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ORIGINAL ARTICLE

Tendon entrapments and dislocations in ankle and hindfoot fractures: evaluation with multidetector computed tomography

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Abstract The purpose of this study was to assess the incidence of tendon entrapments and tendon dislocations associated with ankle and hindfoot fractures in patients studied by multidetector computed tomography (MDCT). Additionally, we describe particular tendon injuries associated with specific fractures. This was a retrospective review of all individuals with a trauma-protocol CT for suspected ankle and/or hindfoot fractures during a consecutive 41-month time period at a single Level I Trauma Center. Each patient's images were evaluated by two radiologists and an orthopedic surgeon for tendon entrapment, tendon dislocation, and bone(s) fractured or dislocated. There were 398 patients with ankle and/or hindfoot fractures that showed tendon entrapment or dislocation in 64 (16.1 %) patients. There were 30 (46.9 %) patients with 40 tendon entrapments, 31 (48.4 %) patients with 59 tendon dislocations, and three (4.7 %) patients with both tendon entrapment and dislocation. All patients with tendon entrapments were seen with either pilon fractures and/or a combination of posterior, medial, or lateral malleolar fractures. The most frequently entrapped tendon was the posterior tibialis tendon (PTT) in 27 patients (27/30, 90.0 %). The peroneal tendons were the most frequently dislocated, representing 27 (87.1 %) of patients with tendon dislocation; all resulted from a talar or calcaneal fracture or subluxation. This study demonstrates that tendon entrapments and tendon dislocations are commonly seen in complex fractures of the ankle and hindfoot. Pilon fractures were associated with the majority of tendon entrapments, whereas calcaneus fractures were associated with the majority of tendon dislocations.

Keywords Ankle fracture · Tendon injury · Tendon entrapment · Tendon dislocation · Computed tomography · Multidetector computed tomography

Conference Presentation
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Introduction

Ankle and hindfoot fractures can result in tears, entrapment, or dislocation of leg tendons that traverse the ankle [1–3]. Surgical repair and clinical management of patients with lower extremity fractures is complicated by tendon entrapments and dislocation. These can result in stenosing tenosynovitis, tendon tears, and severe restriction of motion and tendon function, as well as acting as an impediment to reduction of fractures or joint dislocations [4, 5].

In the setting of acute trauma with complex fractures of the ankle and hindfoot, computed tomography (CT) is routinely performed following plain radiographs for treatment planning [6]. Although MRI is more sensitive in detecting partial or full thickness tears, the location of the tendons and their relationship with the fracture fragment are clearly defined on CT [5]. Given the potential for complications in ankle fractures due to tendon entrapment and dislocation, it is important for radiologists to be aware of the incidence of these issues in order to optimize diagnostic accuracy. There are few studies examining the incidence of tendon entrapments and tendon dislocation associated with ankle and hindfoot fractures [6–8]. The purpose of this study is to assess the incidence of tendon entrapments and tendon dislocations associated with ankle and hindfoot fractures and joint dislocations in patients studied by multidetector CT (MDCT) imaging. Additionally, we describe particular tendon injuries associated with specific fractures.

Materials and methods

This was an institutional review board-approved retrospective review of all individuals with a trauma-protocol CT for suspected ankle and/or hindfoot fractures during a consecutive 41-month time period at a single Level I Trauma Center. Pediatric patients younger than 17 years old and patients with postoperative CTs were excluded. Each patient's images were evaluated independently by two board-certified attending radiologists and a board-certified attending orthopedic surgeon for (i) tendon entrapment, (ii) tendon dislocation, and (iii) bone(s) fractured or dislocated. Disagreements were solved by consensus; images were reviewed as a group and if there was still a dispute, majority vote was used. If tendon entrapment or dislocation was noted, the involved tendon was recorded as well.

For our study, tendon dislocation was defined as a tendon not located in the normal anatomic position, therefore losing anatomical relationship with the adjacent bony structures due to its malposition. Our study did not differentiate between subluxations and dislocations, and all tendon "dislocations" in this study include tendon subluxations; this follows the example of a similar previous study by Ohashi et al. [6]. Tendon entrapment was defined as a tendon incarcerated within fracture fragments with more than 50 % of the tendon circumference surrounded by those fragments. Calcaneal fractures were categorized according to the Sanders classification system [9].

