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Syndesmotic Ligaments of the Ankle: Anatomy, Multimodality Imaging, and Patterns of Injury

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Injuries to the syndesmotic ligaments of the ankle or "high ankle sprains" are common in acute ankle trauma but can be difficult to diagnose both clinically and on imaging. Missed injuries to the syndesmosis can lead to chronic ankle instability, which can cause persistent pain and lead to early osteoarthritis. This review will illustrate the anatomy of the syndesmotic ligamentous complex, describe radiographic, CT, and MR imaging of the syndesmosis, demonstrate typical mechanisms of injuries and associated fracture patterns, and provide an overview of important management considerations.

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Introduction

Syndesmotic injuries are common, occurring in up to 20% of acute ankle injuries.[1] Management of syndesmotic injuries can present diagnostic and management challenges for the treating physician. Syndesmotic injuries are often associated with prolonged recovery times compared to ankle sprains involving the lateral collateral ligamentous complex[2,3] and can cause persistent pain and disability.[4] Furthermore, many of the physical exam maneuvers to assess for syndesmotic injury, such as the external rotation, squeeze, drawer, and Cotton tests have limited sensitivity for detecting syndesmotic injury.[5-7] In the setting of ankle fractures, syndesmotic injuries can be assessed intraoperatively using fluoroscopic stress views, or by direct visualization.[8,9] Arthroscopy can be useful for both diagnosis and treatment of syndesmotic injuries,[10-12] but is not routinely used for diagnosis given its expense and invasive nature. Weening et al. found that reduction of the syndesmosis in ankle fractures was significantly associated with better functional outcomes,[13] which highlights the importance of accurate and timely diagnosis. Given the difficulty in assessing the syndesmotic ligaments both by physical exam and operative evaluation, imaging plays a significant role in the diagnosis of syndesmotic injury, but also brings its own challenges. This article will review anatomy and multimodality imaging of the distal tibiofibular syndesmosis, describe common mechanisms of injury, and emphasize the surgical implications of common fracture patterns associated with syndesmotic disruption.

Anatomy of the Distal Tibiofibular Syndesmosis

Bony Anatomy

The bony anatomy of the distal tibia and fibula is important for the osseous stability of the tibiofibular joint. At the distal tibia, near the apex of the syndesmosis, the lateral ridge of the distal tibia bifurcates into an anterior and posterior margin, forming a larger anterior tibial tubercle (Chaput's tubercle) and a smaller posterior tubercle of the tibia (Volkmann's tubercle)[14] (Fig. 1). These tubercles serve as the tibial attachment sites of the anterior and posterior syndesmotic ligaments, respectively. Corresponding anterior (Wagstaffe tubercle) and posterior fibular tubercles represent the fibular attachments of the anterior and posterior syndesmotic ligaments (Fig. 2A).

Between the anterior and posterior margins of the tibia is a concave groove termed the incisura tibialis (also known as the fibular notch of the tibia or syndesmotic notch), in which the corresponding convex margin of the fibula rests (Fig. 2B). The bony anatomy in this region is thought to be important in the stability of the ankle, with a shallow incisura tibialis, retroverted (small) anterior tibial tubercle, and disengaged fibula associated with syndesmotic disruption in patients with high fibular fracture.[15] Variable bony anatomy is also important in rates of malreduction after internal fixation of fibular fractures.[16] In 3 quarters of ankles, there are cartilage covered facets at the tibiofibular contact zone, forming a true synovial joint.[17]

Ligamentous Anatomy

The ligamentous structures of the syndesmosis function in conjunction with the bony supports to provide syndesmotic stability, and include the anterior inferior tibiofibular ligament (AITFL), posterior inferior tibiofibular ligament (PITFL), inferior transverse ligament, and interosseous ligament. The AITFL, also referred to as the anterior syndesmotic or anterior tibiofibular ligament, is the most important ligamentous stabilizer of the syndesmosis, and also the

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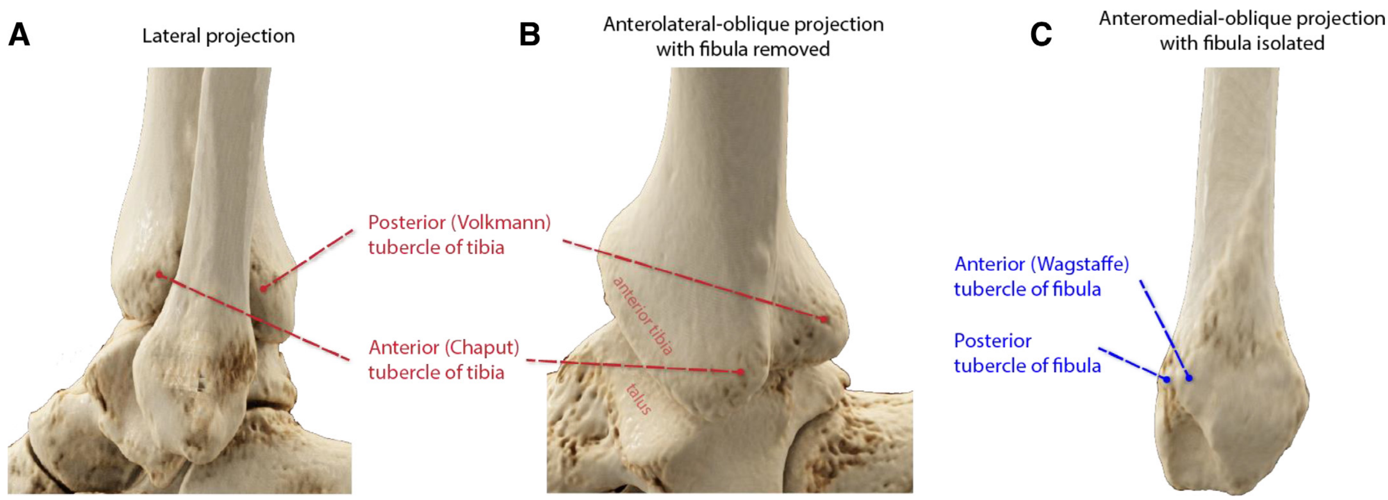

