American Journal of Emergency Medicine (2010) **28**, 1002–1008

The American Journal of Emergency Medicine

www.elsevier.com/locate/ajem

Original Contribution

# Ultrasound-guided reduction of distal radius fractures

**Shiang-Hu Ang*, Shu-Woan Lee, Kai-Yet Lam**

*Department of Emergency Medicine, Changi General Hospital, 529889 Singapore*

Received 6 April 2009; revised 28 May 2009; accepted 30 May 2009

**Abstract**

**Introduction:** In our local emergency departments (EDs), manipulation and reduction (M&R) of distal radius fractures are performed by emergency doctors, with blind manual palpation, using postreduction x-rays to assess adequacy. We sought to study the effectiveness of ultrasound guidance in the reduction of distal radius fractures in adult patients presenting to a regional ED.

**Methods:** This was a before-and-after study. Eligible patients were adults older than 21 years who presented to the ED with distal radius fractures that required M&R. Sixty-two patients were prospectively enrolled from October 2007 until June 2008, and they underwent ultrasound-guided M&R. The control group was a retrospective cohort of 102 patients who presented from January to June 2007. They had M&R done using the blind manual palpation method. All M&R procedures were performed by doctors within the ED, and supervision was provided by senior emergency physicians. Ultrasound guidance was performed by the senior emergency physicians.

**Results:** Baseline characteristics between the ultrasound and control groups were similar. The rate of repeat M&R was reduced in the ultrasound group (1.6% vs 8.8%; $P = .056$). The postreduction radiographic indices were similar between the 2 groups, although the ultrasound group had improved volar tilt (mean, 5.93° vs 2.61°; $P = .048$). An incidental finding of a reduced operative rate was also found between the ultrasound and control groups (4.9% vs 16.7%; $P = .02$).

**Conclusion:** Ultrasound guidance is effective and recommended for routine use in the reduction of distal radius fractures.



## 1. Introduction

### 1.1. Background

In Singapore, distal radius fractures are a common presentation in our emergency departments (EDs). Manipulation and reduction of such fractures come under the purview of ED doctors. In the 1-year period from January 1, 2006, until December 31, 2006, 1203 patients presented to our ED with fractures of the forearm (*International Classification of Disease* code 813, fractures of the radius and/or ulnar). About 16% of these patients with distal radius, or distal radius and ulnar fractures, required manipulation and reduction (M&R) before splinting. Locally, the technique for M&R of the distal radius is done with blind manual palpation, with postreduction x-rays as guidance for adequacy. The outcome of those with unsatisfactory reduction may be (1) a repeat M&R with repeat follow-up x-rays, (2) admission to orthopedic surgery for remanipulation in the operating theater under fluoroscopy or for surgical management, and (3) in cases where functional outcome is less of an issue, accepting a suboptimal reduction. Those patients who require repeated M&R represent an additional investment in ED personnel, time, and resources. Based on retrospective data, our ED's repeat M&R rate was

* Corresponding author. Fax: +65 6260 3756.
*E-mail address:* shiang_hu_ang@cgh.com.sg (S.H. Ang).

0735-6757/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.ajem.2009.05.022

approximately 10%. Fluoroscopy has been proposed to guide reduction in the ED [1], but the disadvantages include radiation exposure to both patient and medical personnel, and cost. In addition, fluoroscopy is not routinely available in the local EDs. All local EDs have portable ultrasound machines, and simple 2-dimensional (B-mode) imaging is sufficient in assessing and guiding fracture reduction.

In the pediatric age group, ultrasound has been used to detect long bone fractures [2], as well as to guide their reduction [3,4]. In the adult population, a small study of 27 patients with various forms of distal radius fractures has shown that ultrasound guidance helped achieve anatomic or near anatomic reduction on x-rays [5].

There is currently no known risk with the use of ultrasound. Using ultrasound to guide all distal radius fracture reductions could result in many benefits to patients. These include reduced exposure to radiation from x-rays; reduced repeated M&R attempts, thus reducing need for repeat procedural sedation-analgesia or anesthesia; and overall reduction in procedural time and ED turnaround time.

