Diagnostic Accuracy of Portable Ultrasonography in Confirmation of Adequate Reduction of Distal Radius Fracture

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ABSTRACT

Background: Distal radius fracture (DRF) is one of the most common injury presented to the emergency ward and compromise about one sixth of fractures managed by emergency physicians

Methods: This study was performed in ED of two regional hospitals in eastern part of Iran, with combined census of 150,000 patients per year, serving a largely low-income population.

Results: Thirty patients were enrolled during the study period. Five patients required repeated M&R, one refuses to continue and 4 patients were reduced for the second time.

Conclusion: In the present study we show that US-guided DRF reduction has high sensitivity and specificity to diagnosed reduction adequacy in comparison with standard radiography.

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►*Implication for health policy/practice/research/medical education:* Portable Ultrasonography in Confirmation of Adequate Reduction of Distal Radius Fracture

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1. Introduction:

Distal radius fracture (DRF) is one of the most common injury presented to the emergency ward and compromise about one sixth of fractures managed by emergency physicians (1-3). The usual victim is a middle aged or elderly woman who falls on the outstretched palm of her hand. Management of DRF varies based on the type of fracture. In extra-articular fracture, it generally needs closed reduction, casting and future follow up (4). Restoration of displaced anatomical alignment is a cornerstone for treatment of DRF; otherwise nonunion, malunion, early osteoarthritis and carpal tunnel syndrome may occur (5, 6).

At present, the standard diagnostic tool to assess bone alignment following manipulation and reduction (M&R) is radiography. Radiography is a dawdling technique especially in overcrowded

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emergency department (ED). It also needs repeated X-ray exposure based on reduction adequacy and can cause more painful process if the additive effects of repeated manipulation take into consideration. Fluoroscopy, on the other hand is a real-time tool to assess fracture reduction. From the executive point of view, this tool is expensive, space-occupying and need shielding to protect patient and physician; All above, makes it unreasonable to have it on EDs.

Ultrasonography (US) has various desirable properties that make it as an alternative modality to assess fracture reduction in DRF. Ultrasound waves reflect by the cortical bone which create unique findings in fractured bone (7). These findings are included sub-periosteal hematoma, cortical disruption and reverberating echoes (8). To date, there are several studies examining ultrasonography as an accessible, fast and accurate diagnostic tool to assess bone alignment in children (9-14). But such a study in adult patients is not enough.

Alongside the radiology remains the gold standard for evaluating DFR, more rapid and accessible tests with acceptable accuracy is desirable. Therefore, we conducted a study to determine the accuracy of ultrasonography in the diagnosis of DRF reduction adequacy.

2. Materials and Methods:

Study design and setting

Protocol for this prospective study was approved by Mashhad University ethic committee, Mashhad, Iran. Written informed consent was taken from all patients before inclusion. This study was performed in ED of two regional hospitals in eastern part of Iran, with combined census of 150,000 patients per year, serving a largely low-income population.

Selection of patients

Patients presenting to ED due to distal forearm fracture were enrolled over a 6 months period between May to October 2013. Patients were enrolled prospectively when the investigators or study associates were available in the ED. Inclusion criteria was defined as (i) adults more than 21 years of age and (ii) acute distal radius or distal radius and ulnar fracture with significant displacement that requires M&R. Exclusion criteria include any of the following: (i) Severe edema that limit the applicability of closed reduction; (ii) BMI>30 (iii) Need for general anesthesia; (iv) Multiple fracture in the other site; (v) Pathologic fracture; and (vi) Open fracture. Following admission, Diagnosis of DRF was confirmed by antero-posterior (AP) and lateral radiography. Assessing the need for M&R prior to casting was made by emergency physician faculty based on their judgment of the X-ray, experience and desired functional outcome.

Physician preparation and training

For this study, ultrasound guidance was performed only by faculty EPs, who was educated via a lecture and instructional video by a radiology faculty and experience was gain in a pilot study of 10 patients done before commencement of the actual study.

