Evaluation of the effectiveness of bedside point-of-care ultrasound in the diagnosis and management of distal radius fractures

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Abstract

Objective: The aim of the study was to compare the effectiveness of point-of-care ultrasound (POCUS) with direct radiography in diagnosis and management of the patients with distal radius fractures (DRFs).

Methods: In this study, patients between ages 5 and 55 years admitted to the emergency department with low-energy upper extremity trauma with suspected DRF were evaluated with POCUS and direct radiography by emergency physicians (EPs) trained in either musculoskeletal (MSK) imaging or x-ray interpretation of DRF. The EP performing the POCUS examination was blinded to the x-ray results.

Results: A total of 83 patients with DRF were included in the study. There were 18 (22%) females, and 65 (78%) males enrolled in the study. Mean age was 13 ± 14 years for males, and 15 ± 13 years for females. Compared with direct radiography, POCUS yielded 98% sensitivity, 96% specificity, 98% positive predictive value, 96% negative predictive value, and 98% accuracy of the test in detecting fractures. POCUS yielded 96% sensitivity, 93% specificity value in detecting linear fractures; 78% sensitivity, 98% specificity in detecting torus-type fractures, and 100% specificity and sensitivity for detecting fissure fractures. Specificity of POCUS in the decision for reduction was 100% and sensitivity was 98%; specificity was 100% for splint application.

Conclusion: In our study, it was shown that POCUS could be applied easily by EPs trained in MSK POCUS imaging with success in diagnosing DRF and determining the correct fracture type and required treatment methods.

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1. Introduction

Orthopedic injury is a frequent cause of emergency department visits. In adults, one of the most commonly detected injuries is distal radius fracture (DRF). Distal radius fracture constitutes an average of 1 of 6 of fractures treated in the emergency department [1]. Radiography is often used in determining the type of fracture and treatment to be applied. Revealing the characteristics of the fracture with standard posterior-anterior, lateral, and oblique direct radiographs is required. If sufficient information cannot be acquired with direct radiographs, computed tomography (CT) may be used for better evaluation of fracture fragments and articular surface [2]. Radiation exposure is a concern with CT and plain radiographs, especially in children whose tissues are more radiosensitive compared with adults. Alternative imaging techniques should be considered to help reduce radiation exposure especially for children [3].

Despite the standard use of direct radiography in the evaluation of orthopedic injuries, point-of-care ultrasound (POCUS) is being increasingly used for diagnosis. Musculoskeletal POCUS was shown to be of significant advantage in the radiation-sensitive pediatric population, in the prehospital environment, in pregnant patients, and to reduce exposure of serial direct radiographs in fracture reduction [4,5]. Especially in children, cartilage fragments of epiphyseal region can be evaluated by ultrasound without using standard radiographic techniques and radiation exposure [6]. Unlike CT and magnetic resonance imaging, as dynamic examination is performed with ultrasound, muscle, tendon, and joint functions can be evaluated simultaneously, also comparative examination with contralateral extremity can be performed [5].

Although closed reduction, splint, and close follow-up are often enough in the treatment of DRF, fracture management varies depending on the type of fracture [7]. Ultrasonography has been used with success in the diagnosis and ultrasound-guided fracture reduction in DRF [8–10]. However, there is no study in the literature regarding the use of POCUS in determining the choice of treatment in patients with suspected DRF.

In this study, the aims were to compare the effectiveness of POCUS with direct radiography in diagnosis of DRFs and to determine the type of fracture and choice of treatment methods in patients admitted to the emergency department with low-energy trauma.

2. Materials and methods

This was a prospective observational study to detect fractures of the distal radius using POCUS compared with plain radiographs, and also to
determine the treatment options based on diagnostic findings. The study was approved by the hospital ethics committee. Patients between the ages of 5 and 55 years, and applying to Antalya Education and Research Hospital Emergency Department between February 2014 and July 2014 with simple low-energy extremity trauma were included in this study. Informed written consent was obtained from all patients and/or patients’ relatives enrolled in the study. Patients with prediagnosed radius injury, open fractures, neurovascular injury, fracture with dislocation, other systemic injuries, unstable vital signs, or life-threatening injury and patients who did not give consent to participate were excluded.