### 1.2. Study objectives

We aim to answer the following: (1) Can ultrasound guidance be used effectively in aid of reducing the distal radius fracture? We defined effectiveness as reduction or elimination of repeated attempts at M&R, and we sought to achieve more than 50% reduction in our repeat M&R rate. (2) Can ultrasound assess the traditional radiographic indices of adequate fracture reduction and achieve similar or better radiographic indices compared to the traditional method or repeated x-rays?

## 2. Methods

### 2.1. Study design and setting

This is a before-and-after study. The study protocol was approved by our hospital's institutional review board. We sought to compare a prospective cohort of patients in which ultrasound is used to guide fracture reductions, with a retrospective group of patients in which fracture reductions were done with the traditional technique of blind manual palpation without ultrasound guidance. This study was conducted in our ED, which operates within a regional hospital in the eastern part of Singapore. Our ED has an annual census of about 140 000.

### 2.2. Selection of patients

Patients undergoing ultrasound-guided M&R were enrolled over a 9-month period from October 2007 until June 2008 and represent a convenience sample. Eligible patients were prospectively recruited based on the inclusion criteria: (1) adults more than 21 years of age and (2) presenting complaint of an acute distal radius or distal radius and ulnar fracture with significant displacement that requires M&R. The decisions for M&R were left to the discretion of the senior emergency physicians (EPs) based on their assessment of the x-rays, experience, and required functional outcome of the particular patient. Patients with fractures that did not require M&R, or in whom M&R were not done primarily in the ED, were excluded. Initial anteroposterior (AP) and lateral (LAT) wrist x-rays were done at presentation to confirm the fracture, and ultrasound was used to guide fracture reductions in these patients after verbal consent was obtained.

The retrospective control group consisted of patients seen in our ED from January 2007 until June 2007, and the same inclusion and exclusion criteria applied for patient selection. During this period, M&R of distal radius fractures were done with the traditional technique of manual palpation, with postreduction x-rays guiding adequacy. All M&R procedures were performed by the ED doctors, and junior doctors performed most M&Rs under supervision by the attending senior EPs. As with the prospective group, the decision for M&R and the postreduction criteria for adequate reduction were at the discretion of the senior EP.

### 2.3. Physician preparation and training

For this study, ultrasound guidance was performed only by senior EPs. The lead author's experience was gained in a small pilot study of 5 patients done before commencement of the actual study. All other participating senior physicians were taught the technique of using ultrasound guidance via a lecture and an instructional video (available as a resource from the Internet) [6]. Individual technique was honed with one-on-one supervision. We believe such short, focused training is sufficient in equipping our EPs with the skills necessary to perform ultrasound-guided distal radius fracture reduction [7].

### 2.4. Intervention

For our study, distal radius fracture M&R were done under regional anesthesia (Bier block is usually preferred) or procedural sedation-analgesia. The attending ED doctors performed all reduction procedures. These doctors were either junior grade medical officers or senior EPs. Junior doctors were trained in distal radius fracture reduction at the start of their 6 monthly rotations, whereas senior EPs were already trained and experienced in fracture reductions. Junior doctors performed most distal radius fracture M&R under supervision by the senior EPs. Both the prospective and retrospective study periods spanned 2 rotations, so the skill levels of the junior doctors were similar.

Senior EP–performed ultrasound guidance consists of 2 long-axis views 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. During the M&R, ultrasound views could be repeated as often as necessary until the best alignment was obtained (Figs. 1 and 2). A

