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AO FAS AMERICAN ORTHOPAEDIC FOOT & ANKLE SOCIETY®

Foot & Ankle Orthopaedics
2025, Vol. 10(1) 1–7

DOI: 10.1177/24730114251328694
journals.sagepub.com/home/fao

Ligamentous Injuries in Stable Ankle Fractures: An MRI-Based Study

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Abstract

Background: Ankle fractures are common orthopaedic injuries, and their management is primarily determined by fracture stability. The Lauge-Hansen classification system categorizes fractures according to mechanism of injury and ligaments involved. Supination external rotation (SER) type 2 fractures correspond to stable weber B fractures and are traditionally treated nonoperatively, whereas SER 3 and SER 4 fractures, characterized by syndesmosis disruption, typically require surgical intervention. We hypothesize that some apparently stable injuries may involve additional structures, challenging the conventional treatment approach. This study aims to determine the prevalence of SER 3 and SER 4 ankle injuries among radiographically stable SER 2 fractures.

Method: The study used baseline data from a longitudinal cohort conducted at Gold Coast Hospital and Health Service (GCHHS). Patients attending the GCHHS fracture clinic with radiographically stable SER 2 fractures were invited to participate. Those meeting the eligibility criteria underwent ankle magnetic resonance imaging (MRI) to evaluate the integrity of syndesmotic and ankle ligaments.

Results: Fifty-six participants were recruited, 38 (68%) female and 18 (32%) male, with a mean age of 47.2 years. All had stable syndesmoses on radiographic assessment and diagnosed with stable SER 2 ankle fractures. MRI scans revealed that 71% (n = 40) met the criteria for SER 2 injuries, 25% (n = 14) for SER 3 injuries with complete ruptures of posterior inferior tibiofibular ligament (PITFL), and 4% (n = 2) for SER 4 injuries with PITFL and deltoid ligament (DL) ruptures. These results challenge the assumption that radiographically stable SER 2 fractures are consistently stable in terms of additional structures involved.

Conclusion: The study highlights that a considerable proportion of seemingly stable ankle fractures involve more structures than previously thought. This suggests the management of SER 3 and SER 4 injuries could include nonoperative treatment.

Level of Evidence: Level III, cohort study.

Keywords: distal fibular fractures, ankle fractures, syndesmosis, MRI, Lauge-Hansen classification

Background

Ankle fractures are common, with 1 in 800 people fracturing their ankles every year.[12] Several classification systems have been proposed to guide when an operation may be necessary, usually relying on clinical assessment and plain film radiographs.

The Lauge-Hansen classification system, which is most widely used and based on cadaveric studies, considers ligamentous injuries and various trauma mechanisms.[3,9] It categorizes ankle fractures into 2 broad groups based on the position of the foot at the time of the injury, supination and pronation. It then subclassifies these groups based on the direction of the deforming force. The supination fractures

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Table 1. Classification Systems of Malleolar Fractures.

	Classification system		
Fibular fracture	Danis-Weber	Lauge-Hansen (stages)	AO/OTA
Infrasyndesmotic	Type A	Supination adduction 1. Transverse fracture of lateral malleolus 2. Vertical fracture of medial malleolus	44-A1 (isolated lateral) 44-A2 (lateral, medial) 44-A3 (lateral, medial, posterior)
Transsyndesmotic	Type B	Supination-external rotation 1. Injury of AITFL 2. Low oblique/short spiral fracture of lateral malleolus 3. Injury of PITFL or fracture of posterior malleolus[19] 4. Deltoid ligament injury or fracture of medial malleolus[3]	44-B1 (lateral) 44-B2 (lateral, medial) 44-B3 (lateral, medial, posterior)
Suprasyndesmotic	Type C	Pronation external rotation 1. Deltoid ligament injury or fracture of medial malleolus 2. Injury of AITFL 3. High oblique/spiral fracture of distal fibula 4. Injury of PITFL or fracture of posterior malleolus Pronation abduction 1. Deltoid ligament injury or fracture of medial malleolus 2. Injury of AITFL 3. Transverse or comminuted fracture of distal fibula	44-C1 (simple diaphyseal) 44-C2 (multifragmentary) 44-C3 (proximal)

Abbreviations: AITFL, anterior inferior tibiofibular ligament; AO, Arbeitsgemeinschaft für Osteosynthesefragen; OTA, Orthopaedic Trauma Association; PITFL, posterior inferior tibiofibular ligament.

are further classified into supination-external rotation (SER) and supination-adduction. Likewise, the pronation fractures are further classified into pronation-external rotation and pronation-abduction injuries.

