Supination-external rotation (SER) fractures of the ankle may present with a medial ligamentous injury that is not apparent on the initial radiographs. A cadaver gravity-stress view has been described, but the manual-stress view is considered to be the examination of choice for the diagnosis of medial injuries. We prospectively compared the efficacy of these two examinations.

We undertook both examinations in 29 patients with SER fractures. Of these, 16 (55%) were stress-positive, i.e. and had widening of the medial clear space of > 4 mm with a mean medial clear space of 6.09 mm (4.4 to 8.1) on gravity-stress and 5.81 mm (4.0 to 8.2) on manual-stress examination, and 13 patients (45%) were stress-negative with a mean medial clear space of 3.91 mm (3.3 to 5.1) and 3.61 mm (2.6 to 4.5) on examination of gravity- and manual-stress respectively. The mean absolute visual analogue scale score for discomfort in the examination of gravity stress was 3.45 (1 to 6) and in the manual-stress procedure 6.14 (3 to 10).

We have shown that examination of gravity-stress is as reliable and perceived as more comfortable than that of manual stress. We recommend using it as the initial diagnostic screening examination for the detection of occult medial ligamentous injuries in SER fractures of the ankle.

The clinical identification of rupture of the deltoid ligament is of crucial importance in the treatment of supination-external rotation (SER) fractures of the ankle. These fractures are classified by both the Weber/AO\(^1\) and the Lauge-Hansen\(^2\) systems. The Weber/AO system is based on the level of the fracture of the fibula and is reliable and reproducible.\(^3\) The Lauge-Hansen classification system describes both the position of the foot as well as the direction of the deforming force. This is useful since it describes a reproducible sequence of injury based on characteristic patterns of fracture. The most common type of indirect fracture using the Lauge-Hansen system is the SER pattern, which occurs in up to 85% of indirect fractures (i.e., not as a result of direct load injury) of the ankle.\(^4\)

When the foot is in the supinated position and an external rotation force is applied, the pattern of injury starts on the lateral side of the ankle. The first structure to be disrupted is the anteroinferior tibiofibular ligament. Next, a characteristic spiral oblique fracture of the distal fibula occurs, running anteroinferior to posterosuperior followed by disruption of either the posterior tibiofibular ligament or the posterior malleolus. Finally, either a fracture of the medial malleolus or rupture of the deltoid ligament complex completes this injury.\(^5\) We now appreciate that this stage-IV SER fracture is ‘unstable’. When there is sufficient force to cause disruption of the medial malleolus or the deltoid ligament complex it is best treated by internal fixation. The kinematics of the ankle are improved, but are not completely normal after stabilisation of the lateral side of the ankle alone.\(^6\) Clinical studies have shown a poorer outcome in patients with destabilising injuries on both the medial and lateral sides when treated non-operatively, as compared with that in similar patients with such injuries only on the lateral side.\(^7\)^9 The outcome of SER fractures which include medial disruption is improved by operative anatomical stabilisation of the fibula.\(^7\)^10 Identification of patterns of fracture which are inherently stable, or, the restoration of stability by surgery, allows early mobilisation and earlier return of function.\(^11\) The medial side of the ankle may be destabilised by either a fracture through the medial malleolus (SER type IV) or by disruption of the deltoid ligament complex (SER type IV equivalent). Fractures of
the medial malleolus are identified on standard ankle radiographs. The identification of SER type IV equivalent with a medial ligament injury is more difficult. The Ottawa Rules have attempted to correlate physical examination with classification of the fracture. Recent publications have suggested that clinical findings on the medial side of the ankle are not predictive of injury to the deltoid ligament, while stress radiography is a good indicator of medial instability and the integrity of the deltoid ligament complex.

The examination of manual stress is currently the accepted method for clinical determination of medial instability in this pattern of injury. A cadaver model, with proper positioning, has shown that gravity can generate sufficient force to produce lateral displacement of the talus reliably, as seen on a mortise view, after transection of the deltoid ligament complex. While traditional teaching suggests that only SER injuries with localised findings on physical examination consistent with medial injury will demonstrate medial instability, recent investigations have shown that any fracture of this type may be unstable, regardless of physical examination.