FIG 1. CT cinematic rendering of the bony anatomy of the tibiofibular syndesmosis. (A) On the lateral projection, the larger anterior tubercle of the tibia and smaller posterior tubercle of the tibia are apparent. (B) These structures are better appreciated on the anterolateral-oblique projection with the fibula removed. (C) An isolated view of the fibula in the anteromedial-oblique projection demonstrates the anterior and posterior tubercles of the fibula. Together these structures contribute to the stability of the tibiofibular syndesmosis.

most commonly injured ligament of the syndesmotic complex[18] (Fig 3A). This ligament acts as the primary restraint to fibular external rotation.[19,20] The ligament extends in an oblique course proximally from the anterior tubercle of the tibia to insert laterally on the anterior tubercle of the fibula. The ligament contains multiple fascicles, with the most inferior-distal band being implicated in anterolateral ankle impingement and is occasionally mistaken for the anterior talofibular ligament.[21] The AITFL is most frequently supplied by an anterior branch of the peroneal artery, and due to the course which perforates the interosseous ligament this vessel may be especially susceptible to vascular injury in trauma, with devascularization of the AITFL hypothesized as a contributing factor to prolonged healing.[8]

The interosseous ligament is a distal continuation of the interosseous membrane between the tibia and fibula, and acts to restrain lateral translation of the fibula.[19] The interosseous ligament also serves as the roof of the syndesmotic recess, a synovium lined recess that extends superiorly from the tibiotalar joint between the tibia and fibula[14] (Fig 3B). Disruption of this ligament is increasingly been thought to be an important factor for tibiofibular diastasis.[20,22]

The PITFL, also known as the posterior tibiofibular or posterior syndesmotic ligament, courses from the posterior tibial malleolus to the posterior tubercle of the fibula. This ligament acts to restrain posterior translation of the fibula.[19] There is some controversy as to whether the inferior transverse ligament should be thought of as a deep component of the PITFL, or a separate ligament altogether.[14,23] It originates from the proximal malleolar fossa and inserts on the posterior edge of the tibia, acting as a labral analogue to prevent posterior talar translation[14,24] (Fig 3C).

The intermalleolar ligament arises slightly distal to the origin of the transverse ligament from the malleolar fossa and distal to the origin of the transverse ligament, and runs parallel to the transverse ligament[14] (Fig 3D). This ligament is variably imaged; it may blend in with fibers of the transverse ligament and is often not discretely identified.

A biomechanical cadaveric study by Ogilvie-Harris et al evaluated the contribution of each component of the syndesmotic complex to resistance to diastasis and demonstrated that the AITFL contributes 35.5%, the deep PITFL contributes 32.7%, the interosseous contributes 21.6%, and the superficial PITFL contributes 8.7%.[25] The syndesmotic ligament complex can be thought of as being analogous to the talofibular ligament complex in that the anterior ligament, the AITFL is the most commonly disrupted ligament of the syndesmotic complex. In contrast, the PITFL is stronger, with almost all injuries seen concurrently with AITFL disruption; isolated injuries of the PITFL are very uncommon.[5,26,27]