Before starting the study, emergency physicians who participated in the study were divided into 2 equal groups (POCUS and direct radiography). Emergency physicians in POCUS group were given 30-minute didactic and 30-minute practical standard POCUS trainings on assessment of DRFs. Emergency physicians in direct radiography group were given 1 hour direct radiography training for the evaluation of DRFs. Standard data entry form was created. Physical examination of the patients (point tenderness, swelling, ecchymosis, deformity, range of motion, or neurovascular injury) were assessed by 2 physicians from both groups and registered. Then, 2 physicians, who belonged to either POCUS or direct radiography group and double-blinded to each other, evaluated the patient’s distal radius with POCUS or direct radiography.

The physicians in the POCUS group evaluated the distal radius using a 7.5-MHz linear transducer of the standard ultrasound device (Esaote, Firenze, Italy). The longitudinal and lateral images of the distal radius were evaluated from anterior and posterior surfaces in longitudinal and transverse planes. POCUS for distal radius was performed in 8 steps (Table 1). Angulation and step-off were measured using standard software of ultrasound device. Two lines were drawn along the edge of the cortex at the fracture site, and distance at the intersection of the 2 lines was measured for angulation. Step-off was obtained by measuring the distance between the intact cortex and cortex at the fracture site. The findings were confirmed by comparison with intact extremity. According to these results, the physician who performed POCUS decided treatment. Reduction treatment was administered to patients with angulation and step-off detected by POCUS. Angulation up to 10° was allowed in children at 6 to 12 years of age for reduction requirement [10]. Surgery was considered in case of intra-articular involvement, angulation of more than 20° in the radius and fractures with dorsal cortex fragmentation.

Emergency physicians who were in direct radiography group and blinded to the POCUS results evaluated posteroanterior and lateral direct radiographs of the patient. After fracture detection, fracture angulation and step-off were assessed on direct radiographs. In addition to shortening of the distal radius, radial inclination was measured on posteroanterior direct radiographs and volar tilt on lateral direct radiographs. Closed reduction was selected as the method of treatment in case of less than 5 mm radial shortening, greater than 15° radial inclination on posteroanterior direct radiographs, 0° to 20° of volar tilt on lateral direct radiographs, and less than 2 mm intra-articular step-off compared with the intact extremity on direct radiographs. The fracture was considered unstable in case of dorsal angulation more than 20°, dorsal cortex fracture, intra-articular step-off greater than 2 mm, and shortening more than 5 mm [7,10,11]. Surgical treatment requirement was determined in the patients with unstable DRF.

Surgery was accepted as the treatment method in the presence of angulation, step-off, and fragmentation in the cortex on POCUS and direct radiography in ulnar fracture.

Splint application was decided in case of simple fractures not requiring reduction on POCUS and direct radiography and presence of limited joint mobility and marked edema. In case of mild edema and tenderness, elastic bandage was selected for treatment.

No treatment decision was given for fractures including epiphyseal line on POCUS and direct radiography.

The data obtained by physicians conducting studies were pooled, and data from both groups were compared. Data analysis was made using SPSS version 21. Sensitivity, specificity, positive predictive value, and negative predictive values of POCUS were measured. For descriptive statistics, data obtained using $\chi^2$ test and kappa statistics were compared.

### Table 1

<table>
<thead>
<tr>
<th>Steps of the POCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Detect the presence of fracture (cortical disruption).</td>
</tr>
<tr>
<td>2. Determine the type of fracture (fissure, linear, fragmented, torus).</td>
</tr>
<tr>
<td>3. Measure the degree of angulation of the fracture.</td>
</tr>
<tr>
<td>4. Measure the distance of stepping-off.</td>
</tr>
<tr>
<td>5. Is there an extension of the fracture into the joint space?</td>
</tr>
<tr>
<td>6. Does the fracture include epiphyseal line?</td>
</tr>
<tr>
<td>7. Detect the presence of concomitant adjacent bone fracture (ulnar).</td>
</tr>
<tr>
<td>8. Control the presence of hematoma in the range of soft tissue and joint.</td>
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</tbody>
</table>

### Table 2

Comparison of the physical examination findings of the patients with the presence of fractures that were determined by POCUS with direct radiography

