Injury, Int. J. Care Injured 50 (2019) 2108–2112

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Technical Note

A reliable method for intraoperative detection of lateral malleolar malrotation using conventional fluoroscopy

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ARTICLE INFO

Article history:
Accepted 7 July 2019

Keywords:
Ankle fractures
Lateral malleolus
Distal fibula
Syndesmosis injury
Maisonneuve injury
Rotational mal-reduction

ABSTRACT

Objective: To introduce a new method for intraoperative detection of rotational malreduction of the lateral malleolus using conventional fluoroscopy.
Material and methods: From January 2014 to December 2017, 56 Weber type C unstable lateral malleolar fractures with syndesmosis injury were identified. The fibular fracture patterns were simple oblique or transverse in 20, comminuted in 25, and Maisonneuve injury with fibular neck fractures in 11 cases. 47 cases were operated with ORIF, and 9 cases of Maisonneuve fractures were operated with CRIF. The mortise view of the contralateral uninjured ankle was used for intraoperative comparison. Two indexes were applied for fluoroscopic detection of distal fibula malrotation, i.e. the contour profile change in lateral malleolar shape, and the intrinsic structure appearance of lateral malleolar fossa cortex. Postoperative talofibular joint congruency was measured on axial CT scan to confirm the reduction quality.
Results: Using the two radiographic parameters for intraoperative fluoroscopic evaluation, we finally achieved satisfying reduction and fixation of the lateral malleolus in all 56 cases. A more spoon-shaped fibula profile and disappearance of the lateral fossa cortex shadow indicates an internal rotation, while a more pointed blade-shaped fibula profile and disappearance of lateral fossa cortex shadow indicates an external rotation. Postoperative CT scanning identified distal fibular no rotation in 44 cases (78.6%), mild rotation less than 5° in 12 cases (21.4%), with 7 cases internal rotation (mean 3.1°) and 5 cases external rotation (mean 2.8°).
Conclusion: Using conventional intraoperative fluoroscopy on mortise view, new radiographic parameters can provide reliable method to detect rotational malreduction of the lateral malleolus.

Introduction

Lateral malleolar deformity in ankle fractures usually happened concomitantly with syndesmotic injury. These deformities can be classified into 6 types, i.e. changes in distal fibular length (shortening or elongation), tibiofibular space (syndesmosis narrowing or widening), fibular tilting in coronal plane (medial or lateral inclination), tilting in sagittal plane (anterior or posterior subluxation), rotation in axial plane (internal or external malrotation), and combination of any two or more of the above deformities.

The relationship between the bony components of the ankle is critical, and a number of empirical "normal" feature measurements are widely recognized in literature [1,2]. However, rotational malreduction of the distal fibula may go undetected if assessed by standard radiographic parameters such as the tibiofibular clear space, Shenton line congruency, talocrural angle, ball sign, and dime sign. In 2011, Marmor et al. [3] reported that up to 30 degrees of external rotation (ER) and up to 10 degrees of internal rotation (IR) of the distal fibula can go undetected by intraoperative fluoroscopy if these conventional radiographic indexes were used. The incidence of rotational malreduction associated with syndesmotic injuries has been shown to be as high as 25%, leading some authors to suggest routine intraoperative CT scanning to prevent such complications [4–7].

However, intraoperative CT scanning is not available for most orthopaedic surgeons. Any simple tool that can improve clinical accuracy of fracture reduction warrants consideration [8,9]. In

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https://doi.org/10.1016/j.injury.2019.07.006
0020-1383/

2013, Marmor et al. [8] developed a set of radiographic criteria in cadaveric specimen to help detect distal fibula internal and external rotation using conventional fluoroscopy. But there was no clinical report regarding its usage.

Radiographic parameters for evaluation of lateral malleolar rotation

As the distal fibula rotates along its longitudinal axis, several changes in its radiographic shape, structure and bony relations of the ankle components can be noted. These changes and differences can be used to evaluate whether the lateral malleolus has rotational deformities and changes in directions or not.

In the 15° internal rotation mortise ankle view, Marmor et al. [8] noted two radiographic changes occurring in internal rotation (IR) and three occurring in external rotation (ER). The IR of the distal fibula was associated with tibiofibular clear space (TCS) widening and/or a spoon-shaped fibula profile. The ER of the distal fibula was associated with tibiofibular space narrowing and/or a pointed-blade shaped fibula profile and/or divergence of Shenton lines.

