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Dynamic stress testing is unnecessary for unimalleolar supination-external rotation ankle fractures with minimal fracture displacement in lateral radiographs

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Abstract

Background: This study aimed to identify factors from standard radiographs that contributed to the stability of the ankle mortise in patients with isolated supination-external rotation fractures of the lateral malleolus (OTA/AO 44-B).

Methods: Non-stress radiographs of the mortise and lateral views, without medial clear space widening or incongruity, were prospectively collected for 286 consecutive patients (mean age 45 y, range 16–85 y), including 144 women (mean age 50 y, range 17–85 y) and 142 men (mean age 40 y, range 16–84 y) from two main trauma centres. The radiographs were analysed for fracture morphology by two orthopaedic surgeons, blinded to each other's measurements and to the results of external rotation stress radiographs (reference of stability). Factors significantly associated with ankle mortise stability were tested in multiple logistic regression. Receiver operating characteristics analyses were performed for continuous variables to determine optimal thresholds. A sensitivity > 90% was used as the criterion for an optimal threshold.

Results: 217 (75.9%) patients had a stable injury according to external rotation stress radiographs (medial clear space < 5 mm). Independent factors that predicted stable ankle mortise were: female sex (OR 2.5, 95%CI: 1.4–4.6), a fracture line width < 2 mm (corresponding to a sensitivity of 0.94 and specificity of 0.39) in lateral radiographs (OR 10.8, 95%CI: 3.7–31.5), and only two fracture fragments (OR 7.3, 95%CI: 2.1–26.3). When the posterior diastasis was < 2 mm and only two fracture fragments were present, the probability of a stable ankle mortise was 0.98 for 48 (16.8% of all patients) women and 0.94 for 37 (12.9% of all patients) men.

Conclusions: Patients with non-comminuted lateral malleolus fractures (85 patients, 29.7%) could be diagnosed with a stable ankle mortise without further stress testing, when the fracture line widths were < 2 mm in lateral radiographs.

Level of Evidence: Diagnostic level II.

Introduction

Ankle fracture classification systems have been developed by Lauge-Hansen (1), Weber (2,3), and the Orthopaedic Trauma Association Committee for Coding and Classification (OTA/AO) (4,5). These classifications are based on non-stress, standard radiographs, and they are useful for describing fracture patterns. However, the reliabilities or prognostic values of these classifications have not been proven to be consistent(6). Stability-based diagnostic algorithms have been developed in the last few decades, due to a fairly comprehensive consensus opinion that fractures with a stable ankle mortise can be treated conservatively, but unstable fractures are expected to have a better outcome with operative treatment (6,7). The exclusion of so-called dynamic instability is thought to be particularly important when the most common type of ankle fracture, known as a supination-external rotation (SER) (1) and classified as OTA/AO 44-B (4,5), comprises an isolated lateral malleolus fracture without medial widening (6,7).

The deltoid ligament and its bony insertion (medial malleolus) are considered the main stabilizers of the ankle mortise (8,9). A displacement of a fibular fracture is thought to be of minor importance in this stability (6). However, clinical signs regarding the deltoid ligament are generally considered insufficient for a reliable prediction of ankle mortise stability (10-12). Consequently, further imaging, either static or dynamic, has been advised. Magnetic resonance imaging (MRI) studies have reported that the deltoid ligament is always injured to some degree in SER-type fractures (13-15). However, due to its moderate reliability, the MRI offers limited value to clinical decision-making (15). Alternatively, manual external-rotation (ER) stress radiographs (10-19), gravity stress tests (16-19), or weight-bearing radiographs (20-22) have been used to quantify possible dynamic instability. Computer tomography (CT) has mainly been used in research settings (23,24).