Intervention

For this study, distal radius fracture M&R were done under hematoma block. The attending ED faculty performed all reduction procedures using Robert Jones method (15); briefly, the thenar eminence of one hand of the manipulator is placed dorsally over the lower radius at the wrist and the other hand placed on the lower forearm, in line with the radial shaft; the lower radial fragment is then manipulated in a volar and medial direction and is also pronated to overcome the supination deformity. After desirable reduction had been reached, US guidance performed in two long axis view of the distal radius: an AP view on the dorsal surface of the distal radius and a LAT view on the lateral radial aspect of the distal radius. An acceptable reduction by ultrasound was aligning the proximal and distal bone into a direct line that was seen in both AP and LAT views (16). Irrespective of the US results, all patients were taken AP and LAT radiography as the standard diagnostic

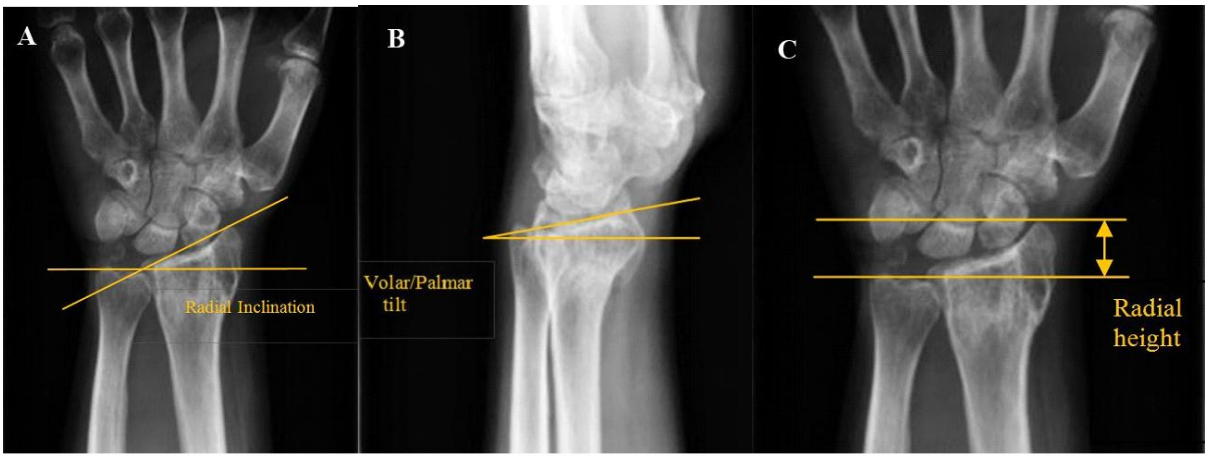

Fig. 1. It shows Criteria to judge on the appropriateness of reduction in plain radiography.

tool. Criteria to judge on the appropriateness of reduction in plain radiography were the same as previous literature (17, 18), defined as (i) the normal radial inclination of 15-25°; (ii) a radial height of at least 5 mm or more; and (iii) volar/palmar tilt of −10° to +20° (10° volar tilt is normal) (Figure 1). If the reduction was deemed inadequate by radiography, therefore, M&R was repeated. One complete M&R attempt is defined as the M&R procedure itself, application of the plaster splint, and post-reduction X-ray. If a patient fails for adequate reduction on control X-ray, he was attempted for another M&R and the cycle was repeated.

Data collection and processing

Patient age, sex, mechanism of fracture, fracture angulation, and reduction attempts were entered on a data collection sheet. Review of the ultrasound images and X-ray measurements were done by the authors. The outcome measures were the overall rate of successful reduction based on standard radiography, and the sensitivity and specificity of US-guided EP faculties' assessment of successful reduction.

Statistical Analysis

Fracture reduction success rates and sensitivity, specificity, and predictive values of US assessment for reduction success were calculated using SPSS version 20 (IBM® SPSS®). The kappa value expresses the amount of agreement between US and standard radiography, beyond chance expectation. That is, "0" is no more than chance agreement and "1" is perfect agreement. We applied the following, previously used, subjective limits for grading agreement: 0 to 0.2 slight agreement, 0.2 to 0.4 fair, 0.4 to 0.6 moderate, 0.6 to 0.8 substantial and >0.8 almost perfect agreement (19). The level of significance considered P value less than 0.05.

3. Results:

Thirty patients were enrolled during the study period. Five patients required repeated M&R, one refuses to continue and 4 patients were reduced for the second time. Demographic data of the included patients are presented in table 1.

Times of M&R were analyzed against age of patients. It reveals patients with older age were at increasing risk of primary M&R failure (P value=0.007). Among thirty patients, 4 (13.3%) and 5 (16/6%) patients required a repeat M&R attempt based on post reduction US and radiography respectively. Radiography results were used as the basis for judgment on reduction adequacy. Four of 5 patients who diagnosed failure on primary M&R, accept to try repeated M&R and one of them refuses; among them, all have acceptable reduction on second M&R

Table 1: Demographic data of 30 patients with distal radius fracture

Variable	Number (%)
Age	
Mean±SD	44 ± 12.7
Range	26-73
Sex:	
Male	21 (70)
Female	9 (30)
Fracture angulation at baseline	
5°	8 (26.7)
10°	12 (40)
15°	10 (33.3)
Direction of angulation	
Dorsal	27 (90)
Volar	3 (10)
Fracture mechanism	
Falling	25 (83.3)
Motor-car accident	2 (6.7)
Violence	3 (10)

Table 2: Comparison of radiography and ultrasonography according to cortical alignment by manipulation and reduction in distal radius fracture

	Radiography	
US	Normal	Abnormal
Normal	25	1
Abnormal	0	4

based on both radiography and US (Table 2).

