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BRIEF REPORT

The Accuracy of Bedside Ultrasonography as a Diagnostic Tool for Fractures in the Ankle and Foot

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Abstract

Objectives: Ultrasonography (US) has been shown to be helpful in diagnosing fractures in the emergency department (ED) setting. The aim of this study was to determine the diagnostic accuracy of US for fractures in patients presenting to the ED with foot and/or ankle sprain and positive Ottawa foot and ankle rules.

Methods: This was a prospective study of consecutive patients aged 18 years and over were admitted to the ED with acute foot and/or ankle sprain and positive Ottawa foot and ankle rules. After the patients by were examined by bedside US, anteroposterior and lateral ankle radiographs were obtained, as well as anteroposterior and oblique foot radiographs. The films were evaluated by an orthopedic surgeon who was blinded to the US examination results. The orthopedic surgeon's evaluation was considered the criterion standard for diagnosing a fracture.

Results: A total of 246 patients were included in the study. In 76 (30.9%) of the patients, a total of 79 fractures were detected by radiography. Ten false-negative and nine false-positive results were obtained by US examination. Only one patient, whose US showed a fracture but whose radiographs were normal, had a fracture detected by computed tomography (CT). The sensitivity and specificity of US scanning in detecting fractures were 87.3% (95% confidence interval [CI] = 77.5% to 93.4%) and 96.4% (95% CI = 93.1% to 98.2%), respectively.

Conclusions: Ultrasound had good sensitivity and specificity for diagnosing fifth metatarsal, lateral, and medial malleolus fractures in the patients with foot and/or ankle sprain. However, sensitivity and specificity of US for navicular fractures were low.

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Acute foot and ankle sprains are among the most common presentations to the emergency department (ED). Most of these patients request emergency physicians (EPs) to perform x-rays. Nevertheless, the negative radiography rate in these patients is between 75% and 80%.[1–4] Bedside ultrasonography (US) has been shown to be helpful in diagnosing fractures in the ED.[1,2,5,6] US has many advantages, including low cost, wide availability, easy application at the bedside, reliability, rapid display of multiple fields for symmetrical structure comparison, lesser length of stay in the ED, and increased patient satisfaction. The aim of our study was to determine the diagnostic accuracy of US for fractures in the patients presenting to the ED with foot and/or ankle sprain and positive Ottawa ankle and foot rules (OAR).[2]

METHODS

Study Design

This prospective, cross-sectional study was conducted between April and August of 2013. Before patient enrollment, local ethics committee approval and written consent from the patients were obtained.

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Study Setting and Population

The setting was a tertiary ED that has approximately 200,000 visits annually. Emergency medicine (EM) residents evaluated patients who presented to the ED with acute foot and/or ankle sprains. A sonographer was called when the patient was 18 years and older of age and had positive OAR. Patient enrollment only occurred when one of five sonographers was available. The sonographer recorded the demographic and clinical data of each patient who met the inclusion criteria. The same sonographer then performed the bedside US examination. Patients were excluded if they refused to consent, were admitted to the ED more than 48 hours after injury, had an open wound on the injury site, or had a history of prior fracture at the injury site; if radiography or US examination could not be performed; or if the sonographer was aware of the radiographic result. US examinations were performed before radiography. After US was completed, anteroposterior (AP) and lateral radiographs of the ankle and AP and oblique radiographs of the foot were collected. The sonographers were blinded to the imaging findings. The ongoing clinical management of the patient was conducted by the primary EM resident.

Selection of the Sonographer. All of the sonographers had been trained on the use of musculoskeletal US in a 4-hour theoretical and practical training by another EP who is experienced in musculoskeletal US. To improve the competency of the sonographers, each sonographer was asked to diagnose fractures on predefined test patients (with 10 cases each of lateral and medial malleolus fractures and five cases of fifth metatarsal fractures).

Study Protocol

Ultrasound examinations were performed with a 10-MHz linear probe (Mindray M5, color Diagnostic Ultrasound System, China). The following four regions were defined for the US examinations: 1) up to 10 cm proximal to the distal end of the lateral malleolus, 2) up to 10 cm proximal to the distal end of the medial malleolus, 3) navicular bone in the anteromedial aspect of the ankle, and 4) fifth metatarsal from the proximal to the distal tip. US was not performed on the unaffected areas of the feet and ankles. The criteria for a fracture in an ultrasonographic view were described as cortical disruption or stepping or axial deviation on the bone surface.

The final evaluation of both the radiography and the computed tomography (CT; if ordered in the ED) views of the ankle and foot by an orthopedic surgeon was considered the criterion standard for the diagnosis of fracture. The orthopedic surgeon was blinded to the US views and clinical findings.