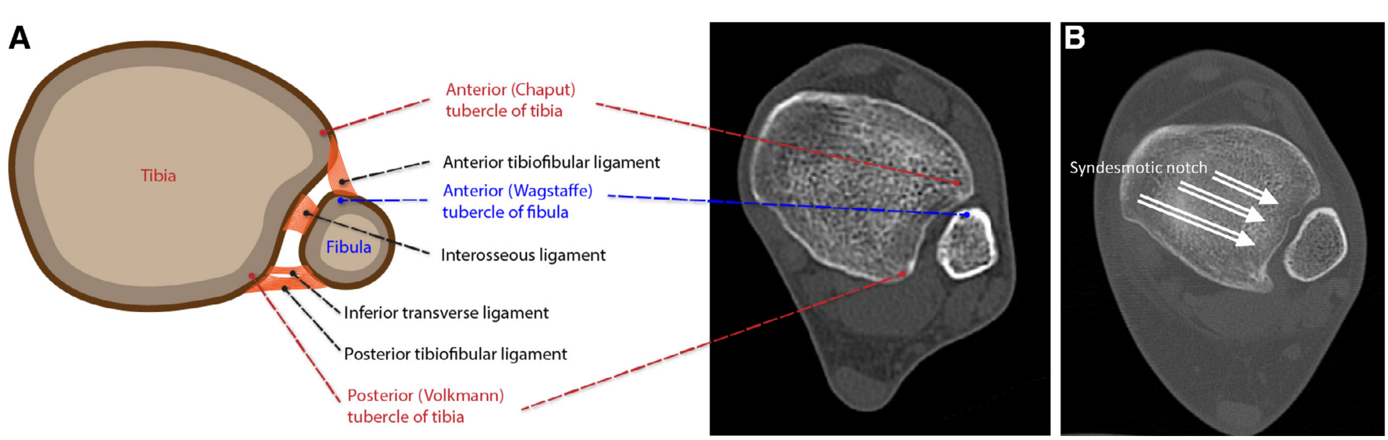

FIG 2. (A) Bony anatomy of the distal tibiofibular syndesmosis with illustration and corresponding axial CT image highlighting the location of the anterior (Chaput's) tubercle of the tibia, the anterior (Wagstaffe) tubercle of the fibula, and posterior (Volkmann) tubercle of the tibia. Note the relation of the ligaments to the bony landmarks. (B) The incisura tibialis (open arrows) in a different patient.

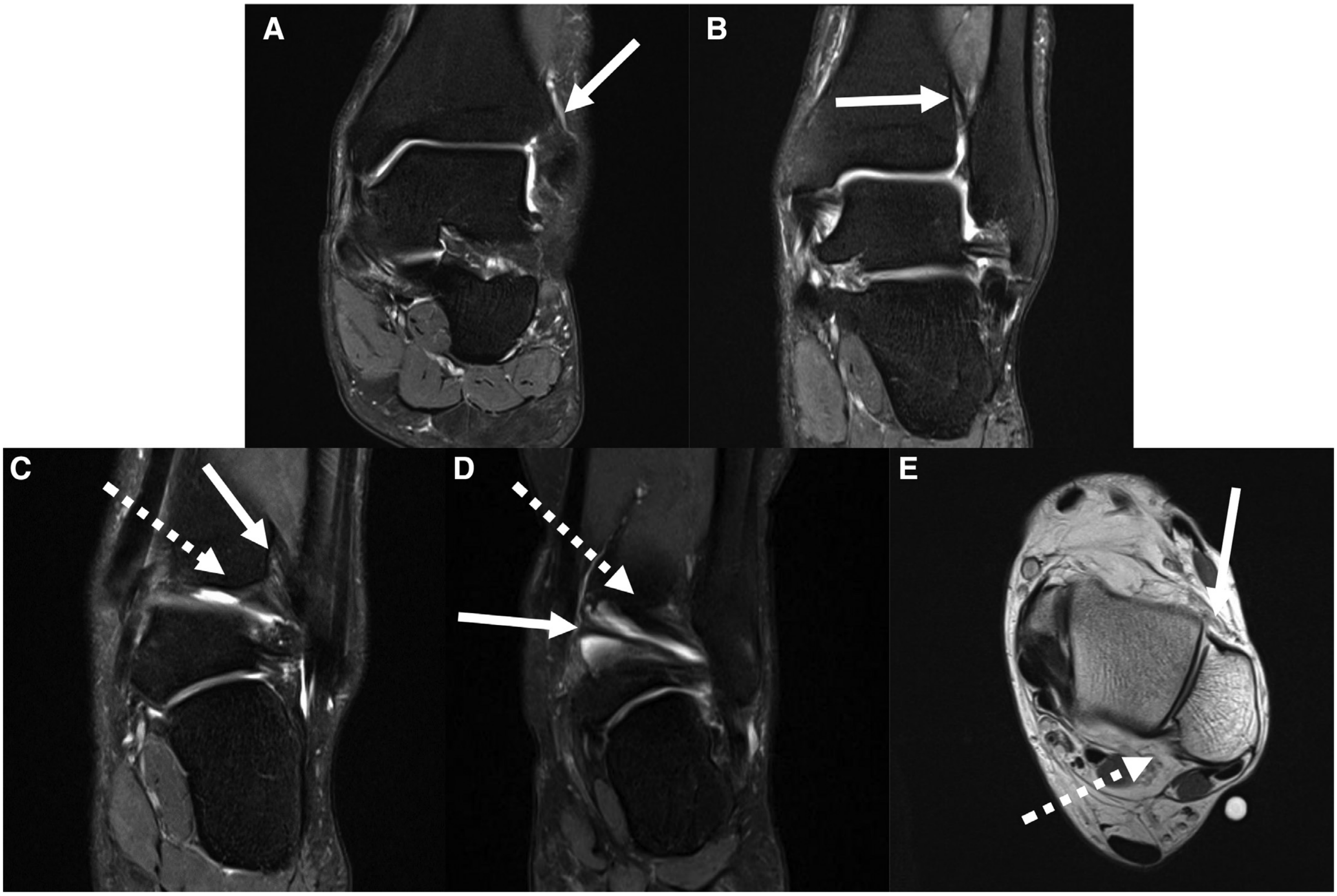

FIG 3. Normal anatomy of the ankle syndesmosis on coronal proton density fat saturated images, from anterior to posterior (A through E) and axial proton density imaging (E). (A) Anterior inferior tibiofibular ligament. (B) Interosseous Ligament. (C) Posterior inferior tibiofibular ligament (solid arrow) and inferior transverse ligament (dashed arrow). (D) Intermalleolar ligament (solid arrow) and inferior transverse ligament (dashed arrow). (E) Anterior inferior tibiofibular ligament (solid arrow) and posterior inferior tibiofibular ligament in a different patient (dashed arrow). Note the flat appearance of the distal fibula indicates this is the expected level to visualize the syndesmotic ligaments.