CT was performed by using either a 16-detector row scanner (LightSpeed; General Electric, Fairfield, CT) or a 64-detector row scanner (Somaton Definition; Siemens, Malvern, PA). Imaging parameters for the 16-row scanner included tube voltage, 120 kV; tube current, 200 mAs; rotation time, 0.8 s; pitch, 0.51; collimation, 0.62 mm; reconstruction increment, 2.5 mm; and reconstruction thickness, 2.5 mm. The following parameters were used for the 64-row scanner: tube voltage, 120 kV; tube current, 120 mAs; rotation time, 0.8 s; pitch, 0.8; collimation, 0.8 mm; reconstruction increment, 2 mm; and reconstruction thickness, 2 mm. Transverse, sagittal, and coronal multiplanar reformatted images to the long axis of the tibia were available.

Once the database was established, each patient's imaging was analyzed to identify the following parameters: the distribution patterns of fractures, the patterns/distribution of tendon entrapments with the fractures, and the patterns/distribution of the tendon dislocations. After this data was collected and compiled, the findings were reviewed and confirmed a second time by the radiologists for accuracy. Descriptive statistics were used to summarize the data, and Student *t* test and chi-square were used to compare differences in demographics and patterns of fractures and tendon injuries (tendon injuries defined as either tendon entrapment or dislocation). Statistical significance was defined as a p value of less than 0.05. The data were recorded and analyzed using Microsoft Excel 2011 (Microsoft Corporation, Redmond, WA).

Results

Our evaluation of 398 patients with ankle fractures and dislocations showed tendon entrapment and/or dislocation in 64 patients (16.1 %), male = 35, female = 29, mean age = 40.0 ± 12.6 years; range = 17 to 68; median = 40 years. Of the 64 patients, there were 30 (46.9 %) patients with 40 tendon entrapments, 31 (48.4 %) patients with 59 tendon dislocations, and three (4.7 %) patients with both tendon entrapment (4 total) and dislocation (6 total). When assigning the three patients with concurrent entrapment and dislocation to both groups, the overall incidence of tendon entrapments was 8.3 % (33 of 398 patients) and tendon dislocations was 8.5 % (34 of 398 patients). There were no significant differences between tendon dislocation and entrapment with respect to gender ($p = 0.24$) or age ($p = 0.086$). Patients with tendon entrapments had significantly more fractures compared to those with tendon dislocations (2.47 fractures per patient with tendon entrapment compared to 1.29 fractures per patient with tendon dislocation, $p < 0.001$). Conversely, patients with tendon dislocations had significantly more tendon injuries compared to patients with tendon entrapment (1.90 tendon dislocations per patient compared to 1.33 tendon entrapments per patient, $p < 0.001$). These data are summarized in Table 1.

Tendon entrapments

All 30 patients with tendon entrapments were seen with either pilon fractures and/or a combination of posterior, medial, or lateral malleolar fractures. The pilon fractures were associated with 19 tendon entrapments (19/30; 63.3 %), and the malleolar fractures were associated with 20 tendon entrapments (20/30; 66.7 %); pilon and malleolar fractures were

Table 1 Demographics, fracture, and tendon injury characteristics of patients with tendon entrapments or dislocations

	Entrapments	Dislocations	*p* value
Patients*	30	31	–
Gender	$M = 19, F = 11$	$M = 15, F = 16$	0.24
Mean age	37.5	43.1	0.086
Total tendon entrapments or dislocations (mean)[†]	40 (1.33)	59 (1.90)	<0.001
Total fractures (mean)	74 (2.47)	40 (1.29)	<0.001
Total joint dislocations or subluxations	0	8	–

*There were 64 total patients in our study. Three patients had concurrent tendon entrapments and dislocations are not accounted for in this table. They are presented in Table 2

[†] In each respective column, the total and mean refer to exclusively entrapments or dislocations; concurrent tendon entrapments and dislocations are presented in Table 2

present in combination in nine patients (9/30; 30.0 %). The most frequently entrapped tendon was the posterior tibialis tendon (PTT) in 27 patients (27/30; 90 %). Flexor digitorum longus (FDL) entrapment occurred in six patients (6/30; 20 %). All FDL entrapments were concurrent with PTT entrapments. Pilon fractures were present in five of the six FDL entrapments. Flexor hallicus longus (FHL) entrapment was seen in one patient. There were four patients with peroneal entrapment (4/30; 13.3 %). Concurrent peroneus brevis (PB) and peroneus longus (PL) entrapment occurred in two patients (2/30; 6.7 %),

