Relationship Among Radiographic Ankle Medial Clear Space, Sex, and Height

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abstract

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The ankle medial clear space (MCS) is frequently measured to evaluate ankle stability after an injury. However, controversy exists regarding a threshold size that distinguishes a normal MCS from an abnormal MCS. A retrospective radiographic review of mortise ankle radiographs in the uninjured ankle was performed, with the goal of defining the relationship among patient height, sex, and radiographic ankle MCS. Forty-nine patients with normal mortise radiographs and with information on patient height available in the electronic medical chart were identified for inclusion. For men, mean±standard deviation (in millimeters) was 3.3±0.8 for MCS perpendicular (MCSp), 3.8±0.7 for MCS oblique (MCSo), and 3.8±0.5 for superior clear space (SCS). For women, mean±standard deviation was 2.3±0.6 for MCSp, 2.9±0.5 for MCSo, and 3±0.4 for SCS. Univariate analysis showed that all 3 variables (MCSp, MCSo, and SCS) were statistically different when men were compared with women (P<.0001). Bivariate regression models showed statistically significant (P<.001) positive relationships between each of the measures of clear space and height. In multivariate analysis, female sex alone was associated with a decrease in clear space. When evaluating isolated lateral malleolus fractures, clinicians should consider the patient’s height and sex when measuring MCS and SCS to determine deltoid ligament competence. These data suggest that men and people of tall stature are at risk for a false-positive diagnosis of deltoid ligament rupture when previously published threshold MCS and SCS values, such as 4 mm or 5 mm, are used for diagnosis and operative indication.

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Radiographic evaluation of the ankle mortise is critical to the proper evaluation and treatment of rotational ankle fractures. The most common variant of rotational ankle fractures is isolated oblique lateral malleolus fracture at the level of ankle syndesmosis. The typical appearance of this fracture is an oblique course that begins inferomedially and exits superolaterally on the fibula in the coronal plane. The most common classification used for ankle fractures is the Lauge-Hansen classification.\(^1,2\) Low oblique lateral malleolus fracture is referred to as a supination-external rotation (SER) ankle fracture in the work of Lauge-Hansen.\(^1,2\) There are 4 subtypes of SER ankle fracture injury, according to Lauge-Hansen.\(^1,2\) SER-II ankle fracture is an isolated lateral malleolus low oblique fracture without medial injury. SER-IV ankle fracture is the same low oblique lateral malleolus fracture in combination with medial ankle injury, including either a medial malleolus fracture or a complete disruption of the deltoid ligament. The deltoid ligament is the primary restraint to lateral translation of the talus, attaching to the talus and the medial malleolus.

Recognition of SER-IV ankle fracture that includes a medial malleolus fracture (or bimalleolar ankle fracture) is straightforward with routine radiography. However, in the presence of a radiographically isolated lateral malleolus fracture, differentiating between SER-II and SER-IV bimalleolar equivalent injury, wherein the deltoid ligament is ruptured, relies on proper assessment of the integrity of the deltoid ligament. Because SER-II lateral malleolus fractures can be reliably treated nonoperatively, whereas SER-IV equivalent lateral malleolus fractures, in which the deltoid ligament is ruptured, are treated with operative stabilization of the lateral malleolus, making the proper diagnosis is critical to patient care.\(^3\)

One of the most common methods of objectively assessing the status of the deltoid ligament is by indirect means via medial clear space (MCS) measurement on mortise view radiographs. Manual external rotation stress radiography, lateral gravity stress radiography, and weight bearing radiographs of the ankle have been studied as objective tools for assessing ankle stability.\(^4-11\) Previous studies used a variety of criteria to determine normal vs pathologic widening of the MCS. Threshold MCS values of 4 mm\(^6,11,12\) and 5 mm\(^7,9\) have been published as reliable indicators of injury to the deltoid ligament. Other studies have used comparison with the superior clear space (SCS) as a control for normal anatomic variation of the MCS, stating that the MCS should not exceed 1 mm greater than the SCS.\(^6,12\)

The available literature on MCS mostly reports data produced from measurement of ankles that have sustained a lateral malleolus fracture\(^6,11,12\); therefore, MCS measurements may not represent a truly normal state. In contrast, 2 reports have published mean MCS measurements from a cohort of normal patients. DeAngelis et al\(^13\) reported a mean MCS of 2.7 mm and a mean SCS of 3.6 mm in their series of normal mortise radiographs, noting that values for men were higher than those for women. More recently, Murphy et al\(^14\) reported similar values in their series of normal paired bilateral weight bearing mortise radiographs, again noting a statistical difference between values for men and women.