<table>
<thead>
<tr>
<th>Physical examination findings</th>
<th>Fractures detected by POCUS, no. (%)</th>
<th>Fractures detected by direct radiography, no. (%)</th>
<th>Total, no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>10 (38)</td>
<td>11 (42)</td>
<td>26 (100)</td>
</tr>
<tr>
<td>Edema + sensitivity</td>
<td>23 (68)</td>
<td>22 (65)</td>
<td>45 (100)</td>
</tr>
<tr>
<td>Deformity + edema + sensitivity</td>
<td>19 (95)</td>
<td>19 (95)</td>
<td>38 (100)</td>
</tr>
<tr>
<td>Deforomy + edema + sensitivity + ecchymosis</td>
<td>3 (100)</td>
<td>3 (100)</td>
<td>6 (100)</td>
</tr>
<tr>
<td>Limited joint mobility</td>
<td>44 (81)</td>
<td>44 (81)</td>
<td>88 (100)</td>
</tr>
</tbody>
</table>

### Table 3

Comparison of the types of fractures determined by POCUS with direct radiography

<table>
<thead>
<tr>
<th></th>
<th>No fracture, no. (%)</th>
<th>Fissure, no. (%)</th>
<th>Linear, no. (%)</th>
<th>Fragmented, no. (%)</th>
<th>Torus, no. (%)</th>
<th>Total, no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POCUS</td>
<td>28 (33.7)</td>
<td>5 (6)</td>
<td>32 (38.6)</td>
<td>2 (2.4)</td>
<td>16 (19.3)</td>
<td>83 (100)</td>
</tr>
<tr>
<td>Direct radiography</td>
<td>28 (33.7)</td>
<td>5 (6)</td>
<td>29 (34.9)</td>
<td>2 (2.4)</td>
<td>19 (22.9)</td>
<td>83 (100)</td>
</tr>
</tbody>
</table>

n = number; % = percentage.
in 28 patients (34%). Compared with direct radiography; sensitivity of POCUS in detecting fractures was 98%, specificity was 96%, positive predictive value was 98%, negative predictive value was 96%, and accuracy of the test was 98%.

Detection rates of types of fractures by POCUS and direct radiography were compared (Table 3). POCUS yielded 96% sensitivity, 93% specificity, 87% positive predictive value, and 98% negative predictive value in detecting linear fractures (95% confidence interval [CI], 89%-100%); 78% sensitivity, 98% specificity, 93% positive predictive value, and 94% negative predictive value in detecting torus-type fractures (95% CI, 76%-99%); and 100% specificity and sensitivity for detecting fissure fractures.

In 8 of the patients (10%) enrolled in the study, distal ulnar fracture (DUF) was detected by POCUS and direct radiography. Of all DUF cases, 1 was fissure, 2 were torus-type, and 5 were linear fractures. In patients with ulnar fractures, 3 had linear radius fracture, 3 had torus-type fracture, and 2 had no fractures. Specificity and sensitivity of POCUS in determining the presence and type of DUF fracture were 100%.

The properties of radius fractures such as angulation, step-off, including epiphyseal line, extension into the joint space according to the evaluation with POCUS, and direct radiography were similar (Table 4).

In patients with fractures, proposed treatment methods by both physicians were compared (Table 5). It was determined that splint application and reduction were decided in 39 of both groups. Compared with direct radiography, specificity and sensitivity of POCUS for decision of reduction were 100%. In 24 (44%) patients with fracture, no reduction was found to be required. Forty-nine percent of the patients were decided to undergo splint application according to direct radiography and physical examination results, sensitivity of POCUS was 98%, specificity was 100%, positive predictive value was 100%, and negative predictive value was 98% for splint application (95% CI, 96%-100%).

No treatment was specified for patients suspected of having a compartment syndrome due to intramuscular hematoma or with fractures involving the epiphyseal line. Surgical treatment was decided in 1 patient with fracture extending into the joint space.

### 4. Discussion

Distal radius fracture is one of the most common fractures in adults and constitutes 16% of all fractures. The treatment goal of DRF is to provide anatomic reduction stable enough to allow early mobilization and rehabilitation. The best method of treatment is the approach causing least damage to surrounding tissues and maximum correction of the anatomy. Because many factors affect the choice of treatment, scintigraphy, CT, and magnetic resonance imaging scans are needed in case direct radiography is not sufficient. However, these methods have some disadvantages such as taking time, being expensive, containing ionizing radiation, and not always being easily accessible [6,11,12].