Sensitivity, specificity and predictive value of US were calculated against standard radiography. Sensitivity, specificity, positive predictive value and negative predictive value of US were 100% and 80%, 96.7% and 100%, respectively. Accordingly, US and radiography were 96.6% in agreement with each other. Kappa statistic for no chance agreement between US and radiograph was 0.867. In the other words, US and radiography for evaluating bone alignment in DRF were in a perfect agreement with each other.

4. Discussion:

In our study, we showed that US has an acceptable validity to diagnose reduction adequacy following M&R in DRF. Our sensitivity (100%), specificity (80%) and test agreement with standard tool (96.6%) demonstrate that US can be a practical alternative to radiography in the diagnosis of successful reduction in DRF, especially when US images are interpreted by an ED faculty with advanced skills in ultrasonography.

The previous studies on adult patients have reported the similar sensitivity and specificity, ranging from 94% to 99.3% and 56% to 100%, respectively (20, 21). Esmailian *et al* (21) studied US-guided reduction on 154 patients with dorsal

displacement distal radius fracture in that, he perform Bier block regional anesthesia or procedural sedation-anesthesia. However, we define our inclusion criteria more widely to accept volar inclination in addition to dorsal ones, which make our results more generalizable. In a Cochrane systematic review on 18 randomized trials including 1200 patients who were compared with regard to anesthesia methods, there was no conclusive evidence on the best anesthesia method in relation to effectiveness, safety and influence on fracture reduction (22). Chinnock *et al* (20) on his study on 90 patients stated that whereas US-guided reduction of DRF had the same success rate radiography, it provided the ED physician with visualization of alignment during reduction maneuvers that correlated well with final radiographic alignment.

In the present study, age was a significant determinant of M&R failure rate. The patient's age reflects his or her potential for bone loss and consequently, fracture instability (23), so it should be take into consideration when make decision about the treatment type.

The US has several advantages against radiography: It's an accessible, portable, cheap, quick and real-time tool that make it extraordinary valuable in overcrowded ED. The real-time feedback of US-guided reduction make it extraordinary valuable in reducing the need for repeated procedural sedation and removal and reapplication of the splint (20). **Second**, Swelling of the fracture site is often encountered and decrease sensitivity of palpation in blind reduction, which is not the case in US-guided reduction (16). **Third**, visual judgment of cortical alignment on the US screen is enough, and no measurements need to be made on the ultrasound images (16). **Forth**, If the US images show adequate alignment, it may even substitute post reduction X-rays and only have the X-rays done upon review in the orthopedic clinic (usually 1 week late). On the other hand, the US has some disadvantages: It cannot access articular surface due to deep seated position and masking by carpal component. So we exclude patients with intra-articular fracture. **Second**, the US is highly dependent on experience of operator, so training course for this technique would have strange effect on the outcome. To control that, we just include ED faculty with satisfactory experience on US-guided fracture reduction. Meanwhile, the US has not a significant learning curve (20), so the training course will not limit its applicability. **Third**, after application of plaster splint, the window for ultrasound beam is gone (16). So it may necessitate X-ray or fluoroscopy if there is any doubt on post reduction displacement of the distal fragment during the application of the splint (either through inadequate traction or excessive movement). Fortunately, this was not a problem encountered in our study. **Forth**, the US cannot measure radiologic indices for fracture reduction (16). However fracture reduction in 2 basics type of displacement (radial and dorsal) has been shown to have a satisfactory clinical outcome (24). Then, US by showing cortical alignment in two AP and lateral planes would have a potential to surrogate for radiography.

The main limitation of our study was lack of control group to make comparison between success rate and the cost of US against radiography. The second limitation was that due to the design of our study, we did not study whether the use of US could decrease the time spent in the ED. Third, because of our study protocol to perform all of our US-guided reduction by ED faculty, we could not determine the effect of different training course with US results.

5. Conclusion

In the present study we show that US-guided DRF reduction has high sensitivity and specificity to diagnosed reduction adequacy in comparison with standard radiography. Due to the fact that US is an accessible, portable and quick tool which produce real-time visualization of the

M&R, it can be an excellent surrogate for radiography in DRF reduction.

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