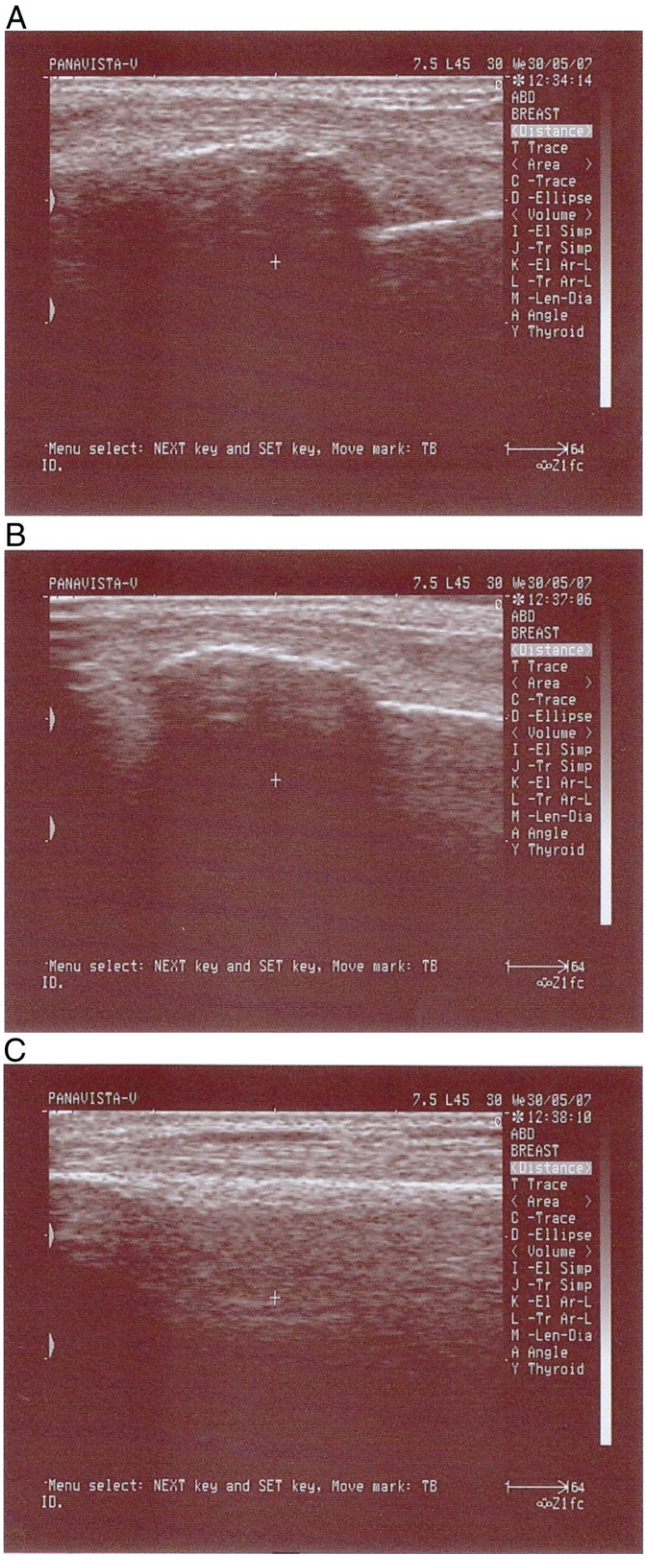


**Fig. 1** Patient X: A, AP long-axis view before reduction; B, in-between reduction; C, postreduction.

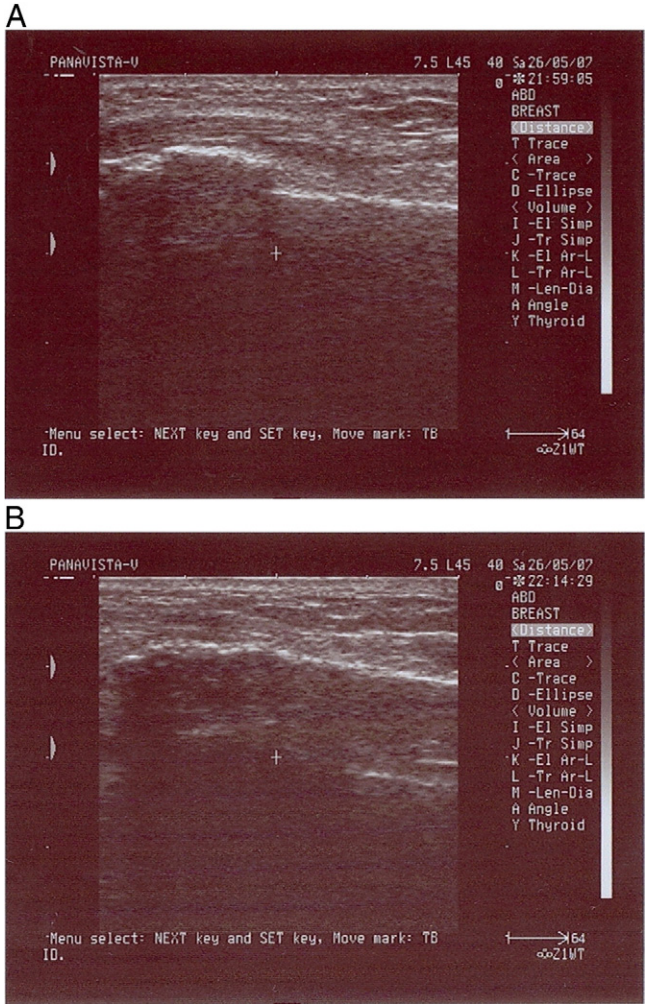


**Fig. 2** Patient X: A, LAT view before reduction; B, postreduction.

satisfactory reduction by ultrasound means aligning the proximal and distal cortices into as straight a line as possible, seen in both AP as well as LAT views. Pre- and postreduction ultrasound images were recorded and printed.

After M&R, AP and LAT follow-up x-rays were done to confirm adequate reduction.

For the purpose of x-ray comparisons in the study, the authors used the following criteria to define anatomical radiographic reduction: (1) normal radial inclination of 15° to 25°, (2) a radial height of at least 5 mm or more, (3) volar/palmar tilt of −10° to +20° (10° volar tilt is normal) [8] (Figs. 3 and 4).

The participating senior EPs were not instructed to perform all M&Rs to achieve anatomical reduction within the criteria as described above. The decision for an adequate reduction was again left to the discretion of the senior EP, and therefore, the postreduction criteria for adequate reduction remain the same as for the indication to M&R. However, if the reduction was deemed inadequate by the senior EP, one or more repeat M&R attempts may be performed. One complete M&R attempt is defined as the M&R procedure itself, application of the plaster splint, and completed


**Fig. 3** Patient X: A, x-ray before M&R; B, x-ray post-M&R.

postreduction x-ray. All patients were either discharged from the ED with an outpatient review at the Orthopaedic clinics or admitted for further treatment. All x-rays were vetted by the senior attending EP, and decisions for hospital admission were also made by the EP. Final decisions for operative or conservative management were made by the attending orthopedic surgeon at either inpatient or outpatient settings.