### Table 4

Comparison of the properties of radius fractures according to the POCUS with direct radiography

<table>
<thead>
<tr>
<th></th>
<th>POCUS, no. (%)</th>
<th>Direct radiography, no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angulation</td>
<td>11 (20)</td>
<td>10 (18)</td>
</tr>
<tr>
<td>Step-off</td>
<td>21 (38)</td>
<td>21 (38)</td>
</tr>
<tr>
<td>Fractures including epiphyseal line</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Extension of the fracture into the joint space</td>
<td>2 (4)</td>
<td>2 (4)</td>
</tr>
</tbody>
</table>

### Table 5

Comparison of the treatment options determined according to the findings of the POCUS with direct radiography

<table>
<thead>
<tr>
<th></th>
<th>Elastic bandages, no. (%)</th>
<th>Splint, no. (%)</th>
<th>Reduction + splint, no. (%)</th>
<th>Surgical treatment, no. (%)</th>
<th>Total, no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POCUS</td>
<td>11 (13.5)</td>
<td>38 (46.9)</td>
<td>31 (39.5)</td>
<td>1 (1.2)</td>
<td>81 (100)</td>
</tr>
<tr>
<td>Direct radiography</td>
<td>10 (12.3)</td>
<td>39 (48.1)</td>
<td>31 (39.5)</td>
<td>1 (1.2)</td>
<td>81 (100)</td>
</tr>
</tbody>
</table>

Because awareness on the dangers caused by even small doses of radiation has increased, alternative techniques to direct radiography are required. Being easy to learn, the use of ultrasound as an imaging method has been increasing. In addition, as a result of being safe and being able to be performed bedside, it is widely used in the differential diagnosis of trauma and nontrauma patients in emergency medicine [13,14].

Marshburn et al [15] showed that ultrasound examination by clinicians after 1 hour of standardized training could be used to rule out low or intermediate probability of fractures of long bones in patients older than 18 years. Images are obtained in 2 planes with the probe placed at the point of maximum sensitivity in POCUS examination with high-frequency linear transducer. Pain sensing can be reduced and image persistence can be provided along the bone with applied thick-layer conductive gel [4]. Sensitivity and specificity of POCUS were higher in studies on bone fractures [16–18]. In our study, diagnosis of fracture, detection of fracture type, and determination of the types of treatment requirements were found to be possible by emergency physicians with a standard POCUS training. This may be related to distal radius being a superficial bone and being easily evaluated by POCUS.

Hidden fractures in clavicle, orbit, feet, ankles, ribs, femur, and humerus that cannot be shown with conventional radiography have been shown with ultrasound [15]. It has been reported that degree of cortical deformation was easier to detect with ultrasound than radiography [13,19]. A study by Chen et al [20] found the sensitivity and specificity of ultrasonography in detection of forearm fractures in children as 97% and 100%, respectively. In another study conducted in children, sensitivity and specificity of ultrasonography in detection of radius and ulnar fractures have been reported as 100% [13]. In addition, sensitivity and specificity for the detection of nonangulated distal forearm fractures with ultrasound have been reported as 96% and 93% [18]. In our study, the sensitivity of POCUS in DRF was 98%, its specificity was 96%, its positive predictive value was 98%, and its negative predictive value was 96%, whereas the specificity and sensitivity for ulnar fracture were 100%.

Careful examination and patient selection by emergency physician constitute the most important step in the diagnosis of fractures with
POCUS. Presence of fractures were detected with POCUS in 38% of patients with only tenderness, in 69% of patients with edema and tenderness, in 95% of patients with deformity, and in 100% of patients when ecchymosis is added to these findings. The probability of fracture increases as physical examination findings increase.

