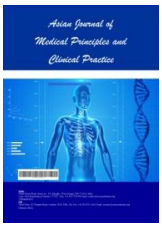

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Diagnostic Accuracy of Ultrasound Compared to Radiography among Patients with Ankle Fracture

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Authors' contributions

This work was carried out in collaboration among all authors. Author MM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EA and MS managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Purpose: This study aimed to compare the accuracy of ultrasound with simple radiography in the diagnosis of ankle fracture due to an ankle sprain.
Methods: This study was performed on 36 patients with an ankle fracture due to an ankle sprain, Emergency Department of Besat Hospital, Tehran, Iran in 2016. Two diagnostic methods, including ultrasound, and radiography were compared with each other. Moreover, true positive, false positive, true negative, and false negative were evaluated in this study.
Results: According to the obtained results of both ultrasound and radiography tests, 94.4% and 5.5% of the patients were diagnosed without and with an ankle fracture, respectively. The value of sensitivity and specificity of ultrasound, compared to radiography approach was equal to 1 (CI: 0.09-1 and 0.85-1, respectively).
Conclusion: The accuracy of ultrasound was equal to one. This finding indicates that both ultrasound and radiography can be used as accurate instruments in the diagnosis of ankle fracture.

Keywords: Ankle fracture; diagnostic accuracy; radiography; ultrasound.

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1. INTRODUCTION

The ankle joint is the most vulnerable joint of the body because it bears the forces and weights [1]. One of the most important reasons for patient referral to medical and emergency clinics is an ankle injury, which accounts for 10% of all emergency department attendance [2]. It commonly occurs among people with the age range of 15-35 years old when the individuals have their maximum physical activity. Totally, 75% of the ankle lesions result from an ankle sprain which is a common musculoskeletal lesion affecting the daily activity and function of individuals [3].

An ankle fracture is often accompanied by a lack of sensory-motor control, including sensory weakness (reduced joint sensory and local anesthesia), a decrease in muscle strength, and weakness in balancing exercise (static and dynamic balance control [4,5]. The most common complications of ankle injuries include pain during activity, joint instability, and recurrence inflammation, which are commonly seen in 10% to 20% of patients with an acute ankle injury [6].

Ankle fractures are common injuries, which are more occurred among people with comorbidities, such as diabetes mellitus, peripheral arterial disease, and osteoporosis. The incidence of ankle fractures in the USA has been estimated at 187 cases per 100,000 individuals [7,8].

In recent years, the use of medical technologies has been dramatically increased. The proper use of these technologies can help diagnose and treat diseases. Imaging techniques contain valuable information on the target organ [9]. Nowadays, imaging methods, such as ultrasound, are introduced that are able to provide non-invasive images of facial muscles in both static and dynamic contractions [10]. Ultrasound is a non-invasive, low-cost, and easy to use imaging method, which is applicable in many cases. It is easily accepted by patients because this method is painless and time-saving. In addition, there are no concerns about ionizing radiation [11,12].

The other imaging method is radiography in which X-ray is radiated to the target organ to provide the required image. Due to the high resolution of this method, it can display details competently; however, if the image is affected by film handling artifacts, there is no possibility to improve the image [13]. With regard to the importance of faster detection of the ankle fracture in order to achieve a better prognosis, it is important to determine the most effective method. This study aimed to compare the accuracy of ultrasound with simple radiography in the diagnosis of ankle fracture due to ankle sprain among patients referred to the emergency clinics of Besat Hospital in Tehran, Iran. To this end, it provided the necessary evidence to decide on a better and faster diagnostic method.

2. MATERIALS AND METHODS

This diagnostic cross-sectional study was performed on patients with an ankle sprain who referred to the Emergency Department of Besat Hospital, Tehran, Iran, in 2016. The inclusion criteria were consciousness and stability. On the other hand, the patients with trauma, open wounds, open fracture, traumatic dislocation, local and systemic inflammatory bone destruction, and internal fixation were excluded from the study.