There is no ”gold standard” method for evaluating the stability of the ankle mortise; however, external-rotation (ER) stress radiographs have been studied most extensively (6,7,10-21). ER stress testing typically requires clinicians with surgical experience (19), and weight-bearing radiographs may not be possible initially, due to pain. Therefore, an early control visit is often needed (20-22). SER-type lateral malleolus fractures are rather common in adult life. Stress test examinations are costly, increase exposure to radiation, and may cause pain to patients (19). Therefore, a less intensive diagnostic protocol would be beneficial.

To our knowledge, no previous study has evaluated morphological factors from standard radiographs that might indicate the stability of the ankle mortise in patients with isolated SER-type lateral malleolus fractures. This study aimed to identify and assess these factors compared to ER stress radiographs, which are considered a reference of stability. Our hypothesis was that ankles with minimally displaced fractures are stable, and therefore, do not require further stress testing.

Patients and methods

The local Ethics Review Board approved the study protocol. Informed consent was obtained from each patient for study participation.

We screened 308 prospectively collected, consecutive, skeletally-mature patients (≥16 years old) with unilateral, Lauge–Hansen (1) SER (OTA/AO 44-B) (4,5) ankle fractures. The facture had to show no indication of medial widening or incongruity on standard ankle radiographs. To avoid inclusion of pronation-external rotation, pronation-abduction, and supination-adduction injuries, we included only patients with typical SER oblique fractures that originated less than 2 cm above the talar dome. Patients were treated within a week after injury at two main trauma centres; the xxx university hospital, between March 2012 and May 2015, and the yyy university hospital, between February 2013 and August 2014. Fractures were classified according to the Lauge–Hansen classification system (1). An ER stress test (15) was performed by a senior orthopaedic trauma surgeon at the xxx university hospital, and by the surgeon on call at the yyy university hospital. The manual ER stress test was the standard protocol at both trauma centres; therefore, all examiners were trained and familiar with performing the test. Patients were excluded when they had a pathologic fracture (n = 0), concomitant fractures that contra-indicated ER stress (n = 1), or a previous notable ankle injury (n = 21).

The final study group comprised 286 consecutive patients (mean age, 45 y; range, 16–85 y), including 144 women (mean age, 50 y; range, 17–85 y) and 142 men (mean age, 40 y; range, 16–84 y). The average time delay from the injury to a clinical evaluation and stress test was 2.4 d (range, 0–6 d).

Radiographic measurements

All measurements were performed to within 1-mm accuracy, with digital imaging and a high-resolution diagnostic monitor. The measurements were calibrated with a standard 30-mm calibration disc and/or a constant 115-cm source-to-detector distance. Mortise radiographs were measured to determine the tibiofibular clear space (TFCS) at the level of the epiphyseal scar on the distal tibia; the maximum width of the fracture line (lateral diastasis); and the distance between the distal tip of the fracture and the talar dome (distal fracture height) (Fig. 1). Measurements on lateral radiographs included the maximum width of the fracture line (posterior diastasis); the anterior and posterior fracture heights, measured perpendicular to the level of the talar dome; and the obtuse angle between the fracture line and the axis of fibula (fracture line angle) (Fig. 2). The fracture fragments were counted, except for the typical antero-inferior tibiofibular ligament (AiTFL)-avulsion fragment. The first author measured the medial clear space (MCS, the distance between the lateral border of the medial malleolus and the medial border of the talus, at the level of the talar dome) from ER stress radiographs (25). The evaluator was blinded to the measurements of standard radiographs. The ankle mortise was considered unstable when the MCS was ≥ 5 mm, and at least 1 mm larger than the superior tibiotalar clear space (15).