Acute compartment syndrome (ACS) should be considered in case of extremity trauma. Acute compartment syndrome is increased pressure inside muscle compartments of the extremities. Unintended results can happen with delayed diagnosis. Numerous studies showed that fractures, soft tissue injuries, and crush syndrome are very common causes of ACS. The most common are seen in tibial shaft, distal radius, and ulna. Here, the mechanism responsible for increased compartmental pressure is tissue swelling and hematomas [21]. Therefore, emergency physician should check for ACS during the examination of patients. Hematoma, soft tissue interposition at the fracture site, interosseous membrane integrity, and fracture healing can also be displayed with ultrasound [15]. In our study, POCUS detected presence of intramuscular hematoma in 14% of patients. Hematoma was found to be at a level to create compartment syndrome in 1 patient. Unlike radiography, evaluation of soft tissue is an advantage of ultrasonography.

Because pediatric periosteum is thick and strong, it retains fracture stability. Therefore, unlike adult fractures, unique fractures such as greenstick and torus occur in children. It has been reported that cortical disruption is 100% especially in children with greenstick and torus fractures, and ultrasound shows cortical disruption very clearly in torus fractures [17]. However, fracture may be overlooked when the probe is placed in the normal cortex area, as these fractures are incomplete. In addition, microfracture areas may be seen in intact areas of incomplete fractures [19]. In the study by Patel et al [8], ultrasonography has been shown to be better than radiographs in distinguishing torus fractures. In our study, sensitivity of POCUS in detecting torus type fractures was 78%, specificity was 98%, positive predictive value was 93%, and negative predictive value was 94%. Torus fractures were determined to be linear fracture in 3 patients. This may be due to the reflection of microfractures to ultrasound images. However, this result did not alter the treatment.

In studies, diagnostic errors in with fractures POCUS have been shown to occur in nearby areas of bone ends or joints, small bones of hands and feet, nondisplaced epiphyseal fractures (Salter-Harris type 1), or fractures with less than 1-mm fracture lines [15,22]. Sensitivity of POCUS was found low, especially for the detection of fractures near the joint in children with open epiphyseal line. In our study, although the number of patients was small, fissure-type fractures, fractures extending to joint space, and containing epiphyseal line were easily identified by comparison intact limb (Figs. 1 and 2).

Distal radius fracture management varies due to patient age, fracture stabilization, loss of function, dislocation, radial shortening rate, intra-articular radiocarpal involvement, and presence of concomitant DUF. However, as in our study, closed reduction, splint, and close follow-up are often sufficient [7,11]. In studies, ultrasound has been shown to be enough for deciding closed reduction and that ultrasound-guided reduction is very sensitive, easy to use, noninvasive, and safe tool in DRF [8,9]. However, to achieve this result, radial height, radial inclination, or volar tilt evaluated by direct radiography cannot be measured directly by ultrasonography. Instead, degrees of angulation and step-off distance are measured. It has been indicated that compliance of proximal and distal parts of the radius in 2 planes on ultrasonography is a good indicator for sufficient reduction, and visual decision of bone compliance can be made with ultrasound image without measuring [9]. In a study carried out by Patel et al on long bone fractures, values for fracture

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**Fig. 2.** Posteroanterior and lateral direct radiographs of the same patient shown in Fig. 1.

**Fig. 3.** Angulation and step-off can be seen in distal radius of a 27-year-old male patient on longitudinal ultrasonographic image.

**Fig. 4.** Posteroanterior and lateral direct radiographs of the same patient shown in Fig. 3.
detection, reduction necessity, and adequacy of reduction were as follows: sensitivity—0.97, 0.93, and 1.00, respectively; specificity—0.85, 1.00, and 0.80, respectively [8]. In our study, angulation was detected in 19% of patients, and step-off was detected in 37% of patients with POCUS-detected fractures (Figs. 3 and 4). According to these findings, fracture reduction was decided for 39% of patients. Specificity and sensitivity of POCUS for necessity of reduction were 100%. In addition, selected treatment of elastic bandage or splint was observed to change in only 1 patient. This may be due to the doctor’s professional experience. Sensitivity of POCUS for splint application was 98%, specificity was 100%, positive predictive value was 100%, and negative predictive value was 98% (95% CI, 96%-100%). Surgical decision was made for only 1 patient in both POCUS and direct radiography as a result of fracture extending into the joint space.

In conclusion, our study showed that POCUS can be easily applied by emergency physicians with training in musculoskeletal POCUS with standard training by emergency physicians. It has high sensitivity and specificity in the determination and management of DRF, and also both soft tissues and bone tissues can be evaluated noninvasively.

References