2.1 Instruments

Ultrasound or ultrasonography is a diagnostic imaging technique, which uses sound waves with higher frequencies than those audible to humans. Many different types of images can be provided by ultrasound to show the acoustic impedance of a two-dimensional cross-section of a tissue, the anatomy of a three-dimensional region, the blood flow and its location, the motion of a tissue, and the presence of specific molecules.

In this technique, the images of internal body structures, such as tendons, muscles, joints, blood vessels, and internal organs are provided to find a source of a disease or exclude pathology. On the other hand, radiography is another imaging technique, in which a beam of X-ray is radiated toward the object to observe its internal form.

2.2 Study Design

In this study, 36 patients with an ankle fracture due to ankle sprain were selected using available sampling. The demographic information of patients was gathered and they were visited by a trained emergency medicine physician. Two diagnostic methods, including sonography and radiography, compared with each other.

Firstly, the ankle fracture was diagnosed by sonography and the detection was confirmed by

radiography findings. The sensitivity and specificity of sonography and radiography as diagnostic tests were assessed in this study. Four conditions were evaluated with regard to the prediction of the outcomes (i.e., true positive, false positive, true negative, false negative). True positive was when the second device confirmed the fracture diagnosis as the first device; however, the false positive was when the second device rejected the fracture diagnosis in contrast to the first device. Moreover, the true negative occurred when the second device rejected the fracture diagnosis as the first device. On the other hand, the false negative was when the second device rejected the fracture diagnosis in contrast to the first device.

3. RESULTS

According to the obtained results, the subjects ranged from 16 to 35 years with the mean age of 21.08±4.32. About 52.7% of the participants were younger than 20 years and 94.5% of the patients were male. Table 1 presents the frequency of education status and economic levels of the participants.

Based on the obtained results of both ultrasound and radiography tests, 94.4% (n=34) and 5.5% (n=2) of the patients were diagnosed without and with an ankle fracture. The ultrasound and radiography findings are shown in Table 2. The results show that the values of false positive and false negative are equal to zero. Moreover, true positive and true negative are 2 and 34, respectively. Based on the obtained results, the value of sensitivity and specificity of ultrasound, compared to radiography approach was equal to 1 (CI: 0.09-1 and 0.85-1, respectively). The accuracy of the test and area under the curve was also equal to 1. In addition, the sensitivity and specificity levels were obtained at 100% and 97%, respectively. The value of sensitivity and specificity of ultrasound, compared to radiography approach based on gender and age are shown in Table 3, figure illustrates the receiver operating characteristic curve.

In addition, the value of sensitivity and specificity of ultrasound, compared to radiography approach among male was 100% (CI: 0.09-1 and 0.85-1, respectively). Moreover, the specificity of ultrasound, compared to radiography approach among females was 100% (CI: 0.86-1). The accuracy of test and area under curve regarding genders was equal to 100%. The value of sensitivity and specificity of ultrasound, compared to radiography approach among patients who were older than 20 years was 100% (CI: 0.09-1 and 0.85-1, respectively). Moreover, the specificity of ultrasound, compared to radiography approach among patients younger than 20 years was equal to 100% (CI: 0.86-1). The accuracy of test and area under curve among patients in all age groups was equal to 100%.