Inter-observer reliability

Two senior orthopaedic trauma surgeons (XX and XY) analysed all standard mortise and lateral non-stress radiographs in separate sessions and blinded to each other's measurements. The inter-observer reliabilities were determined with intraclass correlation coefficients (ICCs) (26). Inter-observer reliabilities and 95% confidence intervals (95%CIs) were excellent for all variables: 0.967 (95%CI: 0.957–0.975) for TFCS, 0.974 (95%CI: 0.965–0.980) for lateral diastasis, 0.981 (95%CI: 0.977–0.985) for distal fracture height, 0.975 (95%CI: 0.968–0.980) for posterior diastasis, 0.983 (95%CI: 0.979–0.987) for anterior fracture height, 0.995 (95%CI: 0.993–0.996) for posterior fracture height, and 0.972 (95%CI: 0.964–0.977) for fracture line angle. Two or three fracture fragment measurements were in perfect agreement between the two observers.

Statistical methods

The summary measurements are presented as the mean and standard deviations (SD) or as proportions (%), unless otherwise stated. Comparisons between stable and unstable ankle mortise groups were conducted with *t*-tests for continuous variables and χ^2- tests for categorical variables. Two-tailed p-values < 0.05 were considered significant.

Variables with p-values < 0.2 were entered, one by one, into the multiple logistic regression analysis to model the stability of the ankle mortise. A variable remained in the model when its p-value was <0.05 or when it had a significant impact on the -2 Log likelihood- value. The logistic regression model results are presented as odds ratios (OR) with 95%CIs.

Receiver operating characteristics (ROC) analyses were performed for continuous variables to test for diagnostic accuracy and to determine optimal thresholds. Variables with areas under the ROC-curve (AUC) > 0.75 were considered adequate for further investigation. A sensitivity > 90% was used as the criterion for an optimal threshold.

The probability of ankle mortise stability was calculated in different situations with a logit function (logit = ln[odds]) (Appendix).

Source of Funding

There was no outside source of funding for this study

Results

The group of 217 (75.9 %) stable ankles had a mean MCS of 3.5 mm (SD 0.6, range 2.0 – 4.0). The group of 69 unstable ankles had a mean MCS of 5.7 mm (SD 1.1, range 5.0–11.0).

These groups showed significant differences in patient sex ($p = 0.001$), TCFS ($p < 0.001$), posterior diastasis ($p < 0.001$), posterior fracture height ($p = 0.031$), fracture line angle ($p = 0.017$), and the number of fragments ($p = 0.001$) (Table I). The multiple logistic regression analysis showed that the female sex (OR 2.5, 95 % CI: 1.4–4.6), a posterior diastasis < 2 mm (OR 10.8, 95 % CI: 3.7–31.5), and only two fracture fragments (OR 7.3, 95% CI: 2.1–26.3) were independent factors for predicting a stable ankle mortise (Table II).

The only continuous radiological variable with an adequate AUC value (0.78, 95%CI: 0.71–0.84) in the ROC analysis was the posterior diastasis, measured in lateral radiographs (Fig. 3). The selected threshold of < 2 mm for posterior diastasis corresponded to a sensitivity of 0.94 and specificity of 0.39.

Among the 85 patients with fractures that had a posterior diastasis < 2 mm and only two fracture fragments, the probability of a stable ankle mortise was 0.98 for 48 women (16.8 % of all patients) and 0.94 for 37 men (12.9 % of all patients). In contrast, among six (2.1%) male patients with fractures that had a posterior diastasis ≥ 2 mm and three fracture fragments, the probability of an unstable ankle mortise was 0.83 (Table III).

Discussion

To our knowledge, this study was the first to show that the fracture line width in a lateral non-stress radiograph (posterior diastasis) was an independent risk factor for instability in SER-type isolated lateral malleolus fractures without medial widening. Previously, an analysis of standard, non-stress radiographs alone was considered insufficient to determine the stability of the ankle mortise in patients with this type of isolated SER fracture (10-22). We also found that female sex and only two fracture fragments were independent factors for predicting ankle mortise stability. According to our results, the ankle mortise can be diagnosed as stable when the posterior diastasis is < 2 mm. However, further stress testing would be recommended when the posterior diastasis is ≥ 2 mm or the fracture is comminuted. The reliabilities of our measurements were excellent.

