Original Article

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Efficacy of Ultrasound in the Detection of Fractures in Comparison with the Conventional Radiography

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Abstract

Background: Given the potential advantages of ultrasonography in remote and resource-poor settings, the validation of this tool in point-of-care fracture diagnosis could potentially allow timely and appropriate management of fractures in the community. Present study was performed with an aim to evaluate the efficacy of ultrasound in diagnosing the presence or absence of fractures in clinically suspected patients in comparison with the conventional radiography. **Subjects and Methods:** Sixty patients of any age group and either sex coming to emergency wing or orthopaedic outdoor or indoor and other departments at our institution with clinically suspected fractures were included for the study. Each patient was subjected to detailed history, local examination, and conventional radiography with appropriate views. This was followed by ultrasonography using real time scanner with a high frequency linear transducer in both longitudinal and transverse planes. The results of radiography and ultrasonography were compared to see their relative efficacy in the detection of fractures. **Results:** Both conventional radiography and ultrasonograhy detected fractures in 25 (62.5%) cases involving long bones and both modalities ruled out bony fractures in 15 (37.5%) cases (Table 1). In case of flat bone fractures, conventional radiography detected fractures in 5 (41.6%) cases and was negative in rest 7 (58.3%) cases, whereas USG detected fractures in 9 (75%) cases and was negative in 3 (25%) cases. Overall sensitivity, specificity, PPV, NPV and accuracy values of CR against USG in this present study came out to be 81.41%, 100%, 100%, 74.25% and 89.2%, respectively. **Conclusion:** Ultrasonographic examination might act as a substitute for radiography in detection of bony fractures, thus saving the patient from radiation exposure.

Keywords: Fracture, Long bones Ultrasonography, Radiography.

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Introduction

The use of ultrasonography in resource-poor settings has been recommended by the World Health Organisation (WHO) as an achievable healthcare goal, with the caveat that its accuracy relies on the skill of the operator.[1] This is a significant economic limitation to its deployment, as it requires adequately trained personnel to operate the device and interpret the images. Nevertheless, it has already been utilized in prehospital settings with promising results, particularly for the remote triage of traumatic injuries.[2]
Injury is a major cause of death and disability worldwide.[3] Bone fractures are common injuries among them. Bone fracture is a surgical condition in which there is a break in the continuity of the bone. They occur when a sizable force causes the bone to break. Falls, moving collisions and forceful blows are traumatic causes of bone fractures. Diseases that weaken the bones and overuse can also lead to pathological bone fractures.[4] There are four major types of bones on the basis of shape-long, short, flat, sesamoid and irregular.[5] All fractures were initially detected on radiograph.[6] However, the fractures may at times be imperceptible on conventional radiographs, either because they are subtle or occult, obscured by overlapping structures, or non-perpendicular to the X-ray beam. A fracture may also involve cartilage and be undetectable, especially in skeletally immature children. Therefore, complimentary imaging would be desirable to eliminate or confirm the presence of a fracture to avoid short-term and long-term complications.[7,8]
Among carpal fractures, scaphoid fractures are by far the most frequently observed and may lead to long-lasting sequelae. However, immediately after injury, up to 65% of scaphoid fractures remain radiographically occult. Thus, in patients with suspected scaphoid fractures (i.e. occult scaphoid fractures), the wrist has to be placed in a scaphoid cast for at least 10 days, until the scaphoid fracture is ruled out with follow-up radiographs. This strategy, however, means that some patients without a fracture would have their wrist immobilized for several days, which is inappropriate and results in both a reduction in the quality of life and an increase in health care costs.9 Because of its excellent sensitivity (95-100%) and specificity (100%), Magnetic Resonance (MR) imaging has been advocated as the imaging modality of choice in these patients; however it

is not widely available in developing countries and is costly. The focus of trauma ultrasonography has previously been on the validation of the FAST examination in remote settings. This technique initially focussed on the imaging of three abdominal windows and has been extended to include a chest examination (eFAST).[10] It has been widely validated for the timely assessment and triage of haemodynamically unstable abdominal or thoracic trauma patients,[11,12] and is a core component of Advanced Trauma Life Support algorithms worldwide.[13]

However, recent studies have suggested that this application might be expanded to include the identification of bone fractures. Given the potential advantages of ultrasonography in remote and resource-poor settings, the validation of this tool in point-of-care fracture diagnosis could potentially allow timely and appropriate management of fractures in the community.

