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Comparison of ultrasonography and conventional radiography in the diagnosis of extremity fractures in the emergency department

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ABSTRACT

Aim: The purpose of the study is to compare the diagnostic accuracy (sensitivity and specificity) of ultrasonography (USG) with that of conventional radiography (CR), the standard imaging modality used to diagnose acute extremities fractures.

Material and Method: The prospective investigation examined 245 patients with clinical symptoms of an extremity fracture. Radiography (anteroposterior and lateral radiographs for each patient, oblique if necessary) and USG were performed on all participants and compared with all the results.

Results: CR verified 98.5% of 132 patients who were determined to have extremities fractures with USG. CR, on the other hand, confirmed 99.1% of 112 patients who were reported to have no extremities fractures by USG. The sensitivity (detection of fractures based on USG of patients with fractures detected based on the CR imaging) was 99.2% (95%CI=95.8-99.9); selectivity (no fracture was detected based on USG of patients with no fracture detected based on the CR imaging) was 98.2% (95%CI=93.8-99.7); the positive predictability was 98.48% (95%CI=94.2-99.6), whereas the negative predictability value was 99.1%(95%CI=94-99.8).

Conclusion: USG and CR showed similar diagnostic performances in the diagnosis of extremity fractures. USG can be considered an alternative to CR in the examination of extremity fractures with comparable diagnostic performance.

Keywords: Ultrasonography, accuracy, sensitivity and specificity, extremity fracture

INTRODUCTION

Suspected extremity fracturesas a result of trauma are a common reason for admissions to the emergency department (ED) (1). "We hypothesized that using the USG to exclude extremities fractures in all age groups would detect the same proportion of fractures as CR, by providing similar diagnostic efficiency (2). Alternatively, Ultrasonography (USG) is increasingly being used in practically all areas of modern medicine for procedural, screening, and diagnostic purposes, with new applications (3).

Although conventional radiographic imaging is accepted as the gold standard diagnostic tool in the diagnosis of fractures, ionizing radiation caused by its use may cause adverse effects especially in the pediatric group with sensitive tissues and in pregnant (4). The accuracy of ultrasonic imaging in identifying fractures following acute trauma was summarized in comprehensive reviews (5-7). USG of bone surfaces can be an effective approach for assessing acute injuries (8). Using USG to detect changes in bone surfaces (discontinuities, displacement, and subperiosteal hematomas) is a reliable and manageable approach to fracture diagnosis (9). The avoidance of radiation exposure is one of the primary benefits of ultrasonic testing; this is especially true in pregnant and children, who are more vulnerable to radiation than adults (10). Ultrasonography as a diagnostic tool in situations of suspected fractures may offer economic, prognostic, and therapeutic benefits, particularly in terms of reducing unnecessary radiation exposure to human body (11).

The purpose of the present study is to compare the diagnostic accuracy of USG with that of CR, the standard imaging modality used to diagnose acute extremities fractures. We hypothesized that using the USG to exclude extremities fractures in all age groups would detect the same proportion of fractures as CR, by providing similar diagnostic efficiency.

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MATERIAL AND METHOD

This prospective study was initiated with the approval of the Health Sciences University Afyonkarahisar Medical Faculty, Clinical Researches Ethics Committee (Date: 03.05.2019, Decision No: 166). Participants were informed in writing about the use and publishing of the anonymized data and consented willingly by returning a questionnaire. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Design and Study Population

Before the study, the emergency physicians (EP) and triage team working in our department were informed about the study. Patients who applied with the suspicion of extremity fracture were referred to the emergency room physician who would perform USG. It was performed by an EP trained phcysian in basic ultrasonography following a therical and practical training periods.. Before the study, the physician performing USG performed ultrasonographic imaging on a sufficient number of patients with extremity fractures on radiographs. The patient was informed by the practicing doctor about the study and the subjects he wanted to learn. Exclusion criteria were as follows: presence of a local or systemic infection, missing follow-up data, and history of allergy to contrast, local anesthetic drugs, and coagulopathy.