We added a new parameter to evaluate distal fibular rotation by its intrinsic structure, i.e. the tangential projection of the lateral wall cortex of the lateral malleolar fossa. In normal ankle mortise view, the lateral wall cortex shows a clear vertical dense projection located in the lateral half of the malleolar width, usually at two-third from medial to lateral (Fig. 1).

The radiographic parameters for evaluation of lateral malleolar rotation are summarized in Table 1, and schematically drawn in Fig. 2.

The purpose of this paper was to develop a new parameter and demonstrate its value in detecting lateral malleolar malrotation using conventional fluoroscopy.

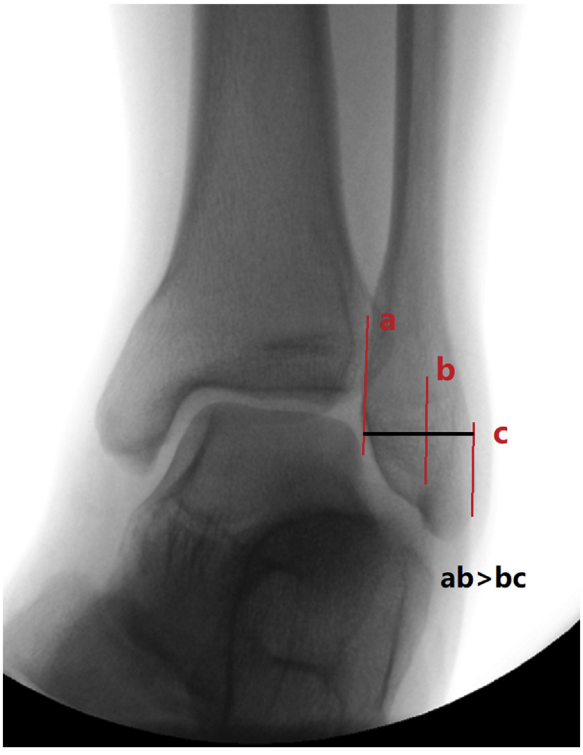

Fig. 1. In mortise view of normal ankle, the lateral wall cortex of the lateral malleolar fossa shows a clear vertical dense projection, which is usually located at the two-third of the malleolar width from medial to lateral.
a: vertical line along medial cortex, b: vertical line along the lateral wall cortex of the lateral malleolar fossa, c: vertical line along the lateral cortex.

Table 1
Radiographic parameters for evaluation of lateral malleolar rotation.

Lateral malleolus	Fluoroscopy in ankle mortise view
In normal position	1 Normal shaped lateral malleolar contour 2 Appearance of fossa cortex shadow in the two-third of lateral malleolar width
In external rotation	1 A pointed-blade shaped lateral malleolus profile 2 Disappearance of fossa cortex shadow 3 Tibiofibular space narrowing 4 Divergence of Shenton lines
In internal rotation	1 A spoon-shaped lateral malleolus profile 2 Disappearance of fossa cortex shadow 3 Tibiofibular clear space widening

Patients and methods

Since 2014, we applied these new radiographic knowledge as assessment criteria in ankle fractures during operation.

After Institutional Review Board approval (No. LL-2019-ZRKX-007), we retrospectively reviewed our database from January 2014 to December 2017. Inclusion criteria were as follows: (1) age between 18 to 70 years, (2) admitted with closed fresh ankle fractures, (3) the lateral malleolar fracture of Weber type C pattern, (4) having mortise and lateral view of the contralateral uninjured ankle, as used for comparison during operation, (5) having complete intraoperative fluoroscopy images and postoperative radiographs and CT scanning. Exclusion criteria were: (1) open ankle fractures, (2) age below 18 or above 70, (3) fractures with ankle osteoarthritis, (4) chronic or malunion ankle fractures.

We identified 56 cases of Weber type C unstable lateral malleolar fractures with syndesmosis injury. The fracture pattern was simple oblique or transverse in 20 cases, comminuted in 25 and 11 in Maisonneuve injury with fibular neck fractures. 47 cases were operated with ORIF, and 9 of cases Maisonneuve fractures were operated with CRIF.