The current study was conducted to define the relationship between patient height and MCS. Although the available literature suggests that sex differences exist in MCS, the authors hypothesized that MCS variability is a function of patient size rather than true sex differences. Furthermore, multiple recent publications have studied the use of weight bearing radiographs to assess the stability of the ankle mortise,\(^12,14,15\) which highlights the importance of defining normal MCS values in weight bearing ankles in addition to fully understanding normal anatomic variation in MCS.

**Materials and Methods**

Ethical review of this study was provided by the authors’ institutional review board.

To isolate normal ankle radiographs, the electronic charts of 1415 consecutive patients (age range, 18-65 years) with ankle radiographs were reviewed. The authors excluded 1023 patients because of a history of ankle or hindfoot pain, trauma, or surgery, or radiographic evidence of ankle or hindfoot pathology. The most common reasons for exclusion were ankle fracture, ankle sprain, ankle degenerative joint disease, and osteochondral lesions of the talus. Of the 392 remaining patients, 83 (21.2%) had bilateral ankle radiographs and were reviewed for side-to-side comparison in a previous study.\(^14\) Ten (12%) pairs of radiographs were excluded because of inadequate mortise views, leaving 73 (88%) patients with bilateral ankle radiographs. Of this cohort, 49 patients had height available in their electronic chart and were included in the study. The authors randomly selected left ankles to review for this study because previous data\(^15\) showed no difference in MCS oblique, MCS perpendicular, or SCS measures between right and left ankle radiographs. The most common presenting diagnoses included adult-acquired flatfoot deformity, hallux valgus, Achilles tendinopathy, plantar fasciitis, midfoot degenerative joint disease, and foot mass (eg, plantar fibroma, ganglion) (Table 1). Patient characteristics were obtained, including age on the date of ankle radiographs, sex, height, and principal diagnosis. All patients underwent a complete history and detailed musculoskeletal physical examination by a fellowship-trained foot and ankle surgeon.

All radiographs were taken by experienced technicians working in a foot and ankle specialty clinic. The patients were in a standing weight bearing position in all radiographs. Mortise radiographs were taken at approximately 15° of internal ro-
Radiographic Measurements

The mortise radiographs were reviewed by a fellowship-trained foot and ankle surgeon who was unfamiliar to all patients in the study. Three variables were measured on mortise view (Figure 1):

1. MCS oblique (MCSo): Measured as the distance from the superomedial aspect of the talus to the superomedial corner of the plafond, recorded in millimeters.

2. MCS perpendicular (MCSp): Measured as the distance from the medial border of the talus to the lateral border of the medial malleolus on a line parallel to the medial articular surface half the distance between the talar dome and the inferior aspect of the medial articular surface, recorded in millimeters.

3. Superior clear space (SCS): Measured from the superior border of the talar dome at the highest point to the inferior border of the tibial plafond, recorded in millimeters.

All measurements were made with a virtual ruler on magnified digital images and rounded to the nearest 0.1 mm. All mortise view ankle radiographs were reviewed by a fellowship-trained foot and ankle surgeon.

The sequence of review of the radiographs was randomized with a random sequence generator (Random.org, built and operated by Mads Haahr of the School of Computer Science and Statistics at Trinity College, Dublin, Ireland). The reviewer was blinded to the sequence of review. One of the authors loaded the digital image mortise view radiographs onto the image viewer for each patient according to the sequence generated, as discussed earlier. The reviewer then performed each of the 3 measurements on the digital image. This process was repeated until all of the radiographs were reviewed and measured.

Statistical Analysis

For each variable (MCSp, MCSo, and SCS) the mean, standard deviation, range, and 95% confidence interval were calculated. The 3 radiographic variables were then compared across men and women using t tests. Scatter plots and bivariate regression models were used to visually and quantitatively assess the relationships between the 3 variables and height. Finally, multivariate regression models included both sex and height as independent variables to elucidate the relative contributions of these variables to differences in the 3 clear space measures across patients.