Data Collection and Imaging

The patients were recorded with demographic characteristics (age, gender, mechanism of trauma) and evaluated in longitudinal and transverse planes with a linear probe with a valence of 4-15 MHz using the ultrasonography device (USMART-3200T model England, United Kingdom) according to the symptom locations. The presence of cortical irregularity or interruption in the bone on USG was considered a fracture. The extremity (right upper extremity, left upper extremity, right lower extremity, left lower extremity), bone and part of the bones, ultrasonographic findings (cortical irregularity, edema, periosteal thickening, fracture), and intra-articular extension were assessed in the study. USG applications were performed following the Musculoskeletal Ultrasound Technical Guide of the European Society of Musculoskeletal Radiology (12).

After the ultrasonographic examination, anteroposterior and lateral, and if necessary, oblique extremity radiography requests were routinely performed by different EP. Radiographic examinations were performed with the LISTEM brand Rex-525R model X-ray. Radiographs were interpreted by the EP who evaluated the patient. Whether a fracture was detected on the radiograph, the name and region of the examined bone, whether it was displaced if there was a fracture, the presence or absence of intra-articular extension with the fracture, and how long the patient's radiographs lasted (in minutes) and whether he felt pain when the X-ray was taken were recorded by the EP in charge. EP who interpreted the radiographs did not have any information about the USG findings.

Statistical Analysis

SPSS v23.0 software was used to analyze the data (IBM Inc,Chicago,USA).The sample's sociodemographic variables were provided descriptively (means, standard deviation, relative and absolute frequencies). The results of the two diagnostic tools (radiography and ultrasonography) and between the 2 readers were compared using Chi-Square ($\chi 2$) testing and Cohen's kappa coefficient(κ)testing for significance (with Fisher-Exact correction). In the data analysis, we employed the McNemar test to evaluate our initial hypothesis. To test for systematic differences, odds ratios (ORs) with corresponding %95 confidence intervals (CIs) were calculated, along with an accurate p-value. The sensitivity and specificity, as well as the positive and negative predictive values, were calculated to test our second hypothesis. The significance criterion has been set at a probability of error of $p<0.05$.

RESULTS

Descriptives

This clinical research involved 245 patients clinical symptoms of an extremity fracture (102 females to 143 males). Thirty-five patients with multiple fractures, who did not sign the consent form, suspected of pregnancy, younger than 4 years, and diagnosed in an external center were excluded from the study.

The mechanism of extremity trauma were as follows: fall (52.7%), blunt impact (17.6%), sprain (13%), crush (8.2%), in-vehicle traffic accident (4%), non-vehicle traffic accident (3.7%), and other (0.8%). According to the fracture region detection, 27.3% of the fractures were in the right upper extremities, 26.1% in the left upper extremity, 25.7% in the right lower extremity, and 20.8% in the left lower extremity. While the USG was used to diagnose 53.9% of extremities fractures, RC was used to diagnose 53.5%. The lower extremity accounted for 39.7% of the 131 fractures diagnosed with RC, while the upper extremities accounted for 60.3%.

Comparison of USG and CR Results

The results were not significant when we compared the CR and USG methods for diagnosing extremities fractures in patients. CR verified 98.5% of 132 patients who were determined to have extremities fractures with USG. CR, on the other hand, confirmed 99.1% of 112 patients who

were reported to have no extremities fractures by USG. Although CR determined fracture, just one incidence of extremities fracture could not be recognized by USG. In addition, CR was unable to identify two incidences of extremity fractures that were determined to be fractured by USG but could not be detected by CR. The following were the characteristics of a single case that could not be detected by USG despite being fractured by CR: A 35-year-old man was determined to have a radius shaft fracture localized to the right upper extremity with a blunt trauma etiology.

As a result of the logistic regression analysis, the CR could be anticipated by examining the results of the USG method (p<0.001), and the Nagelkerke pseudo R2 value was 0.953. The Nagelkerke pseudo R2 score indicated that the USG result accounts for roughly 95% of the variance in the CR. Furthermore, the rate of fracture identification in the USG was determined to be 98.8% in patients with fractures diagnosed in CR. As seen in **Figure**, Receiver Operating Characteristic (ROC) was performed to acquire more specific information about this classification [Area Under Curve (AUC)= 0.987 (95%CI=0.971-0,998)]. The next step was to calculate the sensitivity, specificity, and positive and negative predictability values (Positive and Negative Predictive Values). According to the findings, the sensitivity (detection of fractures based on USG results of patients with fractures detected based on the CR imaging result) was 99.24 % (95%CI=95.8-99.9); selectivity (no fracture was detected based on USG results of patients with no fracture detected based on the CR imaging result) was 98.25 % (95%CI=93.8-99.7); the positive predictive value was 98.48% (95%CI=94.2-99.6), whereas the negative predictability value was 99.1%(95%CI=94-99.8).