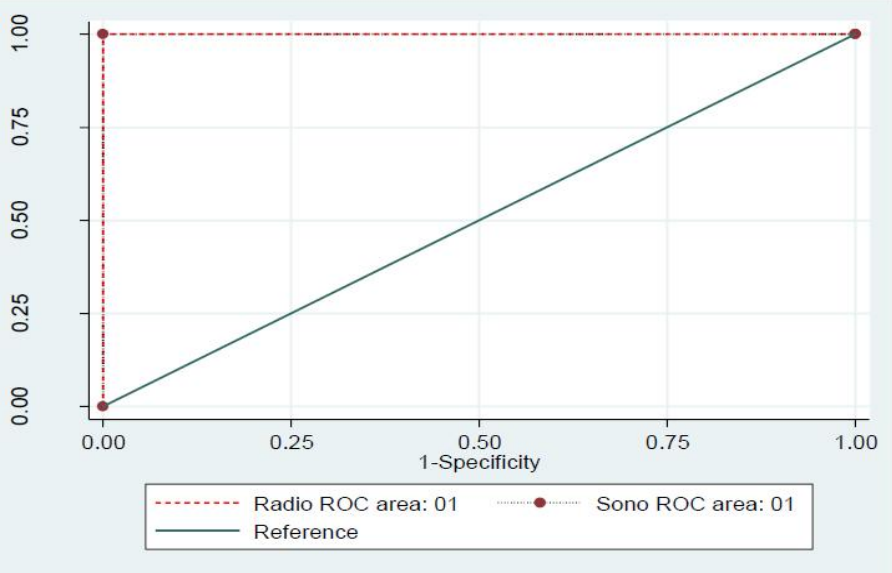

Fig. 1. Receiver operating characteristic curve
**ROC: Receiver operating characteristic curve*

Table 1. Frequency of education status and economic levels of participants

		Number	Frequency
Education status	Less than high school	4	11.1
	High school	28	77.8
	Bachelor	4	11.1
Economic leves	Low	22	61.1
	Average	13	36.1
	High	1	2.8

Table 2. Sonography and radiography findings

Devices		Radiography		Total
		Positive	Negative	
Sonography	Positive	2	0	2
	Negative	0	34	34
Total		2	34	36

Table 3. Sonography and radiography findings based on gender and age

Variables	Sonography		Radiography		Total
			Positive	Negative	
Gender	Female	Positive	0	0	0
		Negative	0	36	36
	Total		0	36	36
	Male	Positive	2	0	2
		Negative	0	34	34
	Total		2	34	36
Age	<20	Positive	0	0	0
		Negative	0	19	19
	Total		0	19	19
	≥20	Positive	2	0	2
		Negative	0	34	34
	Total		2	34	36

4. DISCUSSION

In recent years, the use of diagnostic instruments to detect different fractures has grown widely [14,15]. This technique is useful to diagnose ankle, wrist, scaphoid, and rib fractures which could not be determined through radiography [16-18]. This method has high sensitivity in the diagnosis of some fractures such as ribs, ankle, femur, clavicle, and scaphoid [19].

To the best of our knowledge, there has been no study comparing the reliability of ultrasound and radiotherapy in Iranian population for the diagnosis of ankle fractures. Based on the obtained results of this study, the sensitivity and specificity of ultrasound in the diagnosis of ankle fracture were 100 and 97.1, respectively. The findings of a similar study conducted by Atilla et al. were consistent with the results of the present study in which these values were obtained at 78.3 and 96.4, respectively [20]. The diagnostic accuracy of ultrasound for extremity fractures is assessed in many studies [19-23].

Similar to this study, the accuracy of ultrasound was compared to radiography in one randomized double-blind study by Neri et al. This study was conducted on 204 patients with traumatic hand injuries. Based on the obtained results, the sensitivity and specificity of ultrasound were 91.1, and 97, respectively [21]. These methods were also compared with each other in another study by Aksay et al. on patients with metacarpal fracture. The sensitivity and specificity of ultrasound were 97.4 and 92.9, respectively. They suggested ultrasound as an alternative tool for the diagnosis of fifth metacarpal fractures [23]. In general, the data in both studies were in favor of ultrasound. However, both studies were performed on traumatic hand injuries.

The other similar study by Ekinci et al. was conducted on patients with traumatic ankle

injuries. The aforementioned study estimated the sensitivity and specificity of ultrasound at 100 and 99.1, respectively [24]. The obtained result of this study confirms the effectiveness of ultrasound in the diagnosis of ankle fracture.

Another study performed on patients with fifth metatarsal stress fractures, aimed to evaluate the accuracy of ultrasound regarding the diagnosis of these injuries. The sensitivity ultrasound was measured 97.1 and its specificity was equal to 100 [22]. Moreover, Banal et al. study confirmed the accuracy of ultrasound and normal X-ray for the diagnosis of fifth metatarsal stress fractures. In the mentioned study, magnetic resonance imaging (MRI) was accepted as the gold standard for a stress fracture. Ultrasound was carried out by a trained rheumatologist in another study in which the sensitivity and specificity of bedside ultrasound in the diagnosis of metatarsal fractures was 83% and 76%, respectively.