The efficacy of the examination of gravity stress has been demonstrated in a cadaver model, but this has not been validated in the acute clinical setting. If this procedure was shown to be equivalent to the examination of manual stress in differentiating SER-II from SER-IV equivalent fractures, it may replace the examination of manual stress. It has the potential for eliminating the necessity for clinical examination, standardising the amount of force used and minimising the discomfort associated with the procedure. We have compared the clinical efficacy and discomfort to the patient associated with the examination of both manual- and gravity-stress in the diagnosis of SER-IV equivalent injuries of the ankle.

**Patients and Methods**

Following approval from the Loyola University Medical Centre Institutional Review Board, 29 patients presenting to the University Medical Centre Emergency Department or outpatient clinics with an SER fibular fracture of the ankle between April 2005 and June 2006 were enrolled in the study. There were 17 men and 12 women with a mean age of 42 years (18 to 83). The causes of injury are given in Figure 1. We excluded skeletally immature patients, those less than 18 years old, those with open fractures, those with fractures of the medial malleolus and those with widening of the medial clear space on initial radiographs. Informed consent was obtained from all the patients.

The order of testing was by the examination of gravity stress followed by manual stress. This was chosen to avoid any residual deformity or pain which could be associated with the examination of manual stress. The examination of gravity stress was made with the patient in the lateral decubitus position on the side of the injured ankle, allowing the most distal half of the leg, ankle and foot to be dependent off the end of the table (Fig. 2). A standard radiological mortise view taken in approximately 10° of internal rotation of the tibia, with the beam initiated 40 inches (101.6 cm) from the cassette to obtain true-size radiographs, was used.

For the examination of manual stress following previously published guidelines, the patient was positioned supine with the tibia internally rotated 10°. A similar radiological technique was used. An external rotation force of between approximately 3.6 kg and 4.5 kg was applied to the foot, with the ankle positioned in neutral dorsiflexion. After completion of the procedure, patients were asked to evaluate the discomfort before examination and associated...
with each radiological view using the 10 cm visual analogue scale (VAS).\textsuperscript{16}

The examination was considered to be stress-positive if either gravity- or manual-stress radiographs revealed widening of 4 mm of the medial joint space and an increase of at least 1 mm more than the superior clear space. Surgical stabilisation was advised for all patients who were stress-positive.

All the radiographs were recorded digitally and saved electronically. Measurements were obtained using the Picture Archiving and Communication System (PACS) imaging system (GE Healthcare, Chalfont St Giles, United Kingdom). The mean and ranges for stress-positive and stress-negative examinations of gravity- and manual-stress as well as the VAS scores were calculated using Microsoft Excel software (Microsoft Corporation, Redmond, Washington). Significance was measured using a two-tailed Student’s \( t \)-test with \( p \leq 0.05 \).

**Results**

A total of 16 patients (55\%) were stress-positive with a mean medial clear space measuring 6.09 mm (4.4 to 8.1) on gravity-stress radiographs and 5.81 mm (4.0 to 8.2) on manual-stress examination (Student’s \( t \)-test, \( p = 0.63 \)). Thirteen (45\%) were stress-negative with a mean medial clear space measuring 3.91 mm (3.3 to 5.1) on gravity-stress and 3.61 mm (2.6 to 4.5) on manual-stress examination (Student’s \( t \)-test, \( p = 0.39 \); Fig. 3). There was a statistically significant difference in the mean values of stress-positive and stress-negative examinations in both the examinations of gravity-stress and manual-stress (Student’s \( t \)-test, \( p < 0.0001 \) and \( p = 0.0003 \) respectively; Fig. 4).

The mean absolute VAS score from the examination of gravity stress was 3.45 (1 to 6) and from the examination of manual stress 6.14 (3 to 10). This difference was statistically significant (Student’s \( t \)-test, \( p = 0.0002 \)). The mean increase from pretesting to gravity stress was 0.64 (0 to 6) and from pre-testing to manual-stress testing 2.96 (3 to 9). The change in VAS score from pretesting to gravity-stress testing compared with that from pretesting to manual-stress testing was statistically significant (Student’s \( t \)-test, \( p < 0.0001 \); Fig. 5). There were two false-negative manual-stress examinations and no false-negative gravity-stress procedures.

**Discussion**

The Lauge-Hansen classification system is valuable for the evaluation and treatment of fractures of the ankle. The SER pattern of fracture is the most common mechanism of injury. Failure to recognise the fourth stage in the SER IV equivalent group can lead to poor clinical outcome. Traditional teaching suggests that physical examination can predict medial soft-tissue injuries. One recent study suggested that lack of posteromedical tenderness may be correlated with a competent or partially-competent deep deltoid ligament,\textsuperscript{17} but others have shown that tenderness, ecchymosis and swelling are unreliable in the diagnosis of medial ligament injuries in the SER injury pattern.\textsuperscript{13,14} Therefore, it is...
reasonable to perform stress examination in all SER fractures of the fibula regardless of the findings on physical examination.