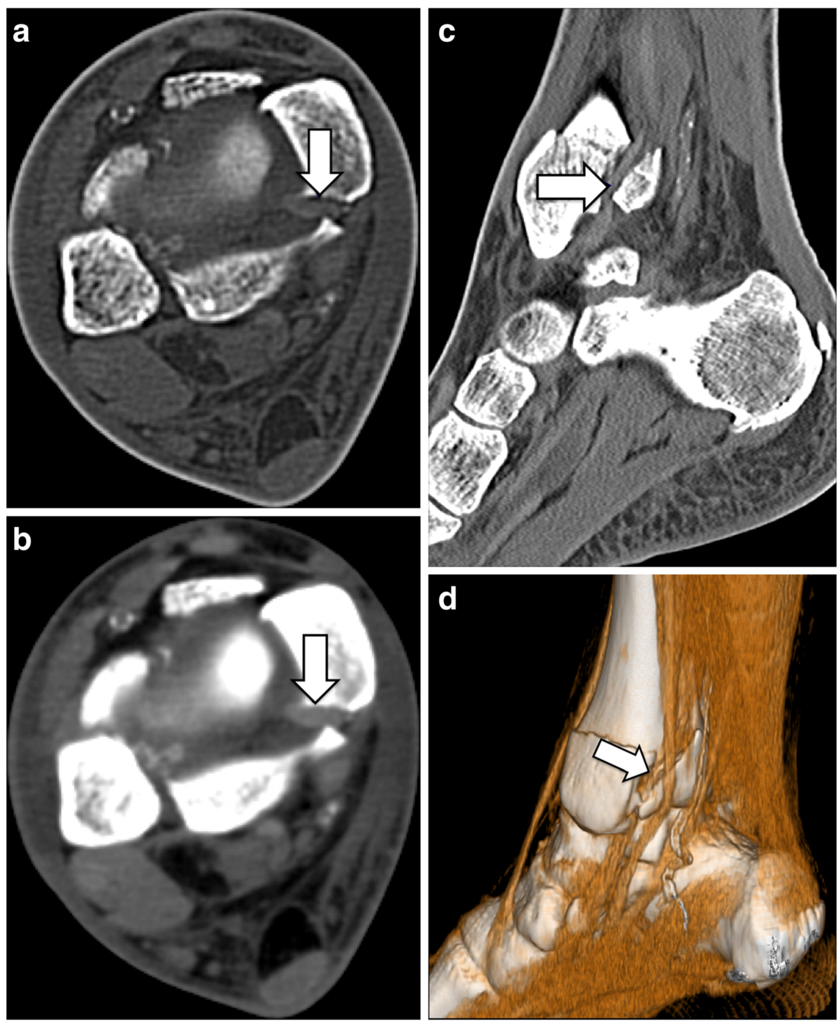

Fig. 1 A 38-year-old male with a history of motor vehicle crash. **a** Axial CT reformatted images of the ankle with bone algorithm showing a pilon fracture with posterior tibialis tendon entrapment (*arrow*). **b** Axial CT reformatted images with soft tissue algorithm showing a pilon fracture with posterior tibialis tendon entrapment (*arrow*). **c** Sagittal reformatted image at the level of the medial malleolus shows the posterior tibialis tendon entrapped in the fracture (*arrow*). **d** MDCT 3D volume rendered image demonstrates a pilon fracture with entrapment of the posterior tibialis tendon (*arrow*)

both caused by pilon fractures with lateral malleolar fractures. A representative case of tendon entrapment is seen in Fig. 1.

Tendon dislocations

There were 31 patients with tendon dislocations including perperoneus longus and brevis (PBL), 23 patients (23/31; 74.2 %); PL, three patients (3/31; 9.7 %); PTT and FDL, two patients (2/31; 6.4 %); PBL and PTT, one patient (1/31; 3.2 %); PTT, one patient; and FHL and PTT, one patient. Calcaneal fractures were associated with 23 of these patients with tendon dislocations (23/31; 74.2 %).