Data Analysis

According to the data obtained from the first 50 enrolled patients, the prevalence of detected ankle and foot fractures was as high as 30%. The specificity of US for fracture diagnosis was 94%. As a result, a sample size of 220 was predicted to narrow the confidence intervals (CIs) around a specificity of 0.90 (within ±10%) with the method described by Carley et al.[7]

All data were saved in Microsoft Excel 2010. Qualitative data were expressed as frequencies and percentages, while quantitative data were expressed as the mean with interquartile range (IQR) and range. The sensitivity and specificity were calculated with 95% CI using VassarStats.

RESULTS

A total of 246 patients were included in the study (Figure 1). The median age of study group was 37 years (IQR = 19 years; range = 18–85 years). A total of 141 (57.3%) patients were female. The median US application time was three minutes (IQR = 1 minute; range = 1–10 minutes.).

In 76 (30.9%) of the patients, a total of 79 fractures were detected. For only one patient, US revealed a fracture on the posterior of the lateral malleolus, while the x-ray view of the injury site was normal; the fracture was eventually diagnosed with CT (Data Supplement S1, available as supporting information in the online version of this paper). The sensitivity and specificity of US are shown in Table 1. The overall performance of the sonographers is shown in Data Supplement S2 (available as supporting information in the online version of this paper).

In our study, three concomitant fractures were also detected in three patients, which were a talus fracture (n = 1); a group of second, third, and fourth metatarsal fractures (n = 1); and a posterior malleolus fracture (n = 1). The sonographers did not detect the talus and posterior malleolus fractures.

DISCUSSION

There are limited reports that US has a high sensitivity and specificity in the diagnosis of ankle and foot fractures.[1,2] We found that US can be used as a good diagnostic tool for detecting ankle and foot fractures in OAR-positive patients.

In our study, use of US showed good sensitivity (87.3%) and specificity (96.4%). In a study of 131 patients, the reported sensitivity and specificity of US were 100 and 99.1%, respectively.[1] In another study that had a sample size of 110, the reported sensitivity and specificity of US for diagnosing fractures were 90.9 and 90.9%, respectively.[2] In both of these studies, 20 and 11 fractures, respectively, were detected in the foot and/or ankle. However, no navicular fractures were detected with US in the study by Ekinci et al.,[1] and distributions of the fractures were not specified in the study by Canagasabey et al.[2] The sensitivity and specificity of US can vary according to the fracture site (Table 1). For example, the sensitivity and specificity of US for detecting navicular fractures were relatively lower in our study. The dorsal surface of the navicular bone is irregular and can only be viewed in the dorsal plane US. Additionally, we did not include navicular fractures in the test patients used for training the sonographers before the study.

On the other hand, Yesilaras et al.,[6] in a similar study, reported that the sensitivity and specificity of US were, respectively, 97.1 and 100% for diagnosing fractures in

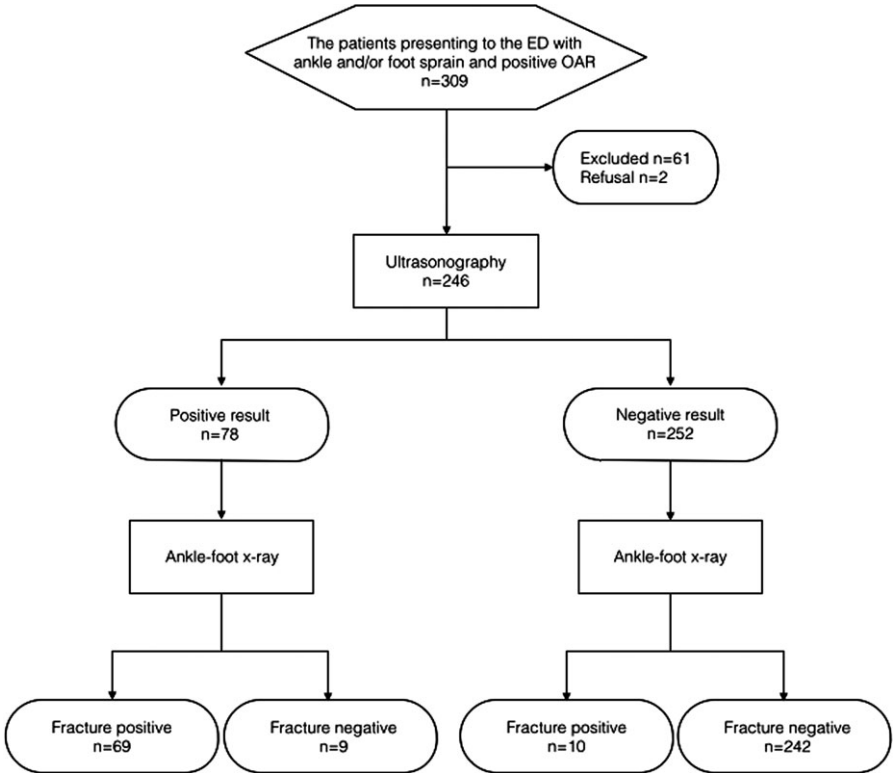


Figure 1. STARD flow diagram. OAR = Ottawa Ankle Rules.

