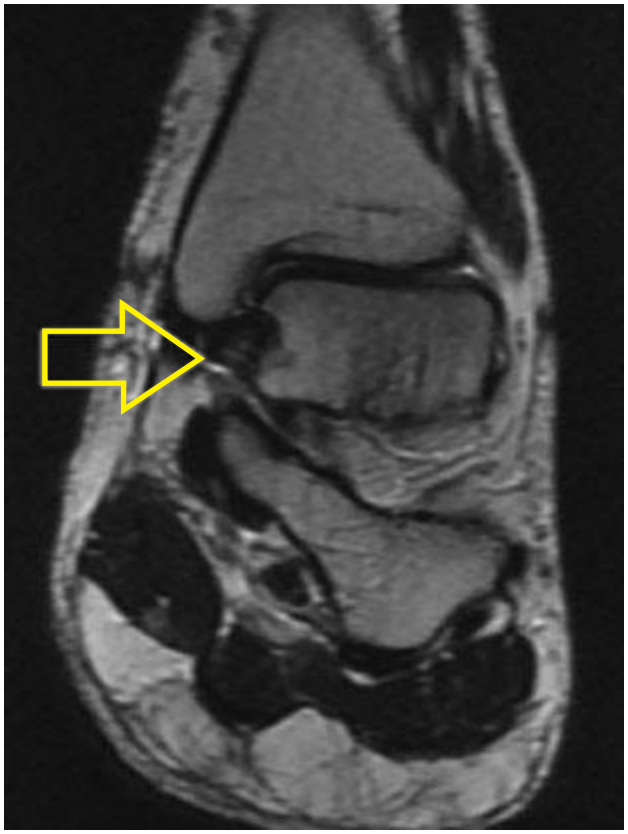

Figure 12: Coronal PD image showing normal Posterior tibiotalar ligament (arrow)

Figure 13(a): Coronal PD image showing Tibiocalcaneal Ligament (Intact)

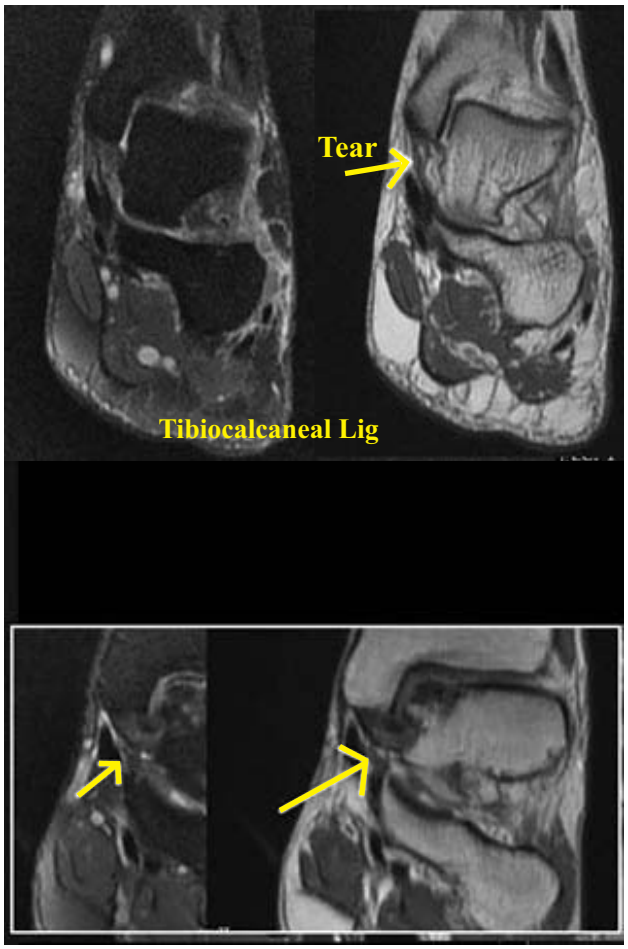

Figure 13(b): Coronal PD FATSAT and PD images showing Tear of Tibiocalcaneal ligament (arrow pointing at torn ligament having wavy appearance, high signals and thickening)

3. Spring Ligament / Calcaneonavicular Ligament complex: It is Located deep to the Tibilais posterior tendon (Locate on Coronal plane).The complex extends from the calcaneus to the Navicular bone.

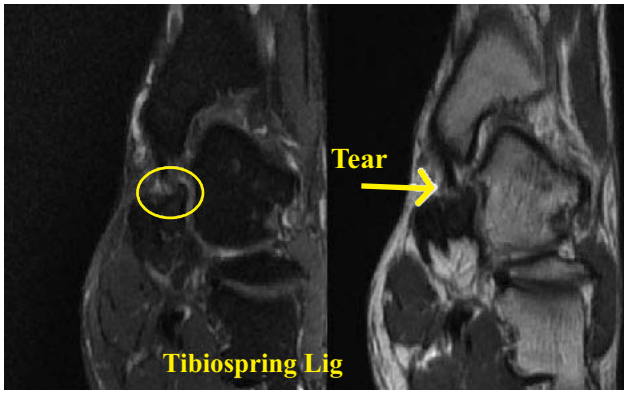

Figure 14: Tibiospring Ligament partial tear (arrow). The intrinsic high signals at junction of tibiospring ligament and spring ligament (arrow).