The classification systems of both the Lauge-Hansen and Danis-Weber have been combined in the Orthopaedic Trauma Association (OTA)/AO classification System. The classification systems are displayed in Table 1. The SER injuries in the Lauge-Hansen classification are known as Weber B or OTA type B fractures and account for approximately 50% of all ankle fractures (Table 1).[3,10,13,21]

Treatment protocols in most centers classify fractures as stable or unstable based on clinical assessment and standard weightbearing ankle radiographs (anteroposterior, mortise and lateral views). Controversy surrounds the management of SER fractures given that true ligamentous damage cannot be appreciated using plain film radiographs.[7,19,20,23]

Magnetic resonance imaging (MRI), which can provide detailed information on ligamentous damage at the time of the fracture, is not routinely available or used. Unless the posterior or medial malleolus is clearly fractured and displaced on a plain film radiograph, judgment of an SER 3 or 4 ligamentous-only injury is challenging. As a result, it is likely that several SER 3 and SER 4 ankle fractures are classified as SER 2 fractures. Given the excellent results found in nonoperative treatment of SER 2 ankle fractures, it is possible that SER 3 and 4 fractures are also being managed well nonoperatively.

The aim of this study was to explore the prevalence of SER 3 or SER 4 injuries in ankle fractures classified as SER 2 to better understand the soft tissue injuries associated with stress-stable SER injuries.

Methods

Design and Recruitment

This was a prospective single-center exploratory study recruiting participants with unilateral, closed and stable radiographic SER 2 fractures on standard ankle radiographs. Participants were recruited directly from the Gold Coast Hospital and Health Service (GCHHS) Department of Musculoskeletal Services fracture clinic after their SER 2 diagnoses. Their management was coordinated as a standard of care. Their participation in this study was only to undergo imaging to detect tissue damage and monitor progress. Participants were not paid for their involvement.

To avoid coercion, all patients who participated in this study were approached by investigators not directly involved with their medical care. On reading the participant information sheet and asking any questions, they provided written consent. After consenting, a full clinical assessment was undertaken by a medical doctor confirming their eligibility.

Eligibility criteria

Inclusion criteria were as follows: skeletally mature patients $\geq$18 years of age; capacity to provide informed consent; no other concomitant fractures or dislocations;

independent mobility before the injury; and no contraindications to MRI studies.

Exclusion criteria were as follows: skeletal immaturity; fractures with radiographic features of instability as described below; previous trauma or surgery to the affected ankle and comorbidities that impede mobilization; medical comorbidities; and previous injuries, surgery, or implants that rendered them unsafe for an MRI study.

Imaging

All radiographs were obtained as part of routine investigations on first presentation and at 1-week follow-up in the orthopaedic fracture clinics. MRI scans were obtained with a private radiology clinic. All imaging was reported by consultant radiologists and reviewed by the treating surgeon.

The radiographs attained at initial assessment and weightbearing radiographs at 1-week follow-up were assessed for features of instability including medial or posterior malleolar fractures and tibiotalar incongruity defined as a nonalignment of the lateral talar dome with the tibiofibular intersection or as a medial clear space widening of 2 mm or more (compared with the superior clear space) on the radiologic mortise view as described by Donken et al.[3]

Ligament Injuries

Radiologists reported the MRIs using a standardized template. Their reports focused on the presence of injuries to the syndesmotic ligaments including the AITFL, PITFL, inferior transverse ligament (ITL), interosseous ligament (IOL), and deltoid ligament (DL).

Ligaments were reported as being ruptured, injured, or intact. A clear distinction was made between a ruptured ligament and an injured ligament. A ruptured ligament was defined as a complete disruption of the fibers and loss of structural integrity of the ligament. An injured ligament was edematous, frayed, or had incomplete disruption of its fibers.

Special attention was paid to the interosseous ligament. While it is not considered in the Lauge-Hansen classification system, biomechanical studies have demonstrated that it is the strongest and stiffest of the syndesmotic ligaments resisting diastasis.[8]

Data analysis

Descriptive statistics of demographics were initially explored and analyzed, followed by summary statistics of the prevalence of ligamentous injuries in ankle fractures. All analyses were conducted using Microsoft Excel.

Table 2. Mechanism of Injury.

