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Ultrasound in Emergency Medicine

ULTRASOUND-GUIDED REDUCTION OF DISTAL RADIUS FRACTURES

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☐ Abstract—Background: Ultrasound (US) may provide the emergency physician with the ability to do real-time assessment of fracture reduction adequacy. Objectives: To assess whether US guidance aids in determining the adequacy of distal radius fracture reduction in the emergency department (ED), and to compare the rates of successful reduction with and without US. Methods: We conducted a prospective study of patients who underwent US-guided reduction of a distal radius fracture, compared to a historical cohort without US guidance. After performing US-guided reduction, but before post-reduction radiographs, physicians filled out a form stating whether reduction was successful or unsuccessful. Successful radiographic reduction was determined by two orthopedic surgeons based on radiographic findings. Main outcome measures were the sensitivity and specificity of US-guided ED physician assessment of successful reduction, and reduction success compared against the historical cohort. Results: We enrolled 46 patients in the US-guided group and compared them to 44 patients in the historical cohort. Pre-reduction characteristics were similar in both groups. Physician assessment of reduction success by US had a sensitivity of 94% (95% confidence interval [CI] 88–98%) and specificity of 56% (95% CI 31–71%) for identifying a successful reduction on post-reduction radiographs. The overall success rates of the US-guided and control groups were similar (83% and 80%, respectively). Conclusions: Physicians had a high sensitivity in predicting adequate reduction of distal radius fractures using US guidance in the ED. The overall rate of successful fracture reduction was similar with or without US. Further study may determine whether US guidance reduces the time spent in the ED for fracture reduction.

☐ Keywords— ultrasound; guidance; fracture; reduction; radius

INTRODUCTION

Distal forearm fractures are a common injury presenting to the emergency department (ED). Conservative treatment with closed reduction and immobilization remains the most common form of definitive treatment. Adequate reduction is essential for the successful treatment of non-operative cases. Dorsal misangulation of the distal radius results in progressive incongruity of the radioulnar joint, and has been shown to correlate with decreased grip strength, range of motion, and activities of daily living (1,2). In the ED, a successful reduction is generally confirmed by post-reduction radiographs. However, an inadequate reduction may lead to further time-consuming sedation and manipulation attempts. Fluoroscopy is a real-time tool for assessment of fracture reduction, but issues of cost, space, and radiation exposure make it impractical in many EDs. Ultrasound (US) may provide another means of assessing for fracture reduction adequacy during reduction maneuvers. Previous studies have demonstrated the utility of US-guided reduction of radius fractures in pediatric patients in the ED (3,4). Chen et al. demonstrated a 92% first-attempt success rate for US-guided forearm fracture reduction in 26 children (3). No previous studies have examined US-guided fracture reduction in both pediatric and adult patients, nor has it been compared to a control group without US.

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The purpose of this study was to assess the ability of physicians using US to predict successful fracture reduction on radiographs. We also sought to determine the success rate of ED US-guided distal radius fracture reduction compared against an historical cohort of ED non-US-guided distal radius fracture reductions.

METHODS

This was a prospective study of a group of patients who had US-guided distal radius fracture reduction compared to an historical cohort of ED patients who had standard distal radius fracture reduction without US guidance. A convenience sample of patients was enrolled 24 h a day during all days of the week. The study was approved by the institutional review board at each facility.

The study was conducted at two urban, academic medical center EDs, with a combined census of 100,000 patients per year, serving a largely low-income population. The EDs have an emergency medicine residency and no orthopedic surgery residency. Patients in the US-guided group were enrolled between November 2005 and December 2007. Patients were enrolled if the emergency physician determined the need for reduction of a distal radius fracture. Those who required immediate operative repair were excluded. The control group was constructed from patients who had closed reduction of a similar fracture during the same time period, but without the use of US. They were selected by examining procedure codes for radius fracture reduction, then performing a structured chart review to confirm that a non-US-guided reduction had occurred in the ED.

A 3-min tutorial in US-guided fracture reduction was created and presented to faculty and residents at a teaching conference. Physicians were trained to use the 7.5-MHz linear array probe by examining the fracture site with the probe oriented in the longitudinal plane on the dorsal aspect of the radius. The tutorial included sonographic images of displaced fractures (Figure 1A), reduced fractures (Figure 1B), and a demonstration of how to identify the cortex and amount of displacement and angulation. For those who did not attend this training session, a short computer tutorial was available online.