Although the current evidence for ultrasound-mediated diagnosis of fractures is sparse, a recent meta-analysis conducted by Douma-den Hamer et al.[13] concluded that sonography is reliable in the diagnosis of distal paediatric forearm fractures. Additionally, several studies have suggested that its multi-planar capabilities might make it superior to radiological imaging in the detection of occult or radiographically undetectable stress fractures.[14,15]

The use of sonography in fracture detection has previously been reviewed in paediatric forearm fractures, in lower extremity stress fractures, in acute extremity fractures, and in long bone fractures.[16,17]

The most frequently seen injury in patients admitted to outpatient clinics and emergency departments with blunt thoracic trauma is rib fractures. Non-displaced rib fractures may be frequently missed with using only direct radiography for diagnosis. Many studies have shown an increased sensitivity of Ultrasonography (USG) in rib fractures in the literature.[18] USG has shown excellent results in the detection of the diaphyseal, nasal, facial and sternal fractures.[19-22]

Thus Present study was performed with an aim to evaluate the efficacy of ultrasound in diagnosing the presence or absence of fractures in clinically suspected patients in comparison with the conventional radiography.

Subjects and Methods

Sixty patients of any age group and either sex coming to emergency wing or orthopaedic outdoor or indoor and other departments at our institution with clinically suspected fractures were included for the study.

Open, unstable or suspected compound fractures, unstable patients with deranged vitals and pregnant females. Each patient was subjected to detailed history, local examination, and conventional radiography with appropriate views. This was followed by ultrasonography using real time scanner (Philips Envisor C and Esaote) with a high frequency linear transducer in both longitudinal and transverse planes. The results of radiography and ultrasonography were compared to see their relative efficacy in the detection of fractures.

Examination technique

Ultrasound was done using a real time scanner (Philips Envisor C and Esaote) with a 5-12 MHz Broad Band linear array probe with musculoskeletal preset. Suspected site was examined patiently in both transverse and longitudinal planes. Care was taken to scan very lightly over the site. On USG, breech in the continuity of the cortex of the bone was used as the criterion to suggest a fracture as it is the most definitive and reliable factor in diagnosing a fracture on ultrasonography. A clear disruption of cortical bone as small as 1-2 mm was detected. Displacement of the fractured ends was also appreciated with the USG probe as step off deformity or avulsion of a bony segment. Limit of about 2 mm was taken as a criterion for deciding displacement to be present or absent.

Statistical analysis

The data were analyzed using SPSS version 15 (SPSS Inc., Chicago, Illinois, USA). For all tests, confidence level and level of significance were set at 95% and 5% respectively.

Results

In the present study of 60 cases, the majority of the cases 51 (85%) were in the age group of 21-60 years, of which 26 (43.3%) were between 21 and 40 years and 25 cases (41.6%) were between 41 and 60 years. Seven (11.6%) patients were < 20 years of age group, while 3 (5%) were > 60 years. Most of the patients were males 49 (81.6%) and the numbers of female patients were 11 (18.3%). Out of the 60 cases, 27 (45%) cases had a history of fall, 19 (31.6%) cases had history of road traffic accident and the rest 14 (23.3%) had a history of alleged assault.

In majority of the cases, radiographic projections required were two in 43 (71.6%) subjects. Maximum projections done were four in 9 (15%) cases and minimum one in 6 (10%) cases. In rest 2 (3.3%) cases 3 projections were done.

In our study, a long bone was injured in 40 (66.6%) cases, flat bone in 12 (20%) cases and short bone in the rest 8 (13.3%) subjects. Conventional radiography with appropriate projections detected fractures in 33 (55%) subjects and did not reveal the fracture in rest 27 (45%) subjects. However, USG detected fractures in 40 (66.6%) cases and was negative in 20 cases.

Our study showed that both conventional radiography and ultrasonograhy detected fractures in 25 (62.5%) cases involving long bones and both modalities ruled out bony fractures in 15 (37.5%) cases (Table 1). In case of flat bone fractures, conventional radiography detected fractures in 5 (41.6%) cases and was negative in rest 7 (58.3%) cases, whereas USG detected fractures in 9 (75%) cases and was negative in 3 (25%) cases [Table 1].

In case of short bone fractures, CR picked up fractures in 4 (50%) subjects and was negative in rest 4 (50%) subjects but USG was positive in 6 (75%) cases and confirmed no fracture in two (25%) [Table 1].

The present study showed that sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and accuracy values of the CR against USG were 100% in the case of long bone fracture detection. However, in the case of flat bone, sensitivity, specificity, PPV, NPV and accuracy values of the CR against USG were 51%, 100%, 100%, 32.3% and 61%, respectively. Further, in the case of short bone fracture detection, sensitivity, specificity, PPV, NPV and accuracy values of the CR against USG were 59%, 100%, 100%, 34.3% and 67.45%, respectively. Overall sensitivity, specificity, PPV, NPV and accuracy values of CR against USG in this present study came out to be 81.41%, 100%, 100%, 74.25% and 89.2%, respectively (Table 2).