Mechanism of Injury—Rolled/Twisted Ankle From:	%
Low energy	
• Trip from standing height	68
• Fall out of bed/chair	5.5
• Playing sports (rugby, futsal, cross-fit)	7
• Skateboarding/roller skating	7
High energy	
• Bicycle	5
• Wakeboarding	2
• Jet ski accident	2
• Crush from heavy weight	3.5

Results

This study recruited 56 participants, 38 female (68%) and 18 male (32%), with a mean age of 47.2 years (SD: 17.4, range 19-81 years). Regarding mechanism of injury, 87% (n=49) were low-energy mechanisms, and 12% (n=7) were high-energy mechanisms (Table 2).

All participants were classified as SER 2 based on radiographs before their MRI. Following their MRI, 40 (71%) met the defined criteria for SER 2, 14 (25%) met the defined criteria for SER 3 and 2 (4%) met the defined criteria for SER 4. Only 18 of the 56 participants (32%) had pure SER 2 injuries, that is, a fibular fracture and AITFL rupture with an intact IOL resisting diastasis as seen in Table 3. Within those classified as SER 2 and SER 3, different injury patterns emerged, also available in Table 3. The ligament injuries sustained by the cohort are detailed in Tables 4 and 5.

Among the patients with SER 3 and 4 injuries, 6 patients (37.5%) had high-energy mechanisms of injury and 10 (62.5%) were of 50 years of age and older. The mean time from injury to MRI was 19 days (n = 2 to 63 days). Twelve of the patients (75%) with SER 3 and 4 injuries had their MRI at more than 2 weeks from their injury, and 28 (70%) for those with SER2 injuries.

Figures 1 and 2 below demonstrate one such SER type 3 fracture with an MRI and radiographs with an occult posterior malleolar fracture.

Discussion

In this study, we examined the MRI findings of 56 individuals diagnosed with SER 2 ankle fractures based on clinical and radiographic evaluations. All fractures were deemed suitable for nonoperative treatment at the time of diagnosis. Our MRI evaluations revealed that 16 of the 56 participants, initially classified with SER 2 fractures, actually had injuries consistent with SER type 3 and type 4 fractures. This reclassification highlights the possibility of underestimating the severity of these fractures when relying solely on initial radiographic and

Table 3. Type of SER 2 and SER 3/4 Injury Patterns.

SER 2	n	% (of 56)
Pure SER 2 (AITFL rupture with intact IOL)	18	32
SER 2 with IOL injury	24	43
SER 2 with PITFL injury	23	41
SER 3 / 4		
Pure SER 3 (PITFL rupture/posterior malleolar fracture)	8	14
SER 3 with deltoid injury	9	16

Abbreviations: AITFL, anterior-inferior tibiofibular ligament; IOL, interosseous ligament; PITFL, posterior-inferior tibiofibular ligament; SER, supination-external rotation.

Table 4. Patterns of Ligamentous Damage in SER Categories.

SER 2	n = 40	% (of 40)
Intact IOL/PITFL/DL	4	10
Injured IOL only	4	10
Injured PITFL only	3	8
Injured DL only	5	13
Injured IOL and PITFL	10	25
Injured IOL and DL	2	5
Injured PITFL and DL	4	10
Injured IOL/PITFL/DL	7	18
SER 3	**n = 14**	**% (of 14)**
Intact IOL/DL	3	23
DL intact	3	23
DL injured	8	54
SER 4	**n = 2**	
Ruptured IOL/PITFL/DL	2	

Abbreviations: DL, deltoid ligament; IOL, interosseous ligament; PITFL, posterior-inferior tibiofibular ligament; SER 2, supination-external rotation type 2; SER 3 supination-external rotation type 3; SER 4, supination-external rotation type 4.

Table 5. Prevalence of Ligamentous Damage (n = 56).

	AITFL	IOL	PITFL	ITL	DL
Intact, n	0	21	16	29	27
Injured, n	15	24	24	18	27
Ruptured, n	41	11	16	9	2

Abbreviations: AITFL, anterior-inferior tibiofibular ligament; DL, deltoid ligament; IOL, interosseous ligament; ITL, inferior transverse ligament; PITFL, posterior-inferior tibiofibular ligament.

clinical assessments. With 62.5% of our reclassified patients being 50 years or older, it may be that older patients are more susceptible to missed syndesmotic injuries with radiographs alone. It also suggests that nonoperative treatment of injuries graded as SER 3 and 4 may be possible.