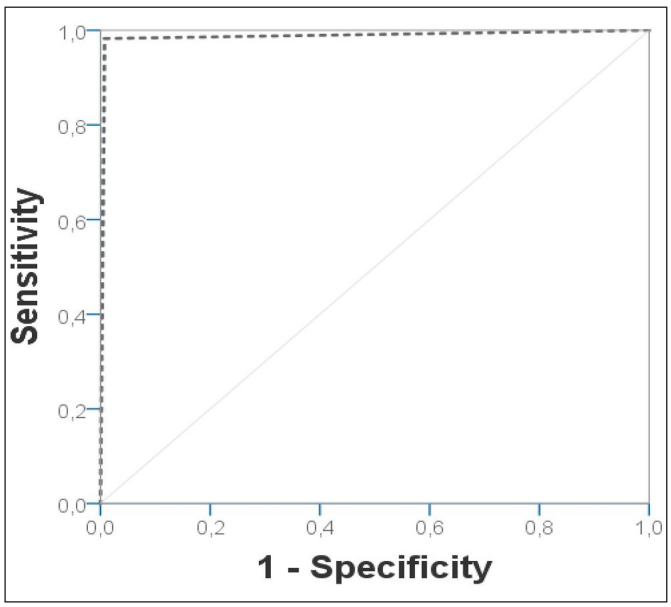

Figure. The ROC for comparison of ultrasonography and conventional radiography

Comparison of Fracture Characteristics

Ultrasonographic examination revealed that it reached the joint in 7.3% of extremities fractures, but not in 46.5%. Cortical irregularity was present in 53.9% of the patients but was absent in 46.1%. The radiographic examination revealed that it reached the joint in 13.1% of extremities fractures, but not in 40.4%, and 30.2% of the extremities fractures were displaced, while 23.3% were not. There were significant discrepancies between the results of CR and USG imaging when assessing the extent of joint fractures(p<0.001). 12.5% of the fractures diagnosed by CR imaging results extended to the joint, but they did not extend to the joint according to the USG result. 83.3% of the 12 patients who complained of pain during the USG procedure also complained of pain during the CR procedure. 98.7% of the 233 people who indicated they didn't feel pain during USG indicated the same thing with CR.

The average time to administer the USG was 3.6 minutes, with a standard deviation of 0.7 minutes. The USG had the quickest application time of 2 minutes and the longest application time of 5 minutes. The mode and median were discovered to be three. The average time to administer the CR was 13.9 minutes, with a standard deviation of 6.5 minutes. The CR had the quickest application time of 5 minutes and the longest application time of 60 minutes.

DISCUSSION

In the present study, we compared ultrasonography with radiography, which is the gold standard in the diagnosis of extremity fractures, and assessed the sensitivity and specificity of USG in recognizing fractures. We have reached important conclusions that USG is a useful instrument for more use in the diagnosis of extremity traumas in emergency departments, due to its duration and cost, and its results being similar to radiography.

Conventional radiographic imaging is the first-line diagnostic tool accepted as the gold standard in the diagnosis of patients admitted to the emergency department with a suspected fracture (13). Serious complications such as bleeding and neurovascular injuries can be seen in bone fractures caused by extremity trauma. While taking critically ill patients to the radiography unit poses many risks, there may not be a radiography unit, especially in regions where geographical conditions are not suitable. For this reason, studies on finding alternative imaging techniques that are safer, economical, and easily accessible have intensified (14). Extremity injuries can occur due to many reasons. Wang et al. (15) reported that the trauma mechanism was caused by falls in the first place and traffic accident in the second place. In a large study by Khorgami et al. (16),

falls, traffic accident, motorcycle accidents, and gunshot wounds cause extremity injuries, in order of frequency. In the present study, falls were determined as the most common cause of trauma.