Radiographic Findings of Syndesmotic Injury

On radiographs, several parameters and measurements have been developed to assess for syndesmotic injury. Among these, the tibiofibular clear space (TFCS) measurement is one of the most important and measures the distance between the medial border of the fibula and the floor of the incisura fibularis at a level 1 cm proximal to the tibial plafond (Fig 4). Another measurement is the tibiofibular overlap (TFO) which is measured from the lateral border of the anterior tubercle of the tibia to the medial border of the overlapped fibula, 1 cm proximal to the plafond. Although this is the method that the majority of authors in the literature use for evaluating the TFCS and TFO, some authors use alternate measurement methods, often adding to confusion.[28] Pitfalls in obtaining the radiographs include improperly positioned radiographs, confusing the anterior and posterior tibial tubercles, and variable anatomic depth of the peroneal groove.[28,29] Depending on the source, a TFCS of greater than 5-6 mm and a TFO of less than 10 mm on AP view is considered abnormal and concerning for syndesmotic injury.[29−31] Syndesmotic injury can cause lateral shift of the talus and this widening of the medial clear space. Medial clear space (MCS) refers to the distance between the medial border of the talar dome and the lateral border of the medial malleolus on mortise view.

The TFO is measured from the lateral border of the anterior tubercle of the tibia to the medial border of the fibula on AP and mortise views (Fig 5). Harper and Keller reported that the TFO should be greater than 6 mm on AP view and greater than 1 mm on the mortise view.[31] Shah et al. reported that lack of any TFO on mortise view may be a normal variant in the setting of a diminutive anterior tubercle of the tibia, and found 7.1% of patients on AP view and 4.3% of patients on mortise view demonstrated a TFCS of greater than 6 mm,[30] raising

FIG 4. Radiographic measurement of tibiofibular clear space and tibiofibular overlap on AP ankle radiograph. The distance from B, the medial border of the fibula, to A (floor of the incisura tibialis), as measured 1 cm superior to the tibial plafond, denotes the tibiofibular clear space. The distance from C, the lateral border of the anterior tubercle of the tibia, to B, the medial border of the fibula, denotes the tibiofibular overlap.

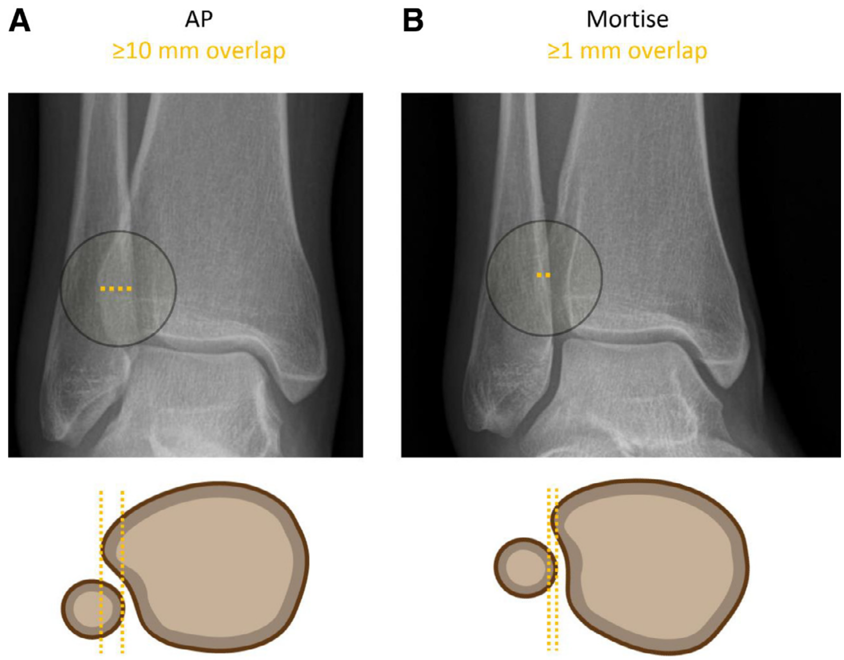

FIG 5. Radiographic measurement tibiofibular overlap on AP (A) views and mortise views (B) with the figures below the radiographs demonstrating how the medial border of the fibula and the anterior tibial tubercle form the respective shadows that define the tibiofibular overlap.

questions about whether current criteria may be over-diagnosing syndesmotic injury. Given the significant variation between patients for the normal distances of these spaces, in equivocal cases, comparison views of the contralateral ankle may be helpful (Fig 6) as the tibiofibular intervals generally do not vary significantly between ankles of the same person.[32,33]

Pneumaticos et al. studied the effect of rotation on these radiographic parameters and found that the TFCS as measured on AP view, was the only parameter not significantly influenced by rotation and thus the most reproducible and reliable parameter for evaluation of the distal tibiofibular joint.[33] Similarly, Schoennagel et al. compared the sensitivity of radiographic measurements to MR diagnosis of syndesmotic injury in patients without ankle fracture, and found of the radiographic parameters, TFCS is the most valid and reproducible parameter for isolated syndesmotic injury in the absence of fracture.[18] Medial clear space was the second most valid parameter, and TFO was found to have no diagnostic or prognostic value.

