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ORIGINAL RESEARCH

Screening Characteristics of Ultrasonography in Detection of Ankle Fractures

Majid Shojaee[1], Farhad Hakimzadeh[1]*, Parisa Mohammadi[1], Anita Sabzghabaei[2], Mohammad Manouchehrifar[2], Ali Arhami Dolatabadi[1]

1. Emergency Department, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
2. Emergency Department, Loghman Hakim Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

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Abstract: **Introduction:** Ankle fracture is one of the most common joint fractures. X-ray and physical examination are its main methods of diagnosis. Recently, ultrasonography (US) is considered as a simple and non-invasive method of fracture diagnosis. This study evaluated the diagnostic accuracy of US in detection of ankle fracture in comparison to plain radiography. **Methods:** In this diagnostic accuracy study, which was done in emergency departments of Imam Hossein and Shohadaye Tajrish hospitals, Tehran, Iran, during 2014, 141 patients with suspected diagnosis of distal leg or ankle fracture were examined by US and radiography (gold standard), independently. Screening performance characteristics of US in detection of distal leg fractures were calculated using SPSS version 21. **Results:** 141 patients with the mean age of 34 ± 11.52 years (range: 15–50) were evaluated (75.9% male). Radiography confirmed ankle fracture in 102 (72.3%) patients. There was a significant correlation between the results of US and radiography [Agreement: 95%; kappa: 0.88 (95% CI: 0.80–0.97); $P < 0.001$]. The screening performance characteristics of US in detection ankle fracture were as follows: sensitivity 98.9% (95% CI: 93.5% - 99.9%), specificity 86.4% (95% CI: 71.9%–94.3%), PPV 94.1% (95% CI: 87.1%–97.6%), NPV 97.4% (95% CI: 84.9%–99.8%), PLR 16 (95% CI: 7.3–34.8), and NLR 0.02 (95% CI: 0.003 – 0.182). The area under the ROC curve of US in this regard was 95.8 (95% CI: 91.9 ± 99.7). **Conclusion:** According to the results of this study, we can use US as an accurate and non-invasive method with high sensitivity and specificity in diagnosis of malleolus fractures. However, the inherent limitations of US such as operator dependency should be considered in this regard.

Keywords: Ankle fractures; radiography; ultrasonography; sensitivity and specificity

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1. Introduction

Foot and ankle fractures are known as the most common traumatic injuries (1). Their incidence in men is three times more than in women, due to their physical and potential differences (2–4). Motor vehicle crash and sport injuries are common causes of ankle fracture, especially tibia fractures, in young people (5). A combination of clinical and radiographic findings is used for primary diagnosis of the mentioned fractures (6). Ultrasonography (US) is considered as an available, economical, safe, and portable tool in fracture diagnosis. Using US can resolve problems of other diagnostic tools such as radiation exposure, patient discomfort, and time investment (7). Barata et al. and Ekinci et al. reported high sensitivity and specificity of US in detection of long bone fractures (8, 9). In addition, Esmailian et al. declared the accuracy of US in guidance and confirmation of distal radius fractures reduction (10). Bianchi and his colleagues showed the valuable role of US in diagnosis of ankle's stress fractures compared to magnetic resonance imaging (MRI) and radiography (11). Emergency medicine specialists are among the first line physicians responsible for management of multiple trauma patients. The accuracy of US performed by emergency physicians regarding detection of fractures is a matter of debate. Therefore, the present study aimed to evaluate the screening performance characteristics of US in detection of distal leg and ankle fractures in emergency setting.

*Corresponding Author: Farhad Hakimzadeh; Emergency Department, Imam Hossein Hospital, Shahid Madani Avenue, Imam Hossein Square, Tehran, Iran; Tel: +989123764779; Email: hakimzadehfarhad@yahoo.com.

2. Methods

2.1. Study Design

The present diagnostic accuracy study was done in emergency departments of Imam Hossein and Shohadaye Tajrish Hospitals, Tehran, Iran, during 2014. The study aimed to compare the diagnostic value of US and radiography in patients with suspected traumatic ankle or distal leg fractures. The study was approved by the ethical committee of Shahid Beheshti University of Medical Sciences. The written informed consent was granted by all participants.

2.2. Participants

141 patients over 15 and under 50 years old, who were admitted to the emergency department with traumatic ankle injuries, were consecutively included. All participants were suspected to have fractures of distal fibula and tibia as well as lateral and medial malleolus. The patients with hemodynamic instability, open fractures, and clear fracture diagnosis due to major deformity were excluded. In addition, the patients who were manipulated by pre-hospital emergency medical service, or orthopedics were not enrolled in the study. No additional costs were imposed on the patients and the costs of procedures were covered by the authors themselves.

2.3. Intervention

The US was performed by an emergency medicine resident, trained for about 10 hours in this regard under close supervision of an expert emergency physician. After the primary and secondary surveys based on advanced trauma life support guidelines (ATLS), the patients were examined by bedside US followed by anterior-posterior, Lateral, and Mortis views ankle x-ray as the gold standard. All radiographs were reviewed and interpreted by one radiologist blinded to the clinical condition of patient. All US were performed using SonoScape SSI-5500BW machine and linear 7.5–13 MHz probe in supine position. All procedures were performed under local or regional anesthesia using 0.2% lidocaine or a combination of 0.1 mg/kg intravenous midazolam and 1.5 $\mu g/kg$ intravenous fentanyl.

2.4. Statistical Analysis

Data were analyzed using SPSS 21 (SPSS, Chicago, IL, USA). Qualitative data were given as frequency and percentage, while quantitative data were reported as mean Âś standard deviation. Sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), negative likelihood ratio (NLR), and positive likelihood ratio (PLR) were calculated with 95% confidence intervals. Area under the receiver operating characteristic (ROC) curve of US in detection of ankle fracture was calculated. P-value ≤ 0.05 was considered statistically significant.