Our findings align with the current literature. Many studies have found that it is difficult to evaluate the degree of ligamentous injury and syndesmotic instability on initial assessment of radiographs, which are obtained preoperatively.[2,14] Bäcker et al[1] found an underreporting of ligament injury when comparing weightbearing plain film radiographs to MRI and Gardner et al[5] comparing plain films to intraoperative findings. Vogl et al[22] compared surgical with MRI findings in 38 patients and noted that MRI had a specificity of 96% to 100% and a sensitivity of 93% to 100% for determining the ligaments injured in syndesmotic injuries. This demonstrates the accuracy of MRI in diagnosing syndesmotic injuries. Hermans et al[6] studying both unstable and stable fractures found a 27% discrepancy between syndesmotic injury as predicted by Lauge-Hansen classification on radiographs and findings at MRI. Notably, 9 of 51 (17%) of their patients had underestimated syndesmotic injuries on radiographs. On radiographs, underestimation of anterior and posterior syndesmotic injury is partly due to missed fibular or tibial avulsion fractures in 50% and 67%, respectively.[6]

Nielson et al[14] found no association between the tibiofibular clear space and overlap measurements on radiographs and syndesmotic instability on MRI. In addition, they found that the absence of syndesmotic diastasis on static radiographs was not sufficient to exclude syndesmotic instability in patients with ankle injuries. Therefore, they concluded that radiographic measurements did not predict syndesmotic instability.

These results could be interpreted as a call for more use of MRI at the time of ankle fracture. However, others have cautioned against an increased use, especially in children.[4] Given the volume of ankle fractures and the costly nature of MRI, this may not be useful, and it could lead to overtreatment. The use of MRI can inflate the pathology identified, especially in older people, where degenerative changes can obfuscate acute pathology. Park et al compared MRI findings of the syndesmotic ligaments with results of intraoperative hook test (Cotton stress test) of 74 patients who underwent surgical fixation of SER and PER fractures. None of the patients had an intact AITFL or interosseous ligament. In the MRI findings of the syndesmotic ligaments, complete tear of the PITFL was the most reliable predictor of syndesmotic instability (sensitivity, 74%; specificity, 78%; positive predictive value, 54%).[17]

Nortunen et al[15] assessed the stability of the ankle mortise in SER fractures with an external rotation stress test and compared these to MRI evaluation of injuries to the deep deltoid ligament. They demonstrated a higher interobserver reliability of the stress test (94%) compared with MRI evaluation of the deep deltoid ligament (72%), thus concluding that MRI lacks additional diagnostic value in SER type fractures.[15] However, their study did not report findings on the individual syndesmotic ligaments. The conclusions

Figure 1. Radiograph with occult posterior malleolar fracture.