Intraoperative evaluation of lateral malleolar rotation was made using the radiographic parameters and comparing to the contralateral uninjured side. Postoperative assessment was made by CT scanning of axial cuts of the talofibular joint. Congruency of the articular region of the joint indicated no malrotation of the distal fibula.

Results

According to intraoperative fluoroscopic evaluation, we achieved eventually satisfying lateral malleolar reduction and fixation in all 56 cases. Postoperative CT scanning identified distal fibular no rotation in 44 cases (78.6%), mild malrotation less than 5° in 12 cases (21.4%), with 7 cases IR (mean 3.1°,range 0.8°–4.5°) and 5 cases ER (mean 2.8°, range 1.0°–4.2°). No case with moderate (5°–10°) or severe (more than 10°) rotational deformity was identified.

We found two indexes reliable in intraoperative detection for rotational malreduction of the lateral malleolus by conventional fluoroscopy, one was the contour profile changes of lateral malleolar shape, the other was the appearance or disappearance of the intrinsic structure of the lateral malleolar fossa cortex.

An illustrative case of percutaneous reduction and screw fixation of Maisonneuve fracture was shown in Fig. 3.

Discussion

Accurate reduction of the lateral malleolus has critical importance in ensuring stability of the talus inside the mortise,

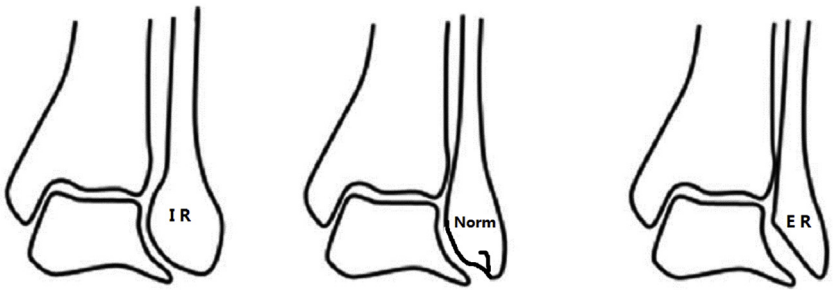

Fig. 2. Schematic drawings to show the radiographic criteria for detection of lateral malleolar rotation.
IR: internal rotation, ER: external rotation.

restoration of normal ankle biomechanics, and achievement of good functional outcomes. It is important to detect malreduction because it may lead to impaired functional outcome and may demand reoperation. Unfortunately, according to a recent systematic review, there is no universal method with cutoff values for the assessment of the distal tibiofibular joint or lateral malleolar reduction in acute syndesmotic injuries with ankle fractures [10].

Compared to distal fibular shortening or tilting, axial rotational deformity, whether isolated or combined, is the most difficult to be identified with the previous knowledge of "normal" anatomy. For example, using cadaver specimen, Marmor et al. [3] reported that up to 30 degrees of ER and up to 10 degrees of IR of the distal fibula can go undetected by intraoperative fluoroscopy.

Using intraoperative and postoperative CT methods with side-to-side differences of more than 10° as criterion, the incidence of rotational malreduction associated with syndesmotic injuries has been shown to be as high as 25% [4–7]. Rotational malreduction of the lateral malleolus may change the biomechanical property of the ankle joint and lead to functional complications in clinic. In a biomechanical study, Thordarson et al. [11] showed that progressive ER of distal fibula from 5° to 15° resulted in a significant increase in contact pressures in the posterolateral aspect of the tibiotalar joint. In 2019, Stroh et al. [12] performed cadaveric study at neutral position and at 5° and 10° of external and internal malrotation, and demonstrated by that any degree of distal fibular ER (5° or 10°) significantly reduced contact pressure in the talofibular articulation with plantar flexion. However, a mild IR of 5° led minimal increase in contact pressure in the tibiofibular and talofibular joints with plantar flexion, but with 10° of IR, the pressure increased significantly in both articulations. These data supported clinical findings that subtle degrees of fibular malrotation, especially ER, may be associated with alteration of lateral ankle mechanics.