Syndesmotic injuries are frequently associated with ankle fractures, and an understanding of the anatomy of the syndesmotic ligaments and mechanisms of these injuries can help the radiologist to identify clinically significant injuries, and to better understand the management implications of ankle fracture classifications. While a detailed discussion of ankle fracture classification is beyond the scope of this review, it is important to understand a few key points to increase understanding of the clinical significance of the syndesmotic ligaments. The most commonly used ankle fracture classifications are the Danis-Weber, Ao-Müller, and Lauge-Hansen classifications. The Weber classification is based on the location of the distal fibular fracture relative to the syndesmosis. Fractures below the level of the syndesmosis are Weber A, fractures at the level of the syndesmosis are Weber B, and fractures above the level of the syndesmosis are Weber C (Fig 7). The syndesmosis is usually uninvolved in Weber A fractures, and the syndesmosis is functionally disrupted in Weber C fractures; however, the status of the syndesmosis is ambiguous in Weber B fractures.

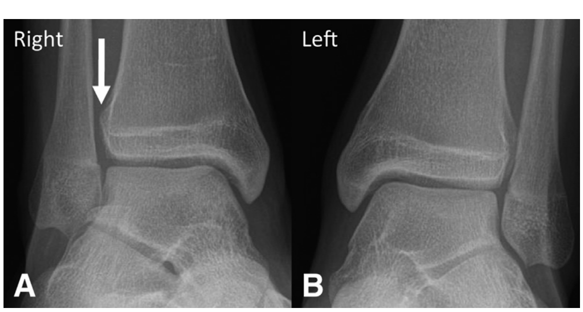

FIG 6. Standing Mortise views of the right ankle (A) of a patient demonstrates subtle widening of the tibiofibular clear space and loss of the tibiofibular overlap (arrow). The findings are much more conspicuous when compared to the same patient's uninjured left ankle (B).

The Lauge-Hansen classification system provides more granular information on the mechanism of injury and specific anatomic structures involved. It incorporates the fracture mechanism, including the position of the foot (supinated or pronated) and the direction of the deforming force at time of injury (a force causing abduction, adduction, or external rotation) and has multiple cumulative stages for each fracture type depending on severity.[34]

Of particular importance to the discussion of the syndesmosis, the status of the syndesmotic ligaments is critical for accurate classification of supination-external rotation types of injuries. These types of fractures are by far the most common mechanism of ankle fractures. According to the Lauge-Hansen classification, when the foot is in a supinated position, a force causing external rotation will either cause a rupture of the AITFL or an avulsion fracture of the bony attachments of the AITFL[34] (Fig 8). The fact that a stage I supination-external rotation injury can result in ligamentous disruption of the AITFL without any visible fracture, or an isolated syndesmotic injury, presents a category of syndesmotic injuries that can be challenging to treat and diagnose. Progressive external rotation in supination results in a Weber B spiral fracture of the fibula,[20] disruption of the PITFL or posterior malleolus, and finally the medial malleolus or deltoid ligament (Fig 9).

When the foot is in pronation, a force causing external rotation will first result in either deltoid ligament injury or a fracture of the medial malleolus and continued external rotation will result in

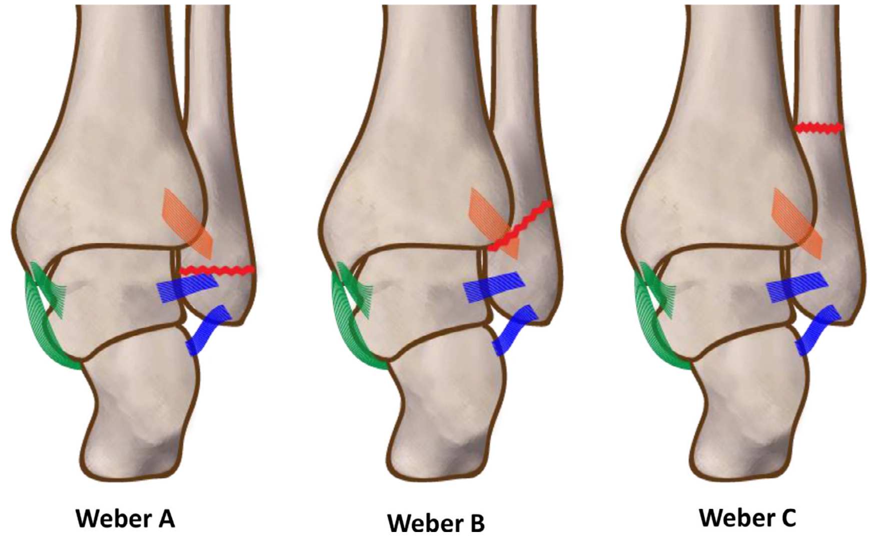

FIG 7. Danis-Weber Fracture classification. Weber (A) fractures occur below the level of the ankle syndesmosis (left figure), Weber (B) fractures occur at the level of the syndesmosis (middle figure) and Weber (C) fractures occur above the level of the ankle mortise (right figure).