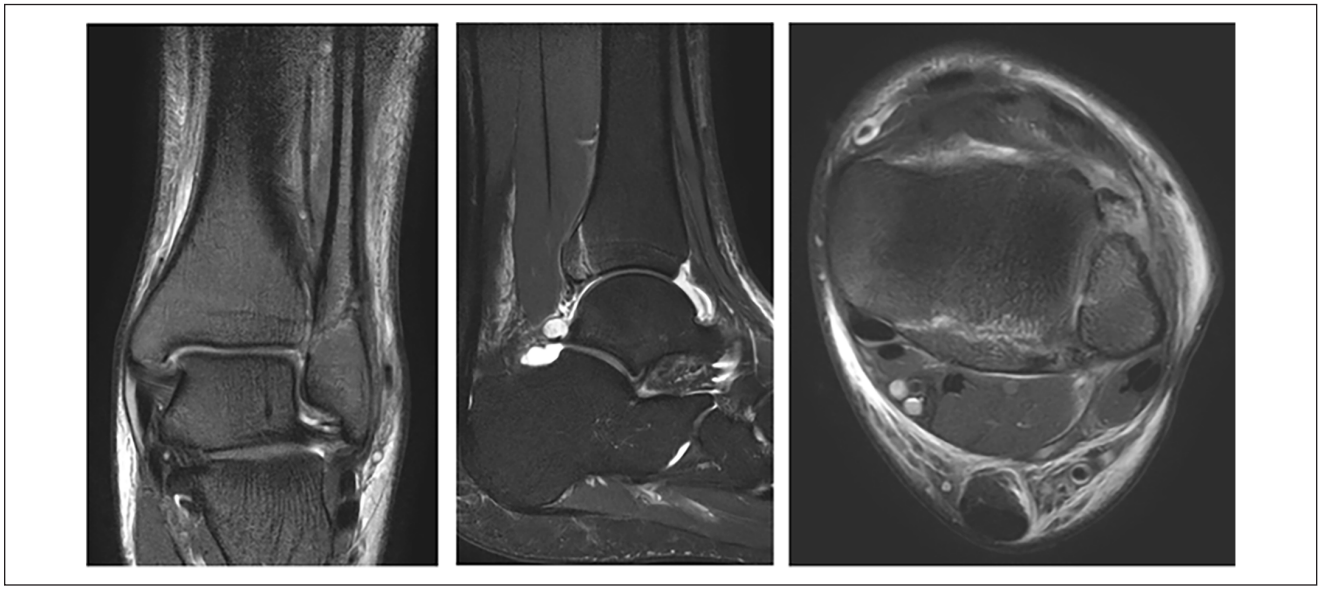

Figure 2. MRI of the same ankle in Figure 1 revealing posterior malleolar fracture.

from these studies imply that MRI studies should be used judiciously in clinical practice; however, it is justified in the research of patterns of ligamentous injuries that can better guide treatment algorithms.

Our findings, however, also suggest that not all SER 3 and SER 4 injuries may require surgical intervention, as some could be effectively managed with nonoperative treatments. The CROSSBAT study found superior outcomes in patients managed nonoperatively (compared to operative management), and it is possible that this study included SER 2-4 injuries, as they examined patients with plain-film radiographs only.[12] For those considered unstable and requiring an operation, perhaps less invasive surgery could be performed. Procedures to reconstruct the syndesmosis could be

reserved for those not responding to less invasive procedures. Indeed, there is much debate as to whether the syndesmosis should be repaired at all. Comparative studies have found no difference in long-term outcomes in patients with or without syndesmosis screw fixation.[11,16] Consequently, although MRI can provide a more detailed assessment and potentially reclassify the injury severity, it does not necessarily mandate a shift to surgical treatment for all cases.

This study does have limitations. The study was commenced as a pilot study, and no formal power calculation was conducted. However, with 29% of patients revealing SER3 and SER4 injuries, we believe that the results are compelling despite the small population. Second, the average time to MRI scan was 19 days following injury; this could potentially affect the degree of injury reported. The MRI scans were reported by multiple consultant radiologists; however, each was studied by a single radiologist and then reviewed by the treating surgeon. The study originally intended on evaluating the clinical progress of all participants, but as the patients were seen across multiple clinics in the midst of the SARS CoV-2 pandemic, it was not possible to track all participant episodes. It is therefore possible that some patients were identified as having unstable ankle fractures during their recovery and managed operatively.

This study found that SER 3 and 4 injuries are common in those thought to be SER 2 injuries. More than 25% of the participants included in this study had injuries that would have reclassified their diagnosis. Given SER 2 injuries are managed well nonoperatively, future studies may determine the prevalence in a larger sample, and clinical trials could examine whether nonoperative management is successful in SER 3 injuries in all age groups. Willett et al[23] evaluated the outcomes of close contact casting versus surgery for unstable ankle fractures in patients older than 60 years concluding that the use of close contact casting compared with surgery resulted in similar functional outcomes at 6 months. Keene et al,[7] in a follow-up study of the same cohort at 3 years, found a maintained equivalence in function. The ongoing Super-Fin trial (surgery versus nonoperative treatment for ER-stress unstable Weber B unimalleolar fractures) hypothesizes that nonoperative treatment yields noninferior functional outcomes to surgery, the current standard treatment, with no increased risk of harms in patients as young as 16 years.[20] Nonoperative management could mitigate the costs and risks associated with surgical treatment of ankle fractures and syndesmotic fixation. These include but are not limited to the need for a second operation to remove syndesmotic screws and the poor outcomes if fixed in a malreduced position.[18]

Conclusion

More than 25% of ankle fractures classified as stable SER 2 injuries would have been classified as SER 3 or SER 4 injuries had they been evaluated with MRI, confirming that radiographically stable Danis-Weber B fractures are associated with occult syndesmotic injuries. This suggests that the management of SER 3 and SER 4 injuries could include nonoperative management.

Ethical Approval

This study was approved by the Gold Coast Hospital and Health Service Human Research Ethics Committee (HREC/2020/QGC/68808).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Disclosure forms for all authors are available online.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Medartis Australia and New Zealand Pty Ltd funded the imaging associated with this study. The funders had no part in the study design, conduct or data analysis and did not have any authority over these activities.

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