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Extremity Fracture Diagnosis Using Bedside Ultrasound in Pediatric Trauma Patients Referring to Emergency Department; A Diagnostic Study

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Abstract

Background
This study performed to assess the efficacy of ultrasound in screening upper and lower extremities fractures in comparison with standard X-ray in pediatric trauma patients.

Materials and Methods
This was a prospective diagnostic study conducted at the emergency department of Imam Khomeini Complex Hospital, Tehran, Iran. All patients with the age under 18-year-old admitted with limb trauma were first evaluated by attending emergency medicine physician using ultrasound and then underwent necessary X-rays. Thereafter, the ultrasound reports were compared with X-ray reports regarding measurement of its accuracy.

Results
Forty patients with the mean age of 9.47 ± 5.26 years (minimum of 2 and a maximum of 17 years) entered the study (75% were male). The average time of performing ultrasound in pediatric population is 3.99± 0.83 minutes which is statistically significant compared to X-ray, 16.12 ± 4.15 minutes (P<0.001). The overall sensitivity, specificity and accuracy of ultrasound in detecting fractures in evaluated pediatrics were 100%, 100% and 100%, respectively. The results showed an almost perfect agreement between ultrasound and X ray for detecting upper and lower extremity fractures in pediatrics population (k=1.00).

Conclusion
It is likely that ultrasound could be an accurate and time saving substitute for X-ray in screening for limb fractures in pediatric trauma patients admitted in emergency department.

Key Words: Bone, Emergency Wounds, Fractures, Pediatric Trauma, Ultrasonography.

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1- INTRODUCTION

Fractures are among the main results of traumatic injuries and represent about 4% of annual emergency department (ED) visits in the United States. Early diagnosis could lead to rapid and appropriate management and also reducing the complication rate (1-3). Portable bedside ultrasound is a safe, rapid and noninvasive diagnostic tool that could be used in ED in this regard. Ultrasound waves are mainly reflected by the dense matrix of the bone which can obscure underlying structures, so they could visualize the cortex of the bone and presence of cortical disruption (4). As a result, ultrasound has been frequently used as a diagnostic tool for fracture management.

It was reported that implication of bedside ultrasound has lower cost and less time-consuming than X-ray, and it is cost-effective both for the patient and health system. As well, using ultrasound instead of radiography would lead to lower radiation exposures, that highly beneficial in radiation sensitive pediatric population and decrease the number of serial imaging during fracture management process (5, 6).

Various non-conclusive studies have been conducted regarding the use of ultrasound for diagnosis, management and follow up of patients with bone fractures or dislocations and the researches are still on (7-9). This study performed to assess the efficacy of ultrasound in screening upper and lower extremities fractures in comparison with standard X-ray in pediatric trauma patients.

2- MATERIALS AND METHODS

2-1. Study design and ethical considerations

This was a prospective diagnostic study conducted at the emergency department of Imam Khomeini Complex Hospital, Tehran, Iran. The protocol of this study was approved by the Emergency Medicine Department Research Council and Ethics Committee of Tehran University of Medical Sciences. Informed written consents from parents or their legally authorized representatives were obtained following thorough explanation of the study procedure. The authors were adhered to Declaration of Helsinki Principles throughout the study.

2-2. Study population

Three-month period, from January 2015 to March 2015, was considered for sampling. The researchers including emergency medicine physicians were present 24 hours a day, 7 days a week, and consecutive sampling method was applied in this study. All patients under 18-year-old who had come to the emergency department with a recent history of extremity trauma or multiple trauma were included. Patients with obvious open fractures, obvious open fracture with visual bone particles, and severe crashed limb deformities in whom performing the ultrasound scan was impossible were excluded.

2-3. Study protocol

A pre-prepared checklist containing the demographic and baseline characteristics was fulfilled for each participant. All the eligible patients were scanned by emergency medicine attending physician. The researcher who were responsible for performing ultrasound exams were fully trained and had credentials in performing the emergency ultrasound based on point-of-care ultrasound curriculum guideline (10). The portable ultrasound machine used in this study was a S6 with C352 (SonoScape Medical Corp; China) with a 7.5 MHz linear array transducer. The point of maximal tenderness and edema which was clinically considered as a possible fracture site was scanned first in the axial and then in the longitudinal views.

Ultrasound waves are mainly reflected by the dense matrix of the bone, so presence of any cortical disruption reported as bone fracture. The final diagnosis in each view and the duration of ultrasound scanning were then recorded in a separate sheet. The patient was then transferred to the radiology unit and all the standard X-ray views were taken. All the X-ray views were then reviewed by the attending radiologist and the reports were available in the Picture Archiving and Communication System (PACS) of the hospital. The results of the X-ray and the duration of patient's placement on the X-ray machine till the end of the procedure were recorded in a separate sheet.

2-4. Data analysis

All data were then analyzed using SPSS version 15 (Chicago, SPSS Inc, 2006) and Kappa correlation was calculated for ultrasound reports by emergency medicine physicians and X-rays reported by the radiologist. Screening performance characteristics including sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) were calculated. T-test was used to compare duration of each procedure. The results were compared regarding the presence or absence of displacement and also in longitudinal vs axial views. P-value less than 0.05 was considered statistically significant.