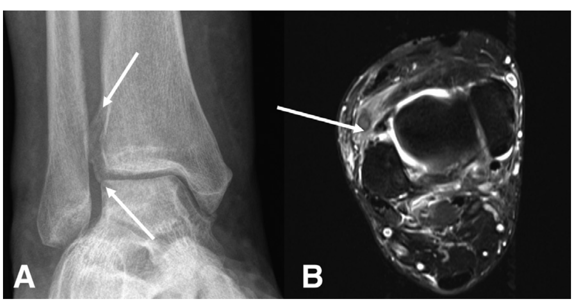

FIG 8. Supination-external rotation stage I Injury. (A) Mortise view of the ankle demonstrates widening of the tibiofibular clear space (arrows), and severe soft tissue swelling about the ankle. (B) Axial proton density fat saturated image demonstrates fluid signal undercutting the anterior inferior tibiofibular ligament attachment on the Wagstaffe tubercle (arrow), consistent with a full thickness tear.

disruption of the AITFL. Further external rotation results in a high fibular fracture, and subsequently a posterior malleolus fracture or PITFL disruption.

The principal advantage of the Lauge-Hansen classification is that it allows inference of syndesmotic injuries even when no appreciable clear space widening is seen, based on the assumption that injuries occur in a predictable sequence and stages cannot be skipped.[35] For example, a radiograph demonstrating an isolated posterior malleolus or an isolated fibular (Weber B) fracture, even in the absence of visible TFCS or medial clear space widening, likely has a radiographically occult syndesmotic injury based on the fracture mechanism (Fig 10).

A recent paper comparing radiographic findings to magnetic resonance imaging for syndesmotic injuries found that the Ao-Müller and Danis-Weber classifications had a 47% sensitivity and 100% specificity for syndesmotic injury, while the Lauge-Hansen classification had a sensitivity of 92% and specificity of 92% for syndesmotic injury when utilizing MR as the comparison gold standard.[27]

Computed Tomography (CT) Imaging of Ankle Syndesmotic Injury

CT has the advantage of high resolution imaging and excellent bone contrast, allowing for accurate assessment of alignment and detection of nondisplaced fractures and subtle avulsion fractures which can be missed by radiographs and MR (Fig 11). CT allows

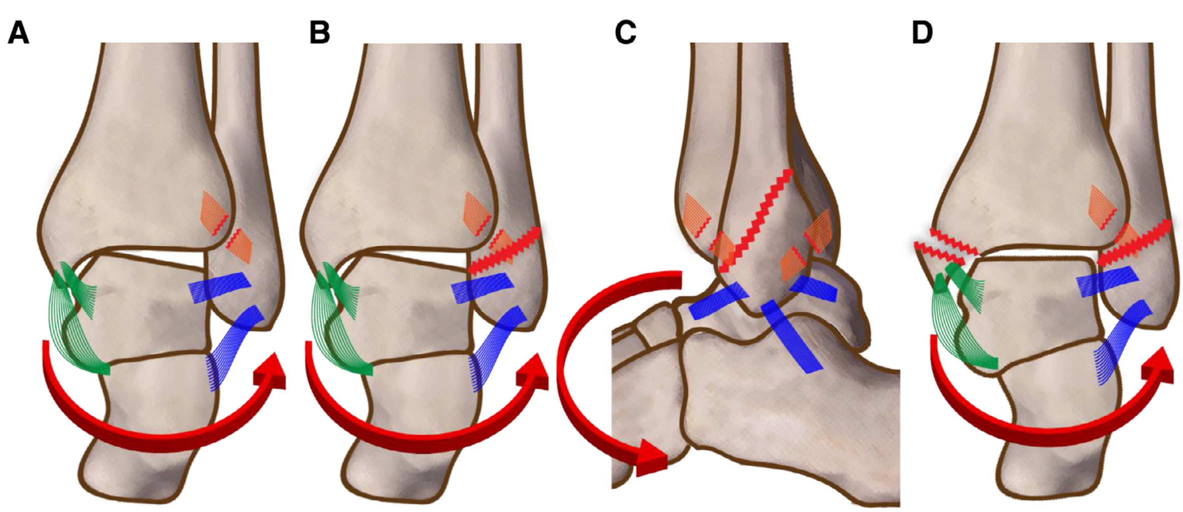

FIG 9. Lauge-Hansen classification for supination-external rotation (SER) injuries. In SER I injuries (A) the AITFL or its bony attachments are disrupted. With continued external rotation, SER II (B) develops with a Weber B spiral fracture of the distal fibula. Continued external rotation results in SER III with disruption of the PITFL (C) or alternatively a fracture of the posterior malleolus (not pictured), and lastly SER IV results in medial malleolar fracture (D) or deltoid ligament rupture (not pictured). AITFL, anterior inferior tibiofibular ligament; PITFL, posterior inferior tibiofibular ligament.