Choi et al. (23) studied SER-type, bi- and trimalleolar fractures. They reported that fracture height, which was comparable to our measurement of the anterior fracture height, was a risk factor for the incidence of syndesmotic injury in stress testing after osteosynthesis. Clearly, the different findings between studies was partly due to the difference in stability between the different types of fractures, but another difference was the patient selection criteria; we excluded patients with fracture heights ≥ 2 cm to avoid including pronation-external rotation injuries. They also found that the length of the fracture (comparable to fracture angle in our study) was not associated with instability. However, they found that fibular bone mineral density (bone attenuation on CTs), young age, male sex, and high trauma energy were significantly associated with instability (23).

Biomechanical (1) and MRI studies have shown that the AiTFL was the first structure to break in SER-type injuries. Moreover, the AiTFL was injured in every case (14,15), even though the posteroinferior tibiofibular ligament might be intact (14). According to the Lauge-Hansen classification, a SER injury starts anteriorly and progresses posteriorly, due to increasing external rotation of the talus (1). It was also shown that the distal fracture fragment follows the talus, as it rotates externally, but the proximal fibula is medialized and internally rotated (24). Our results supported this description, because the diastasis in mortise radiographs did not correlate with the stability of the ankle mortise (27); instead, instability increased with the fracture line width in the lateral radiographs, which increased as the distal fibula rotated externally with the talus.

We did not systematically record the trauma mechanism or the level of dislocating force in this study. Nevertheless, our results suggested that the displacing force of the injury may be the most important factor for ankle mortise stability. It can be assumed that younger males have better bone density than older males and females; thus, with high energy trauma, younger males are likely to sustain more severe ligamentous injuries prior to a fracture of the lateral malleolus (23). In our population, men were ten years younger than women, had more comminution, and a larger proportion had unstable ankles, even though comminution was a rather rare occurrence (5.2%). Therefore, male sex may be a surrogate factor for high energy trauma and not a true independent risk factor for instability of the ankle mortise.

The two primary strengths of our study were (a) the relatively large number of prospectively collected consecutive patients from two main trauma centres and (b) the blinded analysis of standard radiographs by two experienced orthopaedic surgeons, which provided excellent inter-observer reliability. The large number of patients included and the limited number of variables analysed enabled multiple regression analyses with quite narrow confidence intervals. ER stress radiographs were analysed by only one examiner, but we did not consider this a major limitation, because a prior study showed that the reliability of the MCS analysis was nearly perfect (kappa coefficient > 0.8) (19). A potential minor source of error was the calibration of radiographs, because the standard injury radiographs were calibrated with a constant 115-cm source-to-detector distance, but a standard 30-mm disc was used for ER stress radiographs. However, 30% of ER stress radiographs were calibrated with both methods, and the differences between measurements were in the decimal range.

Diagnosis of the isolated SER-type lateral malleolus fracture without medial widening remains controversial. There is rather solid evidence that stable ankle fractures can be treated non-operatively with excellent results (6,7). However, we lack high-quality prospective clinical studies with long-term follow-ups to confirm the prognostic value of any of the currently available tests for dynamic incongruity. Future studies should address this problem; a study by Sanders et al. (28) remains the only investigation of unstable fractures (according to ER stress radiographs) randomized to operative and non-operative groups. They found no difference between groups in functional outcomes, but the risk of displacement and problems with union were substantially lower in the operative than in the non-operative group. Furthermore, the follow-up time of 12 months was too short to assess the prognostic value of ER stress radiographs.

Conclusions

We identified three independent factors for predicting stable SER-type lateral malleolus ankle fractures: a posterior diastasis < 2 mm in lateral radiographs, only two fracture fragments, and female sex. Further stability testing of a non-comminuted lateral malleolus fracture is not necessary when the posterior fracture line width is < 2 mm.