The peroneal tendons were the most frequently dislocated, representing 27 patients with tendon dislocation (27/31; 87.1 %). There were 24 tendon dislocations that involved both the PL and PB tendons with only three involving only a PL tendon. There were no sole PB tendon dislocations. All 27 patients with peroneal tendon dislocations resulted from a calcaneal fracture, talar fracture, or tibiotalar subluxations/dislocations with or without subtalar dislocation. Peroneal dislocations most commonly resulted from calcaneal fractures (23/27; 85.2 %). Of the 23 calcaneal fractures associated with peroneal dislocations, 19 were Sanders type IV (82.6 %; 19/23), two were IIIAC, one was IIIAB, and one was IIA. There were four talar fractures (4/31; 12.9 %) resulting in tendon dislocations, two with PBL, one with FHL and PTT, and one with PTT and PBL. Five patients (5/31; 16.1 %) had tendon dislocations caused by a total of eight tibiotalar subluxations or dislocations with or without subtalar dislocations. Concurrent subtalar and tibiotalar dislocation was seen in three patients who all had PTT dislocations, and two of these patients had FDL dislocation as well. One patient had a PL displacement associated with a tibiotalar subluxation and a medial malleolar fracture, and one patient had PB and PL displacement associated with tibiotalar dislocation. A representative case of tendon dislocation is seen in Fig. 2.

Entrapments with dislocations

There were three patients with combined tendon entrapment and dislocation; all were associated with pilon fractures and PBL dislocations. The demographics, fracture, and tendon injury characteristics are shown in Table 2. These three patients are separate from the 31 patients with tendon

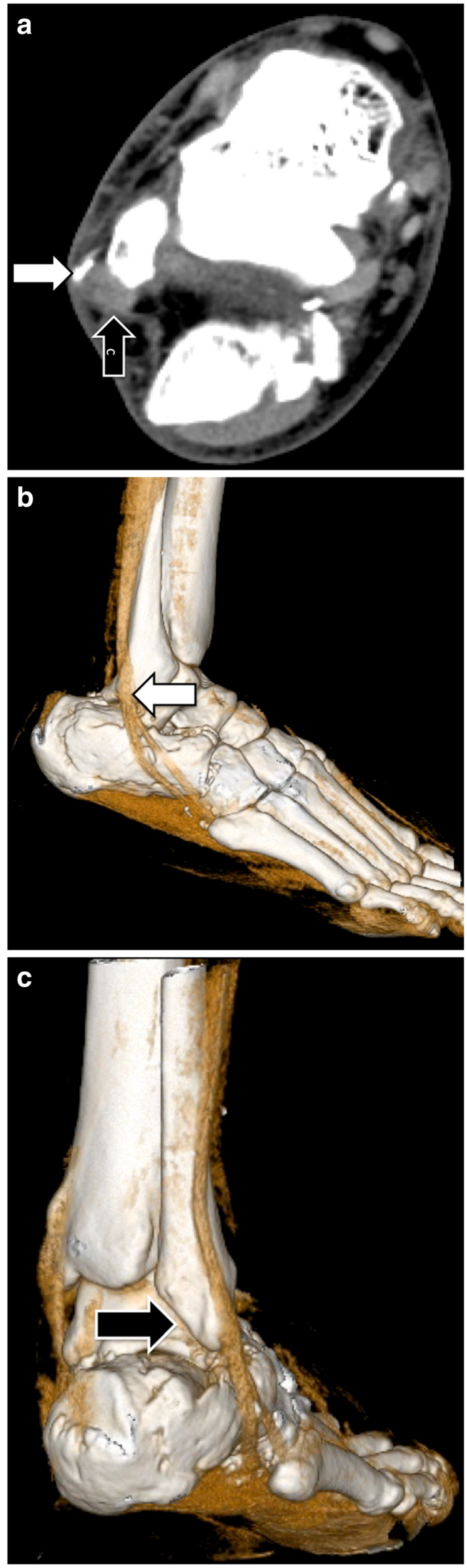

Fig. 2 A 47-year-old male with a history of fall from a rooftop. **a** Axial CT image of the ankle with soft tissue algorithm shows avulsion of the peroneal retinaculum (*white arrow*) and dislocation of the peroneal tendons (*black arrow*). A calcaneal fracture is also seen. **b**, **c** MDCT volume rendered image localizes the dislocated peroneal tendons (**b**, *white arrow*) and shows an empty peroneal groove (**c**, *black arrow*) ▶