Clinical malrotation may be complicated by other deformities. For example, the most common ER combined with fibular shortening. There are also clinical reports that rotational malreductions lead to poor functional outcomes [13,14]. However, the degree of malrotation that is associated with poor clinical outcome has not been established. Vasarhelyi et al. [4] reported that in 61 ankle fractures with ruptures of the syndesmotic complex, 25% showed torsional side-to-side differences of more than 10° malrotation on CT measurement. Clinically, 6 of 20 patients with torsional side-to-side differences of more than 10° had excellent AOFAS functional results, while 7 had good and 7 had moderately results. 6 of the 7 patients with moderate results had fibular malrotation of more than 15°. Warner et al. [15] reported on 155 patients who underwent ORIF either with syndesmotic screw, syndesmotic ligament repair, or both for rotational ankle fractures with syndesmotic instability. Based on CT scan, the mean distal fibular malrotation was 5.8°±4.3° (range, 0.2°–21°) compared to the contralateral uninjured side. However, clinical outcomes based on Foot and Ankle Outcome Scores did not correlate with degree of malreduction at 1 year follow-up.

Marmor et al. [8] provided two parameters for IR detection and three parameters for ER detection by standard fluoroscopy. While the changes in the shape of the lateral malleolus can be explained by the anatomic shape of the distal fibula, the changes in the tibiofibular clear space (TCS) and Shenton line are the result of impingement and alignment of the lateral malleolus relative to the talus, with the concomitant rotation occurring around either an anterior or a posterior pivot point with IR or ER [8]. Therefore, the TCS, which is a projection of the distance of the medial fibula cortical density relative to the tibial incisural cortical density, may be misleading. Moreover, Shenton lines or the ball sign, a reflection of cortical densities of the tibia, talus, and fibula, also can be misleading. However, our clinical practice found that only one parameter, the shape contour profile change of the lateral malleolus, was reliable and distinguishable.

We added a new index, the vertical dense projection of the lateral wall cortex of the lateral malleolar fossa, which is an intrinsic structure of the distal fibula and always appears in mortise view of normal ankle, located at the two-third of the malleolar width from medial to lateral. In rotational ankle positions, or lateral malleolar malrotations, this dense cortical projection will disappear or be difficult to be identified. Our retrospective patient cohort study demonstrated that the incidence and severity of rotational malreduction detected by postoperative CT scanning, was significantly decreased by intraoperative application of our fluoroscopy methods.

These two radiographic parameters are based on standard mortise view. And there is substantial variability in "normal" anatomy between individuals. Therefore, preoperative comparison of mortise view of the contralateral uninjured side is imperative and very helpful.

The occurrence of clinical malrotation is related to several factors. First is the fracture pattern as malrotation usually occurred in highly unstable fractures such as type C lateral malleolar fractures, comminuted fractures, and Maisonneuve fractures. Second is the anatomic variation of the tibial incisura morphology. Cherney at al. [16] found that shallow syndesmoses were correlated with anterior fibular malreduction, and were less likely to be malrotated. Conversely, deep syndesmoses predisposed to posterior sagittal plane and rotational malalignment. Third is the minimal surgical exposure or percutaneous reduction and fixation. Fourth is the imaging technique. Although intraoperative CT scanning and 2D and 3D image reconstruction can provide accurate evaluation for reduction quality of the fracture-subluxation, conventional fluoroscopy is the fundamental armamentarium for most hospitals. Surgeons should know the radiographic criteria related to normal and malreduction in rotational positions.