3- RESULTS

Forty patients with the mean age of 9.47 ± 5.26 years (minimum of 2 and a maximum of 17 years) entered the study (75% were male). Totally, 27 visits were performed due to upper extremity trauma and the remaining 13 were due to lower extremity trauma. The average time of performing ultrasound in pediatric population is 3.99± 0.83 minutes which is statistically significant compared to X-ray, 16.12 ± 4.15 minutes ($P<0.001$). Presence or absence of fractures in pediatric participants diagnosed by ultrasound and X-rays are summarized in **Table.1**. There was not any discrepancy regarding presence or absence of fracture with two methods in current survey.

Performance characteristics of ultrasound in detecting fractures in studied patients considering the presence of displacement have been reported in **Table.2**. Despite the 100% accuracy for diagnosis any fracture in studied pediatrics, the accuracy regarding diagnosis of displacement drops to 87.5%. The overall kappa correlation for detecting fractures by ultrasound and X-ray was 1.00. When considering displaced fractures, the kappa correlation was 0.71. Comparison of axial and longitudinal ultrasound views in adults and pediatrics population considering the ultrasound view shows in **Table.3**. Both longitudinal and axial views have a kappa correlation of 1 regarding diagnosis of bone fractures in studied population.

Table-1: Presence or absence of fractures in participants diagnosed by ultrasound and x-ray (n=40)

Findings	Ultrasound	X-ray
Positive	30 (75.0)	30 (75.0)
Negative	10 (25.0)	10 (25.0)

The values are reported in number (%).

Table-2: Statistical characteristics of ultrasound in detecting fractures in studied patients considering the presence of displacement

Variables	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
All fractures	100% (91.7-100%)	100% (75.1-100%)	100% (91.7-100%)	100% (75.1-100%)	100% (87.6-100%)
Displaced fractures	100% (88.3-100%)	66.7% (47.2-66.7%)	83.3% (73.6-83.3%)	100% (70.8-100%)	87.5% (72.9-87.5%)

PPV: positive predictive value; NPV: negative predictive value.

Table-3: Comparison of axial and longitudinal ultrasound views in adults and pediatrics population considering the ultrasound view

Ultrasound View	Sensitivity (95%CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
Longitudinal	100% (91.7-100%)	100% (75.1-100%)	100% (91.7-100%)	100% (75.1-100%)	100% (87.6-100%)
Axial	100% (91.7-100%)	100% (75.1-100%)	100% (91.7-100%)	100% (75.1-100%)	100% (87.6-100%)

PPV: positive predictive value; NPV: negative predictive value.

4- DISCUSSION

Based on the findings of current study, ultrasound scanning could be considered as a proper and accurate screening method for diagnosing extremity fractures in pediatric trauma patients referring to the emergency medicine department. In pediatric population, most of studies have been done considering the use of ultrasound in detecting fractures. In a study by Barata et al., 53 patients were evaluated by ultrasound and the overall sensitivity and specificity for detecting long bone fractures were 95.3% and 85.5% (1). Another study evaluating forearm fractures showed that ultrasound has a 94% sensitivity and 99% specificity (2).

In the study conducted with Patel et al., 33 patients were evaluated and the agreement between ultrasound and radiographs for fracture identification was 95.5% with the sensitivity of 97% and the specificity of 93% (11). In a study performed by Waterbrook et al., in 2013, both children and adults were evaluated by point of care ultrasound (POCUS). The overall sensitivity, specificity and kappa correlation of the study were reported as 90.2%, 96.1% and 0.92 respectively (12). It seems that our study has the highest level of accuracy compared to the above studies. Dulchavsky et al. claimed that ultrasound is a faster tool in emergency room to detect extremity fractures with an average of four minutes (13). The average time is similar to the estimated duration of ultrasound exam in our study. However, in another study by Mayr et al., the average time for performing a musculoskeletal ultrasound exam in pediatrics population was 10 minutes which was longer compared to the results of our study (14). This study shows that portable ultrasound could be used as a proper substitute for X-rays to screen the presence or absence of fractures in both long and short bones especially in situations which portable X-ray is not available or feasible. We believe that ultrasound could be used for

screening. However, it could not be considered as the gold standard for fracture diagnosis yet.

4-1. Limitations of the study

This study was done in the emergency department of the hospital and the ultrasound was performed by fully trained emergency medicine physicians. Further studies could be done evaluating the role of training and experience in detecting fractures and more physicians and residents could take part in the study to detect role of training. Moreover, studies with larger sample size could be conducted. In this study, none of the pediatric patients were suffering from fractures in phalanx and metatarsal bones. These bones should be evaluated in future studies.

5- CONCLUSION

It is likely that ultrasound could be an accurate and time saving substitute for X-ray in screening for limb fractures in emergency department.

6- AUTHORS' CONTRIBUTION

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

7- CONFLICT OF INTEREST

None declared

8- ACKNOWLEDGMENT

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