Table 1: Association of the results of radiography with result of USG in different types of bones

Type of Bone	Result of radiography	Result of USG		Total
		Negative	Positive	
Long Bone	Negative	15	0	15
	Positive	0	25	25
	Total	15	25	40
Flat bone	Negative	3	4	7
	Positive	0	5	5
	Total	3	9	12
Short bone	Negative	2	2	4
	Positive	0	4	4
	Total	2	6	8

Table 2: Overall Sensitivity, Specificity, PPV, NPV and Accuracy of radiography against USG

Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)	Accuracy (%)
81.41	100	100	72.73	88

Discussion

Ultrasound (US) has the potential to be utilized in both diagnostic and therapeutic capacity for fracture management in both the ED and prehospital settings. US offers a three dimensional evaluation of the boney cortex and can detect subtle disruptions, displacement, and angulation. US can also identify closed fractures that require reduction. This modality can be used to rapidly screen patients to detect fractures, possibly reducing the need for further acute imaging. US allows for rapid evaluation and detection of long bone fractures, with an average performance time of 4 minutes.23 Time to fracture detection should improve in clinical settings with verbal feedback from the patient and tactile feedback during the scan.

The high number of negative conventional radiography results is likely due to inappropriate indication for bone X-ray as well as due to the low sensitivity of this modality for certain types of fractures. It leads to unwanted exposure of the patients to harmful ionizing radiations, missed diagnosis and in appropriate treatment as well financial burden.[19] This indicates the need for alternative methods for accurate detection of fractures, without risk of radiation exposure. Ultrasound may fill this role.[19] Ultrasound shows promise as a diagnostic tool in detection of fractures. The development of hand-held ultrasound systems may therefore enable a means of more quickly identifying clinically significant fractures, through more rapid image acquisition and simultaneous interpretation at the bed side. Because of their small size these are useful in locations where traditional radiography and experienced physicians are not available.[19]

Both conventional radiography and ultrasonography detected fractures in 21 cases of long bones and both ruled out them in 13 cases suggesting that in cases of long bone both the modalities showed equal sensitivity, specificity, NPV, PPV and accuracy. A study done in 2004 found that the USG had high sensitivity and specificity for long bone fracture detection versus traditional radiography and CT.[22]

In a study done in 2012 on emergency USG in the detection of pediatric long bone fractures showed 100% sensitivity for the diaphyseal fractures.[24] A study suggested that USG may gain a more prominent role in pregnant and pediatric population as well as in mass casualty scenarios.[25,26]

In the present study, we had three patients of suspected nasal bone injury. Out of these one case was positive and two cases were negative on CR. While on USG, two cases were positive, and one case was negative for fracture. Complexity of the facial bones and the density of the cranial base make the conventional radiography inadequate for fractures of the facial bones. Adequate imaging of nasal fractures is required because of the possibility of legal consequences, depending on the injury's cause. Although a radiographic examination remains the initial step for the radiologic assessment of nasal injury, its sensitivity is not high, and evaluating sidewall injuries on conventional radiographs is difficult. The low-accuracy rate is usually associated with nasal bone radiographs due to high percentage of false-negative and false-positive results. A study done in 2011 showed the ultrasonographical diagnosis of nasal bone fractures yielded 100% accuracy, sensitivity, specificity, NPV and PPV.[8]

We enrolled 4 patients with chest trauma with the suspicion of rib fracture. Mode of injury was RTA. Two cases were detected positive on both the modalities and one case was proved negative on both investigations. But in one case chest X-ray was negative, however, USG picked up breech in the cortex at the site of the maximum tenderness which was confirmed on CT scan. Along with the detection of the breech in the cortex, limited pleural effusion was also seen in one case of rib fracture with USG. Pleural effusion was an additional finding which further motivated to look for the occult fracture. Moreover, chondral rib fractures are almost invisible on chest x ray unless the fracture involves a strongly calcified cartilage. A study done in 1999 showed that sonography detected ten times more fractures than radiography. Sensitivity, specificity, NPV, and PPV of CR were 15%, 100%, 20%, 100% in detecting rib fracture and 90%, 100%, 69%, and 100% with USG respectively27. Ultrasonography had a higher sensitivity in diagnosis of rib fractures rather than other chest wall bones, while the type of fracture had no effect on diagnostic value of radiography. This finding can be ascribed to the higher attention that physicians pay to rib fractures rather than other chest wall bones such as scapula and sternum. Fractures are diagnosed via ultrasonography based on observation of cortical bone disruption. In cases of small fractures, detection of this sign in sonogram and distinguishing it from other findings is highly dependent on the skills of the operator. The role of operator's skills in detection of injuries via ultrasonography was verified in the present study as well.[28-31] Ultrasonography by a radiologist has a higher sensitivity compared to emergency medicine specialist.

As another alternative to radiography, ultrasonography is a common and easy method that involves no radiation. Despite the many advantages of ultrasonography, including low cost, the lack of ionizing radiation, and no patient preparation, it has several shortcomings. Above all, operator dependency is a common limitation of ultrasonography.

Conclusion

Ultrasonographic examination might act as a substitute for radiography in detection of bony fractures, thus saving the patient from radiation exposure. Further research should be directed at studying the routine use of the ultrasound in the detection of fractures.

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