RESULTS

Mean patient age was 49±12 years, with a range of 19 to 65 years. There were 17 (35%) men and 32 (65%) women. Mean age of the men was 46±12 years, and mean age of the women was 49±12 years (Table 2).

For all patients, mean±standard deviation was 2.7±0.8 mm for MCSp, 3.2±0.7 mm for MCSo, and 3.3±0.6 mm for SCS. For men, mean±standard deviation was 3.3±0.8 mm for MCSp, 3.8±0.7 mm for MCSo, and 3.8±0.5 mm for SCS. For women, mean±standard deviation was 2.3±0.6 mm for MCSp, 2.9±0.5 mm for MCSo, and 3±0.4 mm for SCS. In bivariate analysis, all 3 variables (MCSp, MCSo, and SCS) were statistically differ-
ent when men were compared with women \( (P<.0001) \) (Table 3).

Mean patient height was calculated for all patients as well as for men and women separately. Scatter plots were constructed for each of the 3 measures of MCS (MCSp, MCSO, and SCS) by plotting these values against patient height and applying the best-fit least-squares lines to each of the plots (Figure 2). Bivariate regression models showed statistically significant positive relationships between each of the measures of MCS and patient height. The models suggest that for every additional inch in patient height, MCSp, MCSO, and SCS increase by 0.1, 0.11, and 0.08 mm, respectively \( (P<.001) \). Pearson’s correlation coefficients were likewise similar across the 3 measures, ranging from 0.45 for MCSp to 0.56 for MCSO. For all patients \( (N=49) \), mean height was 67 in (range, 60-75). For men \( (n=17) \), mean height was 70 in (range, 63-75), and for women \( (n=32) \), mean height was 65 in (range, 60-69.5).

In multivariate analysis, female sex was associated with a decrease in MCS. However, the relationship between height and MCS measures (MCSp, MCSO, and SCS) did not maintain statistical significance when the variable for sex was included in the multivariate model. After controlling for height, measures of MCSp, MCSO, and SCS were, respectively, 0.88, 0.62, and 0.62 mm smaller for women compared with men. All estimates were significant, with \( P \leq .01 \). On average, female sex was associated with smaller measures of MCS compared with male sex, even after accounting for differences in patient height.

### Discussion

Ankle fractures are among the most common fractures encountered in the musculoskeletal system. The most common ankle fracture pattern in Lauge-Hansen’s system is the SER mechanism. Distinguishing between the nonoperative SER-II Weber B isolated lateral malleolus fracture and the operative bimalleolar equivalent SER-IV Weber B lateral malleolus fracture is of critical importance.3

The deltoid ligament stabilizes the talus and prevents lateral translation in the presence of a lateral malleolus fracture. Recent publications have assessed methods of evaluating the integrity of the deltoid ligament. There is substantial variability in the available literature regarding pathologic widening of the MCS. The most recent data, based on a cadaveric study by Koval et al,7 suggested that greater than 5 mm of MCS width is pathologic. Gravity stress radiographs have been shown to be equivalent to manual external rotation stress radiography in assessing deltoid ligament incompetence.6,11 Both methods are common in clinical practice. Recently, 2 series have reported the use of weight bearing radiographs as functional stress to determine deltoid ligament instability.12,15 Magnetic resonance imaging has been investigated as a potential method of evaluating the integrity of the deltoid ligament, although this is a cost-prohibitive option.16

The common feature in the current literature is the use of some form of radiographic measurement criteria to differentiate between SER-II and SER-IV bimalleolar equivalent ankle fractures. When threshold values are used, an assumption is made about the normal state for each patient. The current series shows that radiographic MCS and SCS measurements are variable between normal uninjured patients based on sex and height.

An earlier study by DeAngelis et al13 noted that MCS measurements differed on the basis of sex. Additionally, in a recent series, Murphy et al14 showed statistically significant differences in MCS and SCS between men and women. The current study shows sex differences in radiographic measurements of the ankle that were statistically significant \( (P<.0001 \) for all variables) in a univariate analysis model. The hypothesis was that MCS width varies with patient height. A statistically significant correlation was found