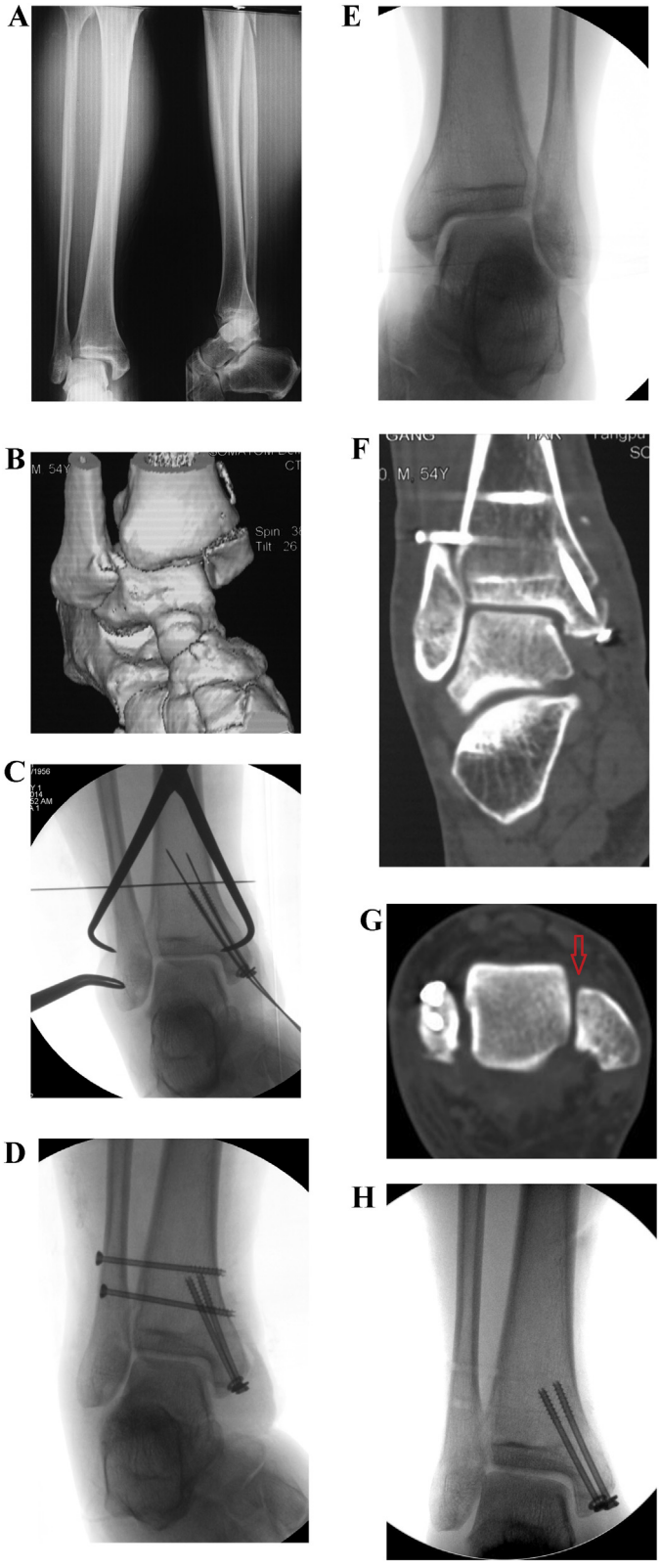

Fig. 3. A 54-year-old male with Maisonneuve ankle fracture.
A: Full-length lower leg AP and lateral radiographs showed talus lateral shifting, medial clear space widening, and tibiofibular space widening. Note an oblique fibular neck fracture in the lateral view.
B: 3D-CT reconstruction image showed medial malleolar fracture and inferior tibiofibular dissociation.
C: The patient was operated by percutaneous reduction and screw fixation. After medial malleolar screw fixation, a towel forceps at the distal fibular was used for traction and rotation to reduce the external rotation and shortening. Another large forceps was applied at the ankle level for compression to restore the syndesmotic reduction. Then temporary K wire was inserted to maintain the reduction.
D: Two 4.0 mm cannulated screws were used for 4-cortical fixation of the syndesmosis. Anatomic reduction of the distal fibula was achieved in the final mortise view.
E: Comparison with the contralateral ankle fluoroscopy, which was obtained before operation.
F: Postoperative coronal CT demonstrated an anatomic syndesmotic reduction.
G: Axial CT scanning showed congruency of the talofibular joint. The lateral malleolus had no rotation.
H: Fluoroscopy after removal of syndesmotic screws two months later. The patient began to walk with full weight bearing.

There are some limitations of this study. Firstly, fluoroscopy is not as sharp as CT in pixel resolution, so the evaluation may not be as accurate as intraoperative CT scanning. Secondly, these indexes can only provide a gross evaluation, and they cannot describe the detailed degree of rotation. Thirdly, this is a radiographic correlation study between fluoroscopy and CT scanning, no clinical results are reported. Further studies are needed to elucidate the correlations among radiographic changes, exact rotational angle, and clinical outcomes.

In conclusion, it is possible to detect rotational malreductions of the lateral malleolus using conventional intraoperative fluoroscopy. Based on a mortise view of the contralateral side, a more spoon-shaped fibula profile and disappearance of the fossa cortex shadow indicates an IR of the distal fibula, and a more pointed blade-shaped fibula profile and disappearance of fossa cortex shadow indicates an ER of the distal fibula.

Ethical approval

The study was approved by Institutional Review Board of Yangpu Hospital, Tongji University.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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