Before reduction attempts, the physicians filled out a standardized data form. Reduction was then attempted, using US after each reduction maneuver to assess adequacy (Figure 1). Before obtaining a confirmatory post-reduction radiograph, the physician was asked whether an adequate fracture reduction had occurred, and if the use of US was "helpful" or "unhelpful."

Pre-reduction radiographs were reviewed by the study investigators to detail fracture characteristics (Table 1). Charts were reviewed for demographic information and mechanism of injury. Fracture characteristics were classified according to a priori definitions and are described in Table 1.

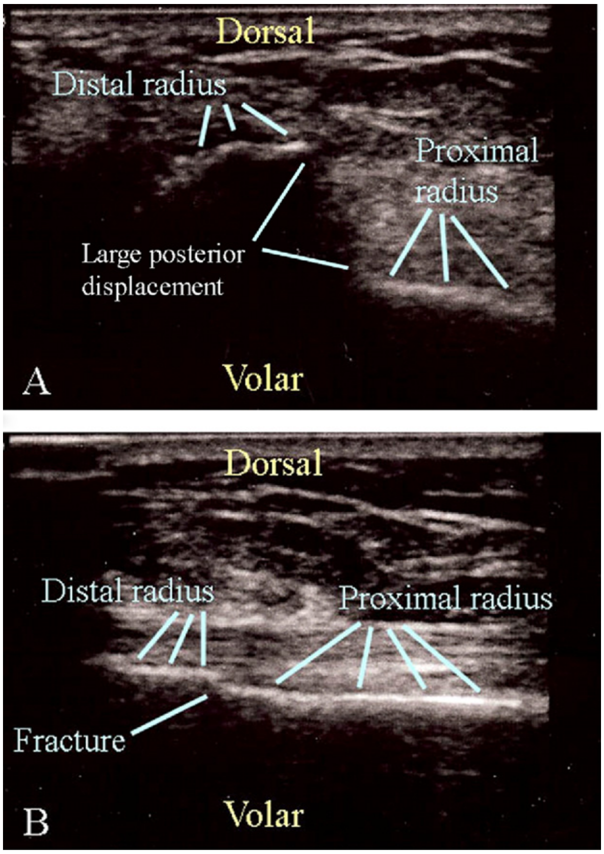

Figure 1. Pre- and post-reduction ultrasound images of a distal radius fracture. The pre-reduction image (A) demonstrates significant dorsal displacement of the distal radius. Post-reduction image (B) demonstrates good alignment with minimal displacement.

Pre-reduction radiographs were also reviewed by two orthopedic surgeons blinded to patient information and to the study hypothesis. The surgeons were asked to rate the pre-reduction assessment of reduction difficulty as "difficult" or "not difficult." If there was disagreement, a third orthopedic surgeon made the final determination.

Chart abstraction was performed by a single individual, with training from the primary investigator, who was not blinded to the study hypothesis. All charts were also reviewed by the primary investigator, and inter-rater agreement between the primary investigator and primary chart abstracter was calculated.

The primary outcome measures were the overall rate of successful reduction, and the sensitivity and specificity of US-guided emergency physician assessment of successful reduction. Reduction success was determined by two orthopedic surgeons reviewing post-reduction radiographs. The fracture reduction was classified as

Table 1. Pre-reduction Characteristics of Patients Having Fracture Reduction With and Without US Guidance

Pre-reduction Characteristics	Control Patients (n = 44)	US-guided Patients (n = 46)
Subject characteristics		
Age in years, mean (range)	30 (3–87)	32 (6–77)
Female gender n (%)	21 (48)	20 (43)
Fracture characteristics		
Angulation of distal fragment		
Posterior, n (%)	32 (73)	37 (80)
Anterior, n (%)	6 (13.5)	6 (13)
None, n (%)	6 (13.5)	3 (7)
Angulation > 20°, n (%)*	24 (55)	22 (48)
AP displacement†		
None, n (%)	19 (43)	17 (37)
Partial, n (%)	9 (20)	11 (24)
Total, n (%)	16 (37)	18 (39)
Shortening, n (%)‡	26 (59)	28 (61)
Intra-articular, n (%)	4 (9)	9 (20)
Comminution, n (%)	6 (17)	9 (20)
Ulna fracture, n (%)	25 (57)	25 (54)
Radioulnar dislocation, n (%)	1	1
Mechanism of injury		
Fall, n (%)	34 (77)	35 (76)
MVA, n (%)	8 (18)	7 (15)
Other, n (%)	2 (5)	4 (9)
Pre-reduction assessment of reduction difficulty		
Difficult, n (%)	17 (39)	21 (47)
Interrater agreement of reduction difficulty (%)	75	85