When the fractures detected on X-rays of our patients included in our study were defined according to the region and bone localization, 39.7% were in the lower extremities and 60.3% were in the upper extremities. While distal radius fractures were most common in the upper extremity, phalangeal fractures were most common in the lower extremities. Bozorgi et al. (17) tested the reliability of USG in detecting extremity fractures and observed that the most fractured bone in the upper extremity was the radius, and the femur in the lower extremity. Wang et al. (15) emphasized that upper extremity fractures were detected more than lower extremity fractures. Although conventional radiographic imaging is accepted as the gold standard diagnostic tool in the diagnosis of fractures, ionizing radiation caused by its use may cause adverse effects especially in the pediatric patients with sensitive tissues and in pregnant (18).

On ultrasonography, bone fractures are seen as cortical irregularity and interruption in the continuity of the cortex on longitudinal scanning (19). In our study, 130 of the 132 fractures detected by USG were also detected by radiographic imaging. Of the 113 fractures that could not be detected by USG, 112 could not be detected in radiographic imaging. With the results obtained, the sensitivity of USG in detecting extremity fractures was 99.24%, the selectivity was 98.25%, the positive predictive value was 98.48% and the negative predictability value was 99.1%. Patel et al. (20) found the sensitivity of ultrasonography as 97%, selectivity at 93%, positive predictability value of 95%, and a negative predictability value of 96% in the identification of fractures. In the study conducted by Dallaudiere et al. (21), the sensitivity, selectivity, positive predictability, and negative predictability of USG in the diagnosis of extremity fractures were respectively; 98.3%, 96%, 98.3%, and 96%. In the Netherlands, Epema et al. (22) found the sensitivity of USG to be 95%, its selectivity to 86%, positive predictability to 92%, and negative predictability to 91%. In our study and the literature, ultrasonography indicates high sensitivity and selectivity in recognizing bone fractures.

In our study, there were significant differences between X-Ray imaging and USG results in determining the extent of fractures to the joint. Of 32 fractures that showed extension to the joint on plain radiography, only 18 of them could be detected by USG. Bozorgi et al. (17) observed only 24 of 50 fractures with intra-articular extension, which they observed in X-ray imaging, by ultrasonography. Tsung et al. (23) found that the sensitivity of ultrasonography was lower in children with active epiphyseal enlargement, especially in the detection of fractures close to the joints. These results show that ultrasonography is insufficient to determine the extension of the fracture into the joint space. In the studies of Avcı et al. (24), and Beltrame et al. (25) on the contrary, fractures that could not be diagnosed by X-Ray were detected by ultrasonography. In a study conducted in Erzincan, CT, USG, and plain radiograms were compared in patients who applied to the emergency department due to elbow injury, and it was reported that 8 fractures that could not be detected by X-Ray were detected by USG (24). In one case in our study, the distal tibia fracture, which was visualized by USG, could not be observed on X-ray. In this case, who was brought to our emergency department due to traffic accident, CT imaging was performed after the orthopedic consultation and a fracture was found in the distal tibia.

The main limitationof the present studywas the low number of patients with fractures extending to the joint. In addition, all patients who applied to the emergency department with the suspicion of extremity fractures during the study dates were not included in the study, since the ultrasonographic examination was performed by a single physician. Randomization was achieved because the day and night study times were approximately equal. Advanced imaging techniques such as CT or MRI were not applied to patients with inconsistency between the results of ultrasonography and direct radiography. Hence, fractures in which USG and direct X-ray gave false positive and false negative results could have been detected. USG is a dynamic and user-specific examination, and both its sensitivity and specificity are tightly connected with user experience and training that credentials of the person performing the US may result in bias.

CONCLUSION

USG and radiography showed similar diagnostic performances in our study results. Ultrasound, which can be carried easily in triage areas and pre-hospital environments where X-Ray devices cannot be carried, does not contain radiation, and is easy to learn with short and simple training, can be used in the diagnosis of tissue and organ injuries. Radiographs may be insufficient in the diagnosis of some fractures because thin fractures may be hidden by overlapping structures or missed by X-rays that are not perpendicular to the fracture line. The USG can be used at the bedside and gives results in a short time, saving time in intensive emergency room conditions, and allowing early diagnosis, especially in the evaluation of critical patients.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Health Sciences University Afyonkarahisar Medical Faculty, Clinical Researches Ethics Committee (Date: 03.05.2019, Decision No: 166).

Informed Consent: All patients signed the free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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