Table 1: Baseline characteristics of the patients

Variable	Number (%)
Sex	
Male	105 (75.9)
Female	34 (24.1)
Side of injury	
Left	67 (47.5)
Right	74 (52.5)
Swelling	
Yes	115 (81.6)
No	26 (18.4)
Ecchymosis	
Yes	14 (9.9)
No	127 (90.1)
Ankle pain	
Yes	1 (0.7)
No	140 (99.3)
Ankle tenderness	
Yes	136 (96.5)
No	5 (3.5)
Type of trauma	
Direct trauma	20 (14.2)
Strain/sprain	28 (19.9)
Multiple trauma	93 (66)
Mechanism of injury	
Motorcycle-car accident	22 (15.6)
Pedestrian-car accident	28 (19.9)
Falling	33 (23.4)
Car-car accident	11 (27.8)

3. Results

141 patients with the mean age of 34 ± 11.52 years (range: 15–50) were evaluated (75.9% male). Baseline characteristics of the participants is summarized in table 1. Radiography confirmed ankle fracture in 102 (72.3%) patients (53.9% internal and 46.1% external malleolus fracture). There was a significant correlation between the results of US and radiography [Agreement: 95%; kappa: 0.88 (95% CI: 0.80–0.97); $P < 0.001$]. The screening performance characteristics of US in detection ankle fracture were as follows: sensitivity 98.9% (95% CI: 93.5%–99.9%), specificity 86.4% (95% CI: 71.9%–94.3%), PPV 94.1% (95% CI: 87.1%–97.6%), NPV 97.4% (95% CI: 84.9%–99.8%), PLR 16 (95% CI: 7.3–34.8), and NLR 0.02 (95% CI: 0.003–0.182). The area under the ROC curve of US in this regard was 95.8 (95% CI: 91.9 ± 99.7; figure 1).

4. Discussion

The results of present study showed the acceptable accuracy of US in detection of ankle fracture. The sensitivity of 98.9% introduced the high screening value of US in this regard. In addition, PLR of 16 declared the ability of this test to increase

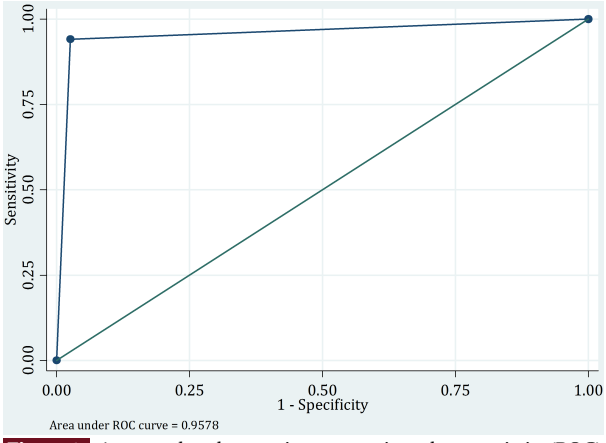

Figure 1: Area under the receiver operating characteristic (ROC) curve of ultrasonography in detection of ankle fracture.

the pre-test probability of ankle fracture, considerably.

Although radiography has been considered as a readily available and low-cost method for diagnosis of fractures for a long time, yet problems such as radiation exposure, quality of the image, and limitations for use in pregnant women have restricted its use. These problems double, when a fracture is present and imaging is needed for confirmation of closed reduction. In their systematic review and meta-analysis, Yousefifard et al. reported the pooled sensitivity and specificity of US in detection of thoracic bone fractures to be 0.97 and 0.94, respectively (20). Since the use of US in emergency departments is increasing day by day, particularly for trauma patients, this study aimed to evaluate the accuracy of US in ankle fracture diagnosis.

The value of US in diagnosing fractures was first introduced in 1980 and its high sensitivity and specificity has been reported in detection of long bones and wrist fractures (12–17). Canagasabey et al. reported 90.9% sensitivity and specificity of US in fracture diagnosis (17). Ekinci and his colleagues supported the high accuracy of US by studying one hundred thirty one patients, reporting 100% sensitivity and 99.1% specificity (9). Trinh et al. showed 100% sensitivity and 88.9% specificity of US in detection of lateral malleolar injuries in comparison with radiography (18). Atilla et.al stated the valuable screening characteristics of US in a study consisting of 246 patients with acute ankle sprain (19). In addition to all the above-mentioned characteristics, we should consider the potential value of US in continuous monitoring of the fracture reduction process.

Although we could not overlook the inherent limitations of US such as the high dependence of its accuracy on the operator's skill. Yet, it can be useful in cases that radiography cannot be performed due to pregnancy, unstable hemodynamics, and inability to transfer the patient to the imaging unit. In addition, in some cases, verification of reductions with US can prevent the need for repeated radiography and more radiation exposure (10, 21).

5. Limitation

Using plain radiography as a reference test, performance of US by emergency medicine residents instead of an experienced emergency physician, not considering other ankle bone fractures such as talus fracture, and not considering the probable ankle joint dislocations, are among the most important limitations of the present study. More thorough studies in this field are suggested by considering more reliable tools such as computed tomography scan.

6. Conclusion

The results of present study showed the acceptable accuracy of US in detection of ankle fracture. The sensitivity of 98.9% introduced the high screening value of US in this regard. In addition, PLR of 16 declared the ability of this test to increase the pre-test probability of ankle fracture, considerably.

7. Appendix

7.1. Acknowledgements

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7.2. Author contribution

All authors passed four criteria for authorship contribution based on recommendations of the International Committee of Medical Journal Editors.

7.3. Funding

None.

7.4. Conflict of interest

None.

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