* Angulation was measured by drawing lines through the center of the proximal and distal fragments, and measuring the angle at the intersection.
† AP displacement was described as "none" if the anterior cortex of the proximal and distal fragments were in contact, "partial" if there was any overlap of the proximal and distal fragments, and "total" if there was no overlap between the proximal and distal fragments.
‡ Shortening was present if the proximal portion of the distal fragment lay proximal to the distal portion of the proximal bone.
MVA = motor vehicle accident; F = female; AP = anterior-posterior.
All *p*-values non-significant.

successful (no further manipulation needed) or unsuccessful. Fracture reduction success rates and sensitivity, specificity, and predictive values of US assessment for reduction success were calculated with 95% confidence intervals using calculators at http://graphpad.com/quickcalcs/ConfInterval1.cfm.

RESULTS

There were 46 patients enrolled in the US-guided reduction group and 44 historical cohort patients in the non-US-guided control group. The pre-reduction characteristics and characteristics of the reduction procedure for each group are listed in Table 1. Pre-reduction fracture characteristics were similar in both groups. None of the control or US-guided group patients had an associated carpal fracture or dislocation. One patient in the control group had a grade 1 open fracture, which was managed with open reduction, internal fixation (ORIF). The mechanism of injury and orthopedic surgeon pre-reduction assessment of reduction difficulty were similar in both groups. In the control and US-guided groups, there were 23 and 32 different practitioners who performed the reductions, respectively. In the US-guided group, there was one practitioner who performed five reductions and one practitioner who performed three reductions. All other practitioners in the control and US-guided groups performed two or fewer reductions.

Emergency physician assessment of reduction success by US had a sensitivity of 94% (95% confidence interval [CI] 88–98%), specificity of 56% (95% CI 31–71%), positive predictive value of 89% (95% CI 83–93%), and negative predictive value of 71% (95% CI 40–91%) for identifying a successful reduction on post-reduction radiographs.

The overall success rates of the US-guided and control groups were similar (83% and 80%, respectively, see Table 2). Success rates were similar in US-guided and control groups for both pediatric (78%, 95% CI 54–92%, vs. 70%, 95% CI 48–86%, respectively) and adult (86%, 95% CI 68–95%, vs. 88%, 95% CI 68–96%, respectively) patients. Inter-rater agreement of reduction suc-

Table 2. Outcome Measures

Outcome 1: reduction success rates		
Outcome measure	Control patients n (%) (95% CI)	US-guided patients n (%) (95% CI)
Successful reduction	35/44 (80%) (65–89%)	38/46 (83%) (69–91%)
Outcome 2: ED physician sonographic assessment of reduction success, compared to radiographic assessment of reduction success by orthopedic surgeon		
	Radiograph: successful reduction	Radiograph: unsuccessful reduction
US: successful reduction	33	4
US: unsuccessful reduction	2	5
Sensitivity 94% (88–98%)	PPV 89% (83–93%)	
Specificity 56% (31–71%)	NPV 71% (40–91%)	

ED = emergency department; US = ultrasound; PPV = positive predictive value; NPV = negative predictive value; 95% confidence (CI) in parentheses.

cess between the two orthopedic surgeons was 78% in the US-guided group and 80% in the control group. The rate of successful reduction was not significantly different for those patients with a pre-reduction assessment of "easy" (87%, 95% CI 74–94%) vs. "difficult" (74%, 95% CI 58–85%).

Of the physicians who performed US-guided fracture reduction, 43/46 (94%) stated that they felt US guidance was helpful in accurately identifying whether a fracture reduction attempt was successful.

Follow-up information was available in 29 patients in the US-guided group and 27 patients in the control group. Nine (31%; 95% CI 17–41%) patients in the US-guided group and 13 (48%; 95% CI 31–66%) patients in the control group required further outpatient operative repair or closed manipulation.