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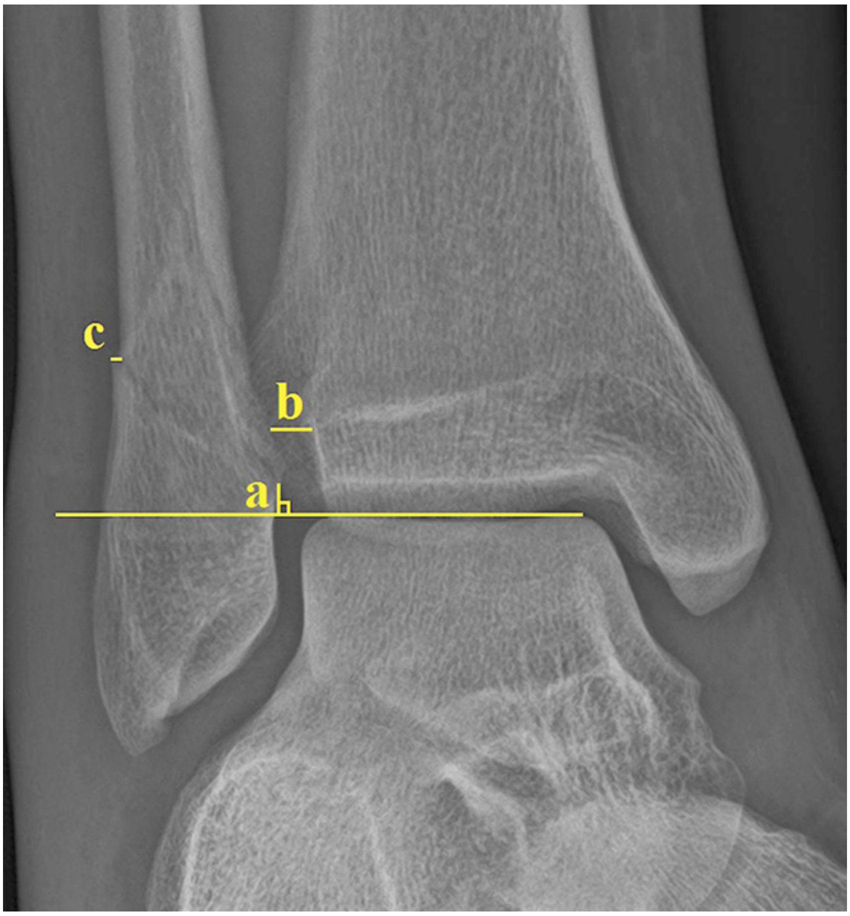

Figure 1.