Its integral function in stabilizing plantar arch. Spring ligament injuries often associated with tibialis posterior tendon dysfunction. (Fig.14)

The spring ligament consists of three components:

- o Superomedialcalcaneonavicular ligament, most often injured.
- o Medioplantar oblique calcaneonavicular ligament.
- o Inferoplantar longitudinal calcaneonavicular ligament.

Tips to approach ligamentson MRI (Fig. 15 & 16):

- For superficial medial ligaments, always start from posterior and the first ligament you see attached to sustentaculumtali is Tibiocalcaneal ligament, followed by tibiospring.
- Posterior deep ligaments in ankle are thick striated band like structures with intrinsic hyperintense striations as a normal finding.

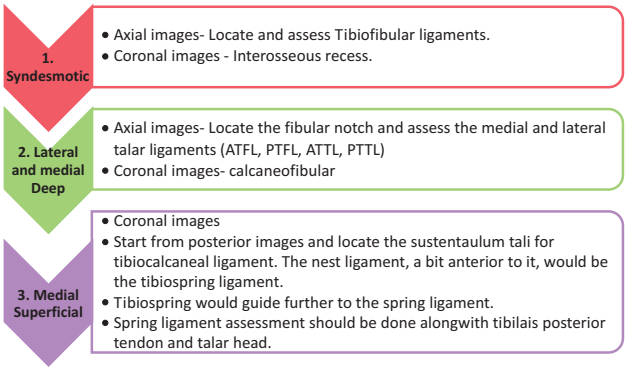

Figure 15: Showing chart flow for easy assessment of Ankle Ligaments.

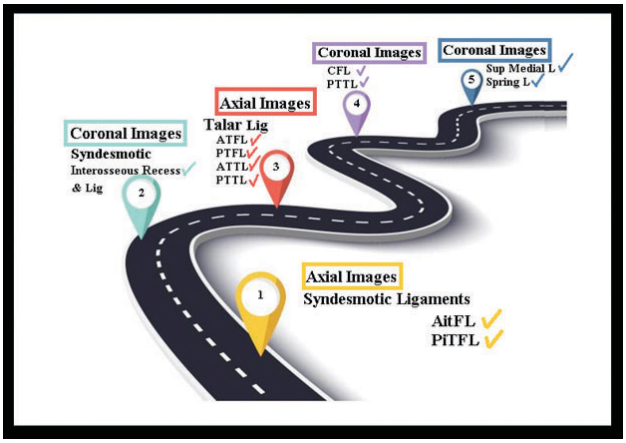

Figure 16: Showing Roadmap for imaging assessment of Ankle Ligaments on MRI.

Conclusion

- MRI of ankle joint is useful in characterizing the ligament tears and PD weighted image is the most useful sequence.
- Emphasis should be given to the understanding of intricate and unique anatomy and orientation of ankle ligaments.
- Injured ligaments on MRI may appear disrupted, thickened, heterogeneous, or attenuated in signal intensity, and may be abnormal in contour.
- Torn ligament has fluid signalsand old scarred ligament in chronic ankle pain has diffuse thickening and ill definition with low signals on all sequences.

Acknowledgement: Special Thanks to Dr. Ravi Padmanabhan, a wonderful teacher and a brilliant MSK Radiologist.

Conflict of Interest: None

References

1. TetyanaGorbachovaT.Magnetic resonance imaging of the ankle and foot. ghg Pol J Radiol. 2020; **85:** e532–e549.

2. Videbaek S, Bueno AM, Nielsen RO, Rasmussen S. Incidence of running-related injuries per 1000 h of running in different types of runners: a systematic review and meta-analysis. Sports Med. 2015; **45(7):** 1017-26.

3. Francis P, Whatman C, Sheerin K, Hume P, Johnson MI. The proportion of lower limb running injuries by gender, anatomical location and specific pathology: a systematic review. Journal of sports science & medicine. 2019; **18(1):** 21-31.

4. Gonzalez FM, Morrison WB. Magnetic resonance imaging of sports injuries involving the ankle. Topics in magnetic resonance imaging : TMRI. 2015; **24(4):** 205-13.

5. Lazzarini KM, Troiano RN, Smith RC. Can running cause the appearance of marrow edema on MR images of the foot and ankle? Radiology. 1997; **202(2):** 540-2.