DISCUSSION

We found that the US was highly sensitive for the detection of a successful reduction. The greatest value in US-guided reduction may lie in its ability to provide the practitioner with immediate imaging of bony alignment after each reduction maneuver, therefore decreasing the need for repeat procedural sedations, and removal and reapplication of the splint. In our historical cohort of non-US-guided reduction, 4 patients required a repeat procedural sedation for fracture reduction, whereas none of the US-guided reduction attempts were followed by a repeat procedural sedation. Besides giving the practitioner the ability to see when further reduction maneuvers are required, US-guided reduction also can determine when reduction is ultimately unsuccessful. In the US-guided group, there were 7 patients who, despite multiple maneuvers, were determined sonographically to have an unsuccessful reduction. One patient required a closed reduction, 3 had an ORIF procedure, and 1 had no available records. Two were "false-negatives," with radiographically successful reductions that were deemed unsuccessful by US (Table 2). Neither had any further procedural sedation or reduction attempts. A sonographic determination of a failed reduction, then, correlated well with the need for further manipulation and operative care, without causing unnecessary further procedural sedations.

We also found that physicians using US during the reduction of distal radius fractures had the same rate of successful reduction as a historical cohort without US. Although the use of US may not directly improve the rate of successful reduction, its value may be in helping the emergency physician decide when the reduction procedure is complete, as noted above.

The simplicity of ultrasound-guided fracture reduction is demonstrated by the fact that, despite only brief training, there was a high rate of satisfaction and excellent correlation of post-reduction sonographic findings with radiographic findings. In addition, this high level of success occurred without a significant learning curve, as almost all the US-guided reductions were done by practitioners who had previously done only one or no reductions.

Limitations

The main limitation of our study was that we compared the US-guided group against a historical control group rather than a prospective randomized control group. Although we attempted to construct the control group in a manner to minimize differences, it is likely that the study groups were different to some degree. It is possible that selection bias could have led to fracture types that were easier or more difficult in the ultrasound group. If such a difference existed, it could have affected our results in either direction. However, our detailed pre-reduction assessment suggested that there were no significant differences in the difficulty of reduction between groups.

Second, due to our design limitations, we did not study whether the use of US could decrease the number of radiographs or time spent in the ED. Although these outcomes are of great interest, we could not make meaningful comparisons to a retrospective cohort.

Third, our outcome measure of "successful" reduction was subjective. We attempted to define it in a practical, functional manner, that is, whether blinded orthopedic surgeons thought the fracture required further manipulation. Although imperfect, we believe this was superior to arbitrarily choosing numbers for degrees of post-reduction angulation or displacement.

Fourth, the inclusion of all age groups is problematic because the criteria for "successful reduction" differ by age. In elderly patients, for example, evidence suggests that there is less correlation between radiographic findings and functional outcome (5–7).

Finally, there may be an effect of level of training, or experience with US. Although we standardized the initial training for the physicians involved, our study size was too small to make meaningful subgroup comparisons based on level of training or prior US experience.

CONCLUSION

Whereas US-guided reduction of radius fractures had the same success rate as non-US-guided reduction, it provided the ED physician with visualization of alignment during reduction maneuvers that correlated well with final radiographic alignment, and could be performed with minimal training. Further study is needed to determine whether this approach may reduce the number of radiographs and time spent in the ED.

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ARTICLE SUMMARY

1. Why is this topic important?

Most distal radius fracture reductions are done by emergency physicians without real-time imaging. When post-reduction radiographs demonstrate poor alignment, this often leads to repeated attempts at sedation, reduction, splinting, and radiographs.

2. What does this study attempt to show?

We studied whether real-time ultrasound (US) guidance enables the emergency physician to reliably predict adequate fracture reduction. In addition, we studied whether US-guided reductions had a higher rate of reduction success, compared against a historical cohort of non-US-guided reductions.

3. What are the key findings?

US guidance had a high sensitivity (94%) for detecting adequate fracture reduction. The overall success rate was similar with or without US.

4. How is patient care impacted?

Emergency physicians can use ultrasound guidance to reliably predict satisfactory reduction on post-reduction radiographs. This may be helpful in avoiding repeated attempts at sedation, reduction, and splinting in ED patients with distal radius fractures.