Fractures without medial injury (SER II) have been shown to be biomechanically stable in cadaver models, and generally have a favourable outcome after non-operative treatment.7,18,19 The current trend is to minimise the immobilisation of patients with stable patterns of fracture, shortening the period of disability and optimising the clinical outcome.11,18,19 However, patients with stage-IV injuries and both medial and lateral instability have a poor outcome when biomechanical integrity is not restored surgically.

Stability of the medial side of the ankle relies on a competent deep deltoid ligament. Michelson et al,15 in a cadaver model, described a new radiological technique, the examination of gravity stress, which correctly identified a transected deep deltoid ligament with both a sensitivity and specificity of 100%. This examination could also distinguish sectioning of the superficial deltoid from the deep deltoid ligament based on the amount of lateral talar shift. The efficacy of this technique has not previously been studied in patients.

Recent studies have questioned the ability of physical examination to identify medial instability of the ankle, suggesting that stress examination may be necessary in virtually all injuries which do not demonstrate medial incompetence on the initial radiographs. The examination of manual stress requires the pressure of an examiner, usually additional trips to the radiology suite and radiation exposure to the examiner. The procedure has been described using an 8 to 10 pounds external rotation force, which may be difficult for examiners to standardise.

The VAS score for examinations of manual stress in our study indicated that patients perceived more discomfort than with gravity testing. It is difficult to standardise the force which different examiners use during the examination of manual stress since patients respond differently to the pain associated with the examination. However, the force of gravity is constant and will not differ based on patient response. McConnell et al11 described two patients in their series who had to undergo diagnostic stress examination under anaesthesia because of pain associated with the examination of manual stress. Patients may have guarding responses to the pain associated with the gravity-stress procedure, but our findings suggest they perceive less pain with this examination.

On manual-stress examination the mean medial clear space was 5.81 mm (4.0 to 8.2) in the 15 stress-positive examinations and 3.61 mm (2.6 to 4.5) in the 13 stress-negative examinations. McConnell et al14 reported a mean medial clear space of 5.69 mm (SD 0.99) in 36 manual-stress positive examinations and of 3.63 mm (SD 0.58) in 61 manual-stress negative examinations. Egol et al11 reported a mean medial clear space measurement of 4.9 mm in positive stress examinations in 66 patients in a mixed group, in only some of whom were there physical findings suggestive of injury to the medial aspect of the ankle. These studies show similar findings to our results.

Two recent studies have questioned the 4 mm threshold for the diagnosis of rupture of the deep portion of the deltoid ligament. One used ultrasound to evaluate deep deltoid disruption and the other used a new cadaver model of the examination of manual stress. Both suggested a threshold of 5 mm for widening of the medial joint space.17,20 Recalculation of our data using a threshold of 5 mm for medial instability would have placed two of our stress-positive subjects in the stress-negative group, but statistical significance would have been maintained. The cadaver investigation also demonstrated that with dorsiflexion-external rotation, there is greater widening of the medial clear space than with neutral or plantar flexed external rotation. We instructed our orthopaedic residents to ensure that the patient maintained neutral ankle dorsiflexion during the examination. If the examinations of gravity stress were performed in too much plantar flexion, the potential error would be a decrease in the medial joint space, giving a potentially false-negative examination.

Our investigation suggests that the gravity-stress examination may be more reliable than the manual-stress procedure in the clinical diagnosis of injury to the medial ligament associated with SER equivalent fractures to the ankle and that patients have less pain. There are several advantages of the examination of gravity stress. Once a protocol is established, it can be performed without a trained examiner. The examiner is not subjected to additional radiation and the force of gravity is constant. With the increased access to remotely-acquired radiographs, the examination of gravity stress has increasing potential for use as a screening tool for patients with unstable fractures of the ankle. In order to assign patients to the appropriate treatment groups, those with stable fractures should not be
burdened with unnecessary immobilization, while patients with potentially unstable fractures need to be identified and stabilised surgically.

We would like to thank the Loyola University Orthopaedic Residents for assistance with the collection of data.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References