Table 2 Demographics, fracture, and tendon injury characteristics of the three patients with concurrent tendon entrapments and dislocations

Age/gender	Fracture(s)	Tendon entrapment(s)	Tendon dislocations
23/male	Pilon, extra-articular calcaneal fracture	Posterior tibialis tendon	Peroneus longus and brevis tendons
31/female	Pilon	Tibialis anterior tendon	Peroneus longus and brevis tendons
27/female	Pilon, fibula, Sanders type IV fracture	Flexor digitorum longus and posterior tibialis tendons	Peroneus longus and brevis tendons

dislocations and 30 patients with tendon entrapments discussed above.

Discussion

Our study showed a 16.1 % incidence of tendon entrapment or dislocation associated with ankle and hindfoot fractures in a study population of 398 consecutive adult trauma patients who underwent CT of the ankle and hindfoot. We were able to discern various patterns of tendon entrapment and dislocation. All tendon entrapments were seen with either pilon fractures or malleolar fractures and the PTT was most commonly entrapped. All dislocations were associated with a talar or calcaneal fracture or subluxation and peroneal tendons were the most commonly dislocated.

Pilon fractures account for 5 to 7 % of all tibial fractures [10]. They result from axial loading, when a combination of compression and shearing forces are produced between the talar dome and the distal tibial articular surface, often resulting in significant fragmentation and displacement [11]. They are usually associated with massive swelling of the foot and ankle as well as with open fractures. Based on our findings, the presence of a pilon fracture indicates that further evaluation for tendon entrapment is warranted. In addition, since all FDL entrapments were associated with PTT entrapments, the presence of an FDL entrapment should prompt the radiologist to suspect that there may be PTT tendon involvement as well. A level of awareness is important as studies have shown that tendon entrapments in lower extremity fractures are frequently missed in radiology reports [12]. Eastman et al. [12] reported a retrospective study of 394 patients with 420 pilon fractures and found 40 patients with entrapped tendons and/or posterior medial neurovascular bundle associated with fractures. They reviewed the patients' CTs, CT reports, clinical course, and operative reports and found that the final interpretation of the CT scan commented on the entrapped structure in only eight of 40 fractures (20 %). Similar to the findings in the present study, the most common tendon entrapment-fracture association was PTT entrapments, which were present in 38 of 40 patients with pilon fractures and entrapped soft tissue structures.

Talar, calcaneal, tibial, and malleolar fractures should be evaluated for PTT entrapment, since all entrapments associated with one of these fractures involved the PTT. From our findings, the posterior tibialis has the highest likelihood of becoming entrapped in ankle fractures and should be considered with a high index of suspicion in instances of leg tendon entrapment. Both tendon dislocation and entrapment occurred together only in pilon fractures, and these fractures are the most common ankle fractures associated with tendon entrapment. Identification of tendon entrapment on MDCT by the radiologist is important for operative planning. Preexisting knowledge of entrapped structures can influence operative approach (may require additional or alternative incisions) and sequence of dissection and reduction [12].