FIG 10. Posterior malleolus fracture. (A) Lateral view radiograph of the ankle demonstrates an avulsion fracture of the posterior malleolus. (B) Mortise view demonstrates absence of any other visible fracture and equivocal TFCS widening. A posterior malleolus fracture is usually associated with additional ligamentous injuries. (C,D) Consecutive axial proton density fat saturated MR images at the level of the syndesmosis demonstrate the posterior malleolar avulsion fracture (arrow) and disruption of the AITFL (dashed arrow). AITFL, anterior inferior tibiofibular ligament: TFCS, tibiofibular clear space.

detailed assessment of the bony anatomy, including depth of the fibular notch, and size of Chaput's tubercle. The importance of joint congruity is highlighted by cadaveric a study demonstrating that a lateral talar shift of 1 mm decreases the tibiotalar articular contact area by an average of 42%.[36] Incongruent reduction of the joint therefore may lead to accelerated osteoarthritis, and meticulous joint reduction is therefore of paramount clinical importance. Taser et al. described the novel use of 3D volume rendering with CT to calculate the volume of the tibiofibular joint space, with the goal of detecting tibiofibular diastasis.[37] Using a cadaveric model, they found a 1 mm diastasis of the tibiofibular syndesmosis resulted in a 43% increase in tibiofibular joint space volume.[37] Elagfy et al. described variation in the degree of the fibular borders and anatomy of the incisura fibularis on CT, and described a system to objectively measure syndesmotic diastasis.[28] Given the significant challenges in accurate position of radiographs and often in interpretation, CT could offer better assessment of syndesmotic displacement, albeit with the disadvantage of higher cost and potential for higher ionizing radiation.[28] Management of syndesmotic injury includes internal fixation, which may be performed with syndesmotic screws, or with suture button fixation.[38,39] CT plays an important role in detection of syndesmotic mal-reduction after internal fixation.[40,41]

MR Imaging of Syndesmotic Injury

While the utility of radiographs for detection of syndesmotic injury still remains a controversial topic, MR has been found to have high sensitivity, specificity, and accuracy in diagnosis of both acute and chronic syndesmotic injuries. For example, Nielsen et al. found no correlation between radiographic TFCS or TFO to injury of the anterior or posterior syndesmotic ligaments on MR.[42] Hermans et al. similarly found no correlation of TFCS or TFO to syndesmotic injury.[27] Gardner et al. found that some ankle fracture classifications were not infrequently unclassifiable under the Lauge-Hansen system, and that the MR findings did not always correlate with the expected pattern of ligamentous disruption and fracture.[43]

MR findings of acute ligament injury include an abnormal course, a wavy irregular appearance, abnormal signal intensity on T2 and T1 sequences, enhancement, or nonvisualization of the ligament[44] (Fig 12). Fracture of the bony attachments, such as a case of a Wagstaffe fracture (Fig 11) can be subtle on MR, but are readily appreciated by CT, and should be reported, as this allows the surgeon to fixate the fracture fragment, with Park et al. reporting a case of an inadequately managed displaced Wagstaffe fracture causing ankle pain and restricted motion.[45]

Increased tibiofibular recess height is significantly associated with acute and chronic syndesmotic injuries, with 1 study finding that a recess height of 1.2 cm and 1.4 cm were associated with acute and chronic syndesmotic injuries respectively, and this study concluded that a height of greater than 1 cm should be considered abnormal[46] (Fig 13).

It has been theorized that chronic syndesmotic injury can cause ankle pain not only due to ligamentous instability, but also hypertrophied soft tissues causing impingement within the distal tibiofibular joint.[47] Han et al. utilized a contrast enhanced 3D-FSPGR sequence in a MR-arthroscopic comparison study to evaluate chronic syndesmotic injuries, and included nodular or irregular enhancement as one of the criteria for chronic syndesmotic injury.[47] Acute and chronic syndesmotic injuries are also associated with fractures, bone contusions, joint incongruity, osteochondral lesions of the talar dome, and injury to the anterior talofibular ligament,[18,46] which can be concurrently assessed by MR.

Several pitfalls exist in the MR diagnosis of syndesmotic ligament injury. The AITFL and PITFL are in close proximity to the anterior and posterior talofibular ligaments, which have a similar obliquity on axial images, which can lead to misidentification. A helpful internal reference to avoid this pitfall is to observe the contour of the distal fibula: the syndesmotic ligaments are seen near or proximal to tibiofibular contact zone, where the fibula assumes a flattened

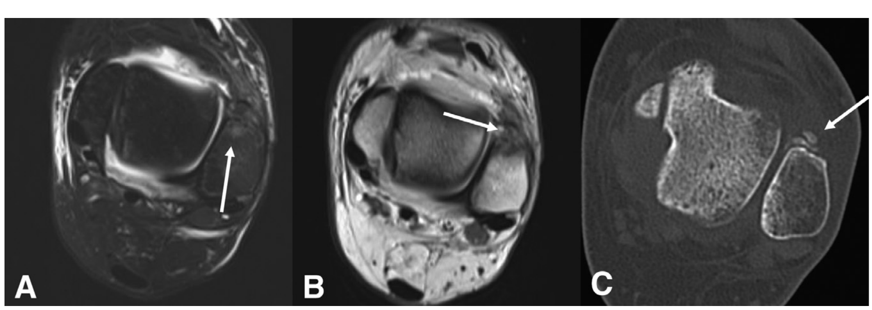

FIG 11. Bony avulsion injury associated with AITFL injury. Axial proton density fat saturated images (A) demonstrate subtle bone marrow edema at the anterior tubercle of the fibula (Wagstaffe-Leforte tubercle). Axial proton density images at the same level (B) demonstrate cortical disruption with loss of the normal hypointense cortical rim at the AITFL attachment on the fibula. Axial CT images at the same level better demonstrate a cortical avulsion fracture of the fibular attachment of the AITFL. AITFL, anterior inferior tibiofibular ligament.