The positive predictive value, negative predictive value, the ratio of a positive test, and the ratio of a negative test were 59% and 92%, 3.45, 0.22, respectively [25]. These data support ultrasound as a reliable diagnostic instrument among patients suspected to fifth metatarsal stress fractures, even if their x-rays are normal.

The obtained results of the study conducted by Simanovsky et al. on patients with traumatic wrist and ankle injuries were consistent with the findings of this study. The data showed false negative and false positive was equal to 0 and 1, respectively. Moreover, true positive and true negative were 12 and 4, respectively (16). In this study, the values of false positive and false negative were equal to zero. In addition, true positive was 2 and true negative was obtained at 34. Similar to these data, Trinh et al. study confirmed the high negative predictive value for an ultrasound [26].

In one study by Oae et al, three techniques, including ultrasound, MRI, and radiography were compared regarding the diagnosis of anterior talofibular ligament injuries. The results showed that the sensitivity, specificity, and accuracy of ultrasound were 100, 33, and 91. However, these values were 67, 100, and 71 in the case of radiography, respectively [27]. According to a study performed by van et al., the sensitivity and specificity of ultrasound in the diagnosis of ankle anterior talofibular lesions were 92 and 64, respectively [28].

Furthermore, 8 meta-analysis studies evaluated the clavicle, upper and lower extremity fractures, and the femur, humerus, and hand injuries. The obtained results showed a high sensitivity (range: 83.3%-100%) and specificity (range: 73%-100%) for ultrasound in extremity fractures. Moreover, the ratio of a positive and negative test ranged from 3.2 to 56, and 0.0 to 0.2, respectively [19]. These findings were in inline with this study results.

Despite the advantages of direct radiography as an applicable and sensitive tool in the diagnosis of fractures, it is accompanied by drawbacks, such as direct exposure to radiation, and long waiting time in the emergency departments. Therefore, understanding and finding the proper diagnostic tools that are equally efficient is very important.

On the other hand, the use of ultrasound has been increased because it is repeatable and easy operated with no ionizing radiation. Moreover, the diagnosis with ultrasound saves time regarding the diagnosis and the emergency department length of stay. In addition, different angles and multiples planes of scanned bones can be provided using this approach.

Furthermore, ultrasound technique provides data on the local hematomas near the fracture [29]. However, it should be noted that there are potential conditions in which ultrasound examinations may show false positive results. For instance, the diagnostic process may be interrupted by the misdiagnosis of previous fractured or sesamoid bones in the area under examination. Moreover, in some areas, dorsal and ventral aspects, as well as the lateral oblique imaging, is very difficult. In addition, the main limitation of ultrasonography includes the highly operator-dependent nature of this examination.

5. LIMITATION

Although this study provides insightful results, it suffers from some limitations. Firstly, the patients in the present study were assigned to diagnostic procedures non-randomly by a physician. In addition, the length of time spent on ultrasound imaging was not measured. Therefore, it was not possible to compare the diagnostic speed of the instruments with each other. As another limitation, our study was a single-center trial. Moreover, no data were provided with regard to the duration or the degree of difficulties involved in the ultrasound examinations. Furthermore, the

sample size was small which limits the generalization of the findings to the other similar population. Future studies are recommended to compare the ultrasound and radiography with other diagnostic instruments which are used to detect ankle and other organ fractures.

6. CONCLUSION

This study showed a high sensitivity (100%) and specificity (97.1%) of ultrasound imaging in the diagnosis of ankle fracture. Moreover, the accuracy of ultrasound was equal to one. High sensitivity and specificity were also observed in the diagnosis of ankle fracture using radiography. These findings indicate that both ultrasound and radiography techniques can be used as accurate instruments in the diagnosis of ankle fracture.

ETHICAL APPROVAL AND CONSENT

As per international standard or university standard guideline participant consent and ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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