### Table 3

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Total ( (N=49) )</th>
<th>Men ( (n=17) )</th>
<th>Women ( (n=32) )</th>
<th>( P^a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial clear space ( (perpendicular) )</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Mean±SD</td>
<td>2.7±0.8</td>
<td>3.3±0.8</td>
<td>2.3±0.6</td>
<td></td>
</tr>
<tr>
<td>95% CI</td>
<td>2.4-2.9</td>
<td>2.9-3.7</td>
<td>2.1-2.5</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>1.5-5.0</td>
<td>2.4-5.0</td>
<td>1.5-4.0</td>
<td></td>
</tr>
<tr>
<td>Superior clear space ( (oblique) )</td>
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<td></td>
<td></td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Mean±SD</td>
<td>3.2±0.7</td>
<td>3.8±0.7</td>
<td>2.9±0.5</td>
<td></td>
</tr>
<tr>
<td>95% CI</td>
<td>3.0-3.4</td>
<td>3.4-4.1</td>
<td>2.7-3.1</td>
<td></td>
</tr>
<tr>
<td>Range</td>
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<td>2.9-5.2</td>
<td>2.1-4.0</td>
<td></td>
</tr>
<tr>
<td>Abbreviation: CI, confidence interval.</td>
<td></td>
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</table>
*Comparison of men and women using a univariate analysis model.
between patient height and all 3 measured radiographic variables (MCSp, MCSo, and SCS) in a univariate analysis model. For every 1-in increase in patient height, MCSp increased by 0.1 mm ($P<.001$, correlation coefficient 0.45), MCSo increased by 0.11 mm ($P<.0001$, correlation coefficient 0.56), and SCS increased by 0.08 mm ($P<.001$, correlation coefficient 0.53).

In the multivariate analysis model, height did not show a statistically significant relationship with any of the 3 measured variables when sex remained in the model. This lack of statistical significance is a limitation of this study. However, despite the lack of statistical significance in the multivariate model, this implication lacks clinical relevance (ie, the current study shows that women have smaller MCS measures). However, nearly every woman in the current study was short. The problem is that height and sex are collinear; therefore, it is difficult to interpret whether height or sex is important. Based on the current sample, the regression model concluded that sex, not height, is the important factor. However, this study showed that MCSp, MCSo, and SCS all increase incrementally with patient height in a bivariate model. The current study provides further evidence that the definition of a normal versus pathologic state of the ankle mortise varies depending on patient-specific factors. Therefore, the use of threshold values such as 4 mm or 5 mm for MCS could lead to inaccurate assessment of the integrity of the deltoid ligament.

Further limitations of this study include the sample size, which likely affects the lack of statistical significance in the multivariate model. As previously discussed, the authors do not believe that this lack of statistical significance in the multivariate model is clinically relevant for the goals and conclusions of the study. Additionally, all included patients were evaluated in a foot and ankle specialty clinic. Despite a thorough history and physical examination, with exclusion of patients who had ankle or hindfoot pathology, the need for evaluation in a foot and ankle clinic suggests that the subjects may not be equivalent to a volunteer population. Furthermore, all radiographs were reviewed retrospectively and were not obtained for the purpose of this study. Additionally, there was slight rotational variation from one subject to another. Because of the risks associated with radiation exposure in volunteer subjects and the inability to simulate physiologic conditions in cadavers, this method of data collection was considered appropriate.

This study showed that MCS and SCS measurements in normal, weight-bearing mortise radiographs differ with statistical significance based on sex. Additionally, MCS and SCS increase incrementally as patient height increases. The hypothesis that MCS is a function of height rather than sex is not supported by the multivariate regression model. However, although they do not support the hypothesis, these data nonetheless provide further evidence that the use of unilateral mortise radiographs in combination with threshold MCS values predisposes clinicians to inaccurate assessment of deltoid ligament injury.

**CONCLUSION**

The findings of the current study have applicability to all clinicians who evaluate rotational ankle fractures. Because the authors identified patient-specific factors (sex and height) that produce statistical differences in radiographic ankle measures that are commonly used to assess SER ankle fractures, the authors recommend the use of MCS and SCS measurements as an adjunct to diagnosis rather than as absolute indicators for surgical intervention. Using a threshold value for operative criteria, whether 4 mm or 5 mm, will lead to operative intervention for some patients with SER-II fractures who can be reliably treated nonoperatively. According to the study findings, men and potentially people of tall stature are at risk for a false-positive diagnosis of deltoid ligament rupture or insufficiency. Comparison radiographs of the uninjured ankle should be considered judiciously in these injuries.

**REFERENCES**


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