Calcaneal fractures are the most common fractures of the foot and present a large socioeconomic burden as they are estimated to account for 2 % of all fractures presenting to emergency departments [13, 14]. Calcaneal fractures are often the result of traumatic axial loading from a fall or automobile accident. In the present study, the majority of peroneal tendon dislocations resulted from calcaneal fractures. The Sanders classification to evaluate calcaneal fractures is based on the number of intraarticular fracture lines and their location on CT images [9]. Ranging from type I to type IV, higher classifications are meant to correspond to greater severity, which may have prognostic indications. Sanders type I fractures includes intraarticular fractures that have less than 2 mm of articular displacement, regardless of the number of fracture lines/fragments present and can often be managed nonoperatively [15]. Sanders type II and III fractures have one and two primary fracture line(s), respectively, whereas Sanders type IV involves three or more primary fracture lines with greater than 2 mm of articular displacement, and are therefore severely comminuted. Our study shows that the majority of leg tendon dislocations (19 of the 23 [82.6 %] of peroneal tendon dislocations) are seen in the setting of Sanders classification type IV calcaneal fractures, suggesting that these fractures should be evaluated for tendon dislocation. We suspect that in these injuries, there is lateral displacement of the lateral calcaneal wall that displaces the tendons laterally causing tearing or avulsion of the superior retinaculum. The fleck sign is a radiographic sign that represents an avulsion fracture of the lateral malleolus at the attachment of the superior peroneal retinaculum. When the peroneal tendons dislocate, the periosteum is stripped from the lateral cortex of the lateral malleolus, sometimes with a small avulsion of that cortex [16]. This flake fracture is best seen on a mortise view of the ankle. This bony fragment is parallel to the fibula. It is highly suggestive of peroneal tendon dislocation with specificities of up to 98 % in larger series [17].

Any tendon of the leg can become malpositioned (subluxed or dislocated), but the peroneal tendons are most commonly involved. The peroneus longus tendon descends posteriorly and laterally to the peroneus brevis in the retromalleolar groove, posterior to the lateral malleolus. Both descend laterally down the leg in the common peroneal synovial sheath and are stabilized by the superior peroneal retinaculum and the calcaneofibular ligament [18]. Dislocations or subluxations of the peroneal tendons may present as a lateral ankle pain and is often misdiagnosed as an ankle sprain. Previous studies have estimated that peroneal subluxations occur in up to 0.5–28.0 % of all traumatic events involving the ankle [17, 19]. Increasing incidence has been reported with more modern series [17, 20]; however, CT may overestimate the true incidence of tendon displacement. Ketz et al. [15] reported a series that corroborated peroneal dislocation on CT with intraoperative findings and found a higher incidence of suspected peroneal subluxation or dislocation on preoperative CT compared to intraoperative findings. In 47 patients with CT evidence of peroneal displacements, there were 36 false positives based on intraoperative exam. It is important to identify acute or recurrent dislocations or subluxations of the peroneal tendons since conservative management often does not have favorable outcomes compared to surgical interventions and the knowledge of tendon dislocation may change operative approach [6, 21–23].

Toussaint et al. [17] reported a three-institution retrospective review querying calcaneal fractures with associated peroneal tendon displacement (displacement was defined as subluxation or dislocation in their series). In 421 calcaneal fractures, peroneal tendon displacement was present in 28 % of cases (118/421). Importantly, the radiology report only identified peroneal subluxation/dislocation in 10.2 % of cases in their study. They also classified calcaneal fractures according to Essex-Lopresti and Sanders classifications and found significantly higher incidence of peroneal tendon displacement with joint depression compared to tongue-type fractures classified by the former and significantly high rates of displacement with increasing Sanders classification [17]. Kwaadu et al. [20] reported similar findings in a retrospective series of 90 patients with 97 calcaneal fractures. They found Sanders type IV calcaneal fractures were associated with a significantly higher incidence of peroneal dislocation requiring repair compared with type III or lower (11 of 55 [20 %] compared to 2 of 42 [4.8 %]) [20]. These data are consistent with the findings in the present study—19 of the 23 (82.6 %) peroneal tendon dislocations associated with calcaneal fractures were Sanders type IV; the remaining four were subtypes of types II and III.

There are a number of limitations to our study. This study is limited by a patient sample from a single institution. As the study was designed only to focus on the incidence and patterns of tendon injuries, we did not record data about surgical management, outcome, and follow-up. Data that correlates surgical findings, whether or not preoperative imaging influenced operative approach, would be useful as a follow-up study. A prospectively collected database would be ideal.

Conclusion

This study demonstrates that tendon entrapments and tendon dislocations are commonly seen in complex fractures of the ankle and hindfoot. Tendon injuries should be described and communicated to the surgeon for proper preoperative planning. Patterns of tendinous entrapments and dislocations have commonly associated fracture injuries, which may have predictive implications. MDCT may aid in a more complete diagnosis of specific tendinous pathologies, which will allow recommendations for appropriate clinical and surgical management.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Disclosures The authors claim no disclosures.

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