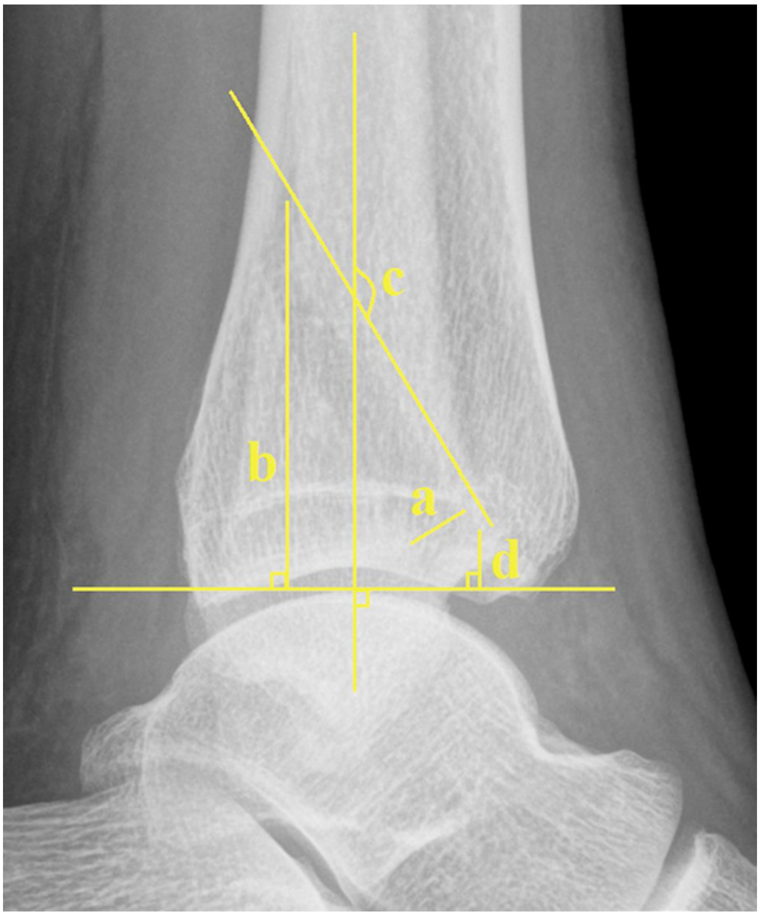

Figure 2.

TABLE I Comparison of Demographic and Fracture Morphology Between Stable and Unstable Groups

	Stable	Unstable	P Value
No. of patients	217	69	
Sex*			0.001
Female	121	23	
Male	96	46	
Age† *(yr)*	46 ± 18	42 ± 17	0.44
Mortise radiographs†			
Tibiofibular clear space *(mm)*	3.2 ± 1.0	3.9 ± 1.3	<0.001
Lateral diastasis *(mm)*	1.5 ± 1.1	1.6 ± 1.7	0.60
Distal fracture height *(mm)*	−1.9 ± 4.4	−0.8 ± 5.8	0.17
Lateral radiographs†			
Posterior diastasis *(mm)*	1.8 ± 1.1	3.3 ± 1.5	<0.001
Anterior fracture height *(mm)*	−0.7 ± 5.8	0.0 ± 7.3	0.47
Posterior fracture height *(mm)*	33.0 ± 12.3	37.0 ± 13.7	0.031
Fracture line angle *(deg)*	146.8 ± 7.8	149.3 ± 7.5	0.017
No. of fracture fragments*			0.001
2	211	60	
>2	6	9	

* The values are given as the number of patients.

† The values are given as the mean and the standard deviation.

TABLE II Multiple Logistic Regression Analysis Results for Factors Related to Ankle Mortise Stability

Variable	OR*	P Value
Female sex	2.5 (1.4 to 4.6)	0.003
Posterior diastasis on lateral radiograph <2 mm	10.8 (3.7 to 31.5)	<0.001
Only 2 fracture fragments	7.3 (2.1 to 26.3)	0.002

* The values are given as the OR, with the 95% CI in parentheses.

TABLE III Sensitivity, Specificity, and Predictive Values of Independent Protective Factors for a Stable Ankle Mortise

	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Female sex	0.56	0.67	0.84	0.32
Posterior diastasis <2 mm	0.94	0.39	0.96	0.33
Only 2 fragments	0.97	0.13	0.78	0.60

TABLE IV Proportional Effect of Different Protective or Risk Factors and Their Combinations on the Probability of a Stable Ankle Mortise*

	Probability	No. of Cases
Sex		
Female	0.34	144
Male	0.17	142
Fracture fragments		
2	0.61	271
>2	0.17	15
Posterior diastasis		
<2 mm	0.69	89
≥2 mm	0.17	197
Fracture fragments		
2	0.61	271
Female and <2 mm	0.98	48
Female and ≥2 mm	0.79	88
Male and <2 mm	0.94	37
Male and ≥2 mm	0.61	98
>2	0.17	15
Female and <2 mm	0.85	3
Female and ≥2 mm	0.34	5
Male and <2 mm	0.69	1
Male and ≥2 mm	0.17	6

* The probability of an unstable ankle mortise is 1 – P(stable).