Table 1
The Sensitivity and Specificity of Ultrasound for Diagnosing Fractures

Characteristic	Total US Scanning Area (n = 330)	Lateral Malleolus Tenderness (n = 147)	Medial Malleolus Tenderness (n = 52)	Fifth Metatarsal Tenderness (n = 97)	Navicular Tenderness (n = 34)
Fracture	79 (23.8)	38 (25.8)	7 (13.5)	29 (29.9)	5 (14.7)
False-negative US	10 (3)	5 (3.4)	2 (3.8)	0	3 (8.8)
False-positive US	9 (2.7)	3 (2)	1 (1.9)	3 (3.1)	2 (5.9)
Sensitivity	87.3 (77.5–93.4)	86.8 (0.71–0.95)	71.4 (0.3–0.95)	100 (0.85–1)	40 (0.07–0.83)
Specificity	96.4 (93.1–98.2)	97.3 (0.92–0.99)	97.8 (0.87–0.99)	95.6 (0.87–0.99)	93.1 (0.76–0.99)

Data are reported as n (%) or % (95% CI).
US = ultrasound.

patients with isolated fifth metatarsal tenderness. We also found that US has the highest sensitivity and specificity in the diagnosis of fifth metatarsal fractures, which may be due to the superficial location of the fifth metatarsal as well as its smooth contours and ease of viewing from the dorsal, lateral, and plantar planes with US.

Ultrasound examinations are affected by the examiner's experience and skills. Therefore, studies with only one sonographer may not reflect the overall success rate of US.[1,6] Although the five sonographers in our study had similar competency during the standard training on test patients, their individual degrees of success were different (Data Supplement S2).

We detected an occult fracture at the posterior aspect of the lateral malleolus with US even though it could not be detected with standard radiographic views (Data Supplement S1). US may be advantageous in detecting occult fractures.[8] The major difficulty in using x-ray to diagnose these fractures is the superimposition of other bony structures. Because a sonographer can change the point of view of the US probe, US may be used to detect some fractures that radiography regularly misses.

LIMITATIONS

Only the patients with acute foot and/or ankle sprains were included in the study. Therefore, our data cannot be generalized to other foot and ankle injury mechanisms. Our criterion standard was the final evaluation of the radiography views by an orthopedic surgeon. In several studies, CT and magnetic resonance imaging have been reported to be more reliable in diagnosing foot and ankle fractures.[9]

Another limitation, which may have increased our false-negative results, is that none of the test patients used for training our sonographers before the

experiment had navicular fractures. The lack of comprehensive scanning may have significantly affected the sensitivity of US compared to radiographic imaging. Other fracture parameters (the degree of angulation, the direction of displacement, joint involvement, disruption and associated ligament injuries) were not analyzed. Finally, US is an operator-dependent imaging technique, and we could not determine the interrater reliability of the sonographers.

CONCLUSIONS

Ultrasound had good sensitivity and specificity for diagnosing fifth metatarsal, and both lateral and medial malleolus fractures in patients with foot and/or ankle sprains. However, sensitivity and specificity of ultrasound for navicular fractures was low.

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Supporting Information

The following supporting information is available in the online version of this paper:

Data Supplement S1. Posterior of the lateral malleolus fracture that was not detected with x-ray; this fracture was identified by computerized tomography and ultrasonography. (A) Direct anteroposterior and lateral x-ray. (B) Fracture line in the computerized tomography coronal cross-section (arrow). F = Fibula, T = Talus, M = Medial malleolus. (C) Cortical disruption in ultrasonographic examination with the longitudinal plane (arrow).

Data Supplement S2. Variation in the sensitivity and specificity based on each sonographer's performance and the number of US scans they applied. The five sonographers are represented on the y-axis and all scans are represented on the x-axis. Each plot at the intersection of x- and y-axis represents a unique sonographer-scan match. The diagnostic results of each sonographer-scan match are represented by a different filling pattern in each plot. The cumulative sensitivity and specificity for all of the sonographers combined were calculated and recorded according to the chronological order of their US scans. For example, the very first scan for each sonographer is plotted in the first x-axis column, and their scans are aligned in order of application from left to right.