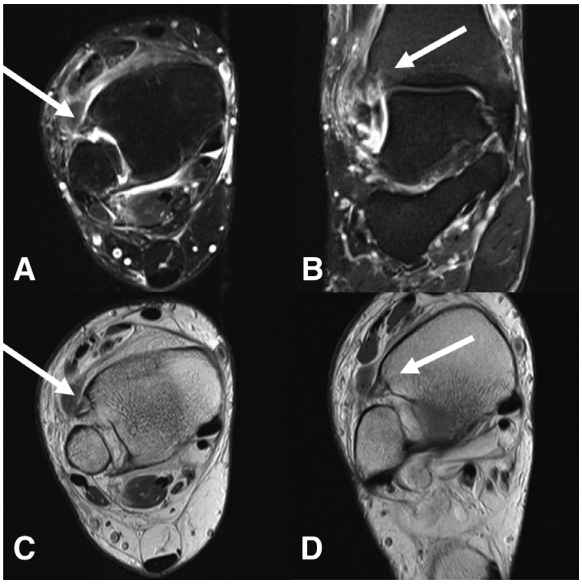

FIG 12. Full-thickness tear of the AITFL. Axial proton density fat saturated (A), coronal proton density fat saturated image (B), axial proton density image (C) and axial oblique proton density image (D) demonstrate an area of fluid signal undercutting the AITFL compatible with a complete tear of the AITFL with surrounding preligamentous edema. AITFL, anterior inferior tibiofibular ligament.

appearance. In contrast, the talofibular ligaments are seen at the level of the curved malleolar fossa.[48] Another pitfall is the multi-fasicular appearance of the AITFL resulting from interspersed areas of fat between the multiple bands of the ligament, resulting in a striated appearance which should not be confused with ligament disruption.[49] Lastly, the oblique course of the syndesmotic ligaments lends them prone to volume averaging, especially on axial images, which can be mistaken for tears. An oblique imaging plane oriented parallel to the course of the syndesmotic ligaments, as described by Hermans et al, can be helpful for assessment of ligament continuity and syndesmotic injury.[50,51]

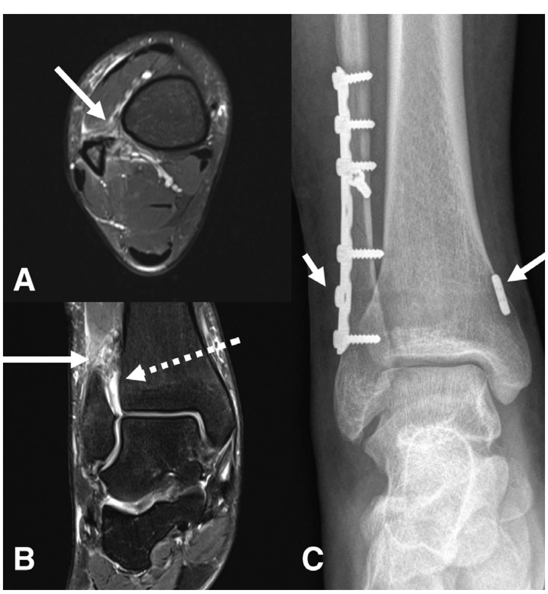

FIG 13. Interosseous ligament disruption. Axial (A) and coronal (B) proton density fat saturated images demonstrate a full thickness tear of the interosseous ligament (arrow). There is prominent fluid extending into the syndesmotic recess (dashed arrow) (C) A concurrent AITFL injury and Weber C fibula fracture (not pictured) were also present, arthroscopy confirmed the syndesmotic injury, and the patient underwent internal fixation of the fibula fracture with tightrope fixation (arrows) of the syndesmosis.

Conclusion

Ankle syndesmotic injuries remain a challenging area to diagnose and treat for physicians, and many aspects of the diagnosis and treatment remain controversial. However, the radiologist can facilitate the timely diagnosis and treatment of syndesmotic injuries through a thorough understanding of the limitations and strengths of each modality. Radiographs are often the initial imaging modality of choice. Understanding how to apply the radiographic parameters such as TFCS, MCS, and TFO overlap, and understanding how to apply the Lauge-Hansen classification can help the radiologist to suspect syndesmotic injury, while acknowledging the limited sensitivity of radiographs for syndesmotic injury. CT is helpful for evaluation of the tibiofibular anatomy and assessment for fractures, as well as assessment for postoperative malreduction. MR remains the modality of choice in detection of syndesmotic injuries and a thorough understanding of anatomy and imaging pitfalls can avoid missed or inaccurate diagnoses of syndesmotic injury.

Conflicts of Interest

None.

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