## 2.5. Data collection and processing

Patient age, sex, handedness, side of fracture, age of fracture, fracture classification, type of analgesia/anesthesia used, performing physician, complications, and patient disposition were entered on a data collection sheet. Pre and post M&R ultrasound images were printed and attached to data collection sheet for review. All x-rays were digitally recorded and saved for review. Review of the ultrasound images, x-rays, and x-ray measurements were carried out by the authors. All patient outcomes were documented via authors' review of ED, inpatient, and outpatient hospital records, with the exception of 2 patients in the control group. One patient went to another country for continuation of care, and one patient went to another local hospital for continuation of care. Distal radius x-rays were classified using a simplified version of the Universal Classification [9].

## 2.6. Primary data analysis

Data analysis was done with SPSS version 12. The $\chi^2$ and Fisher exact tests were used to compare the different rates between groups, and the Student $t$ test was used to compare the difference in means between the groups.

# 3. Results

The ultrasound group consists of 62 patients and the control group 102 patients. Baseline characteristics between the 2 groups were similar (Table 1). The ratio of M&Rs performed by junior doctors vs senior EPs were 83.9% vs 16.1% in the ultrasound group and 73.6% vs 26.4% in the control group, respectively. There was no significant difference ($P = .177$).

In the ultrasound group, only 1 (1.6%) of 62 patients required a repeat M&R attempt compared to the control group (8.8%; $P = .056$) (Table 2).

In this patient, there was difficulty in getting the proximal radius and distal fragment to align; ultrasound showed dorsal displacement of about 3 mm of the distal fragment cortex, and this was shown clearly on the follow-up x-ray. The patient had M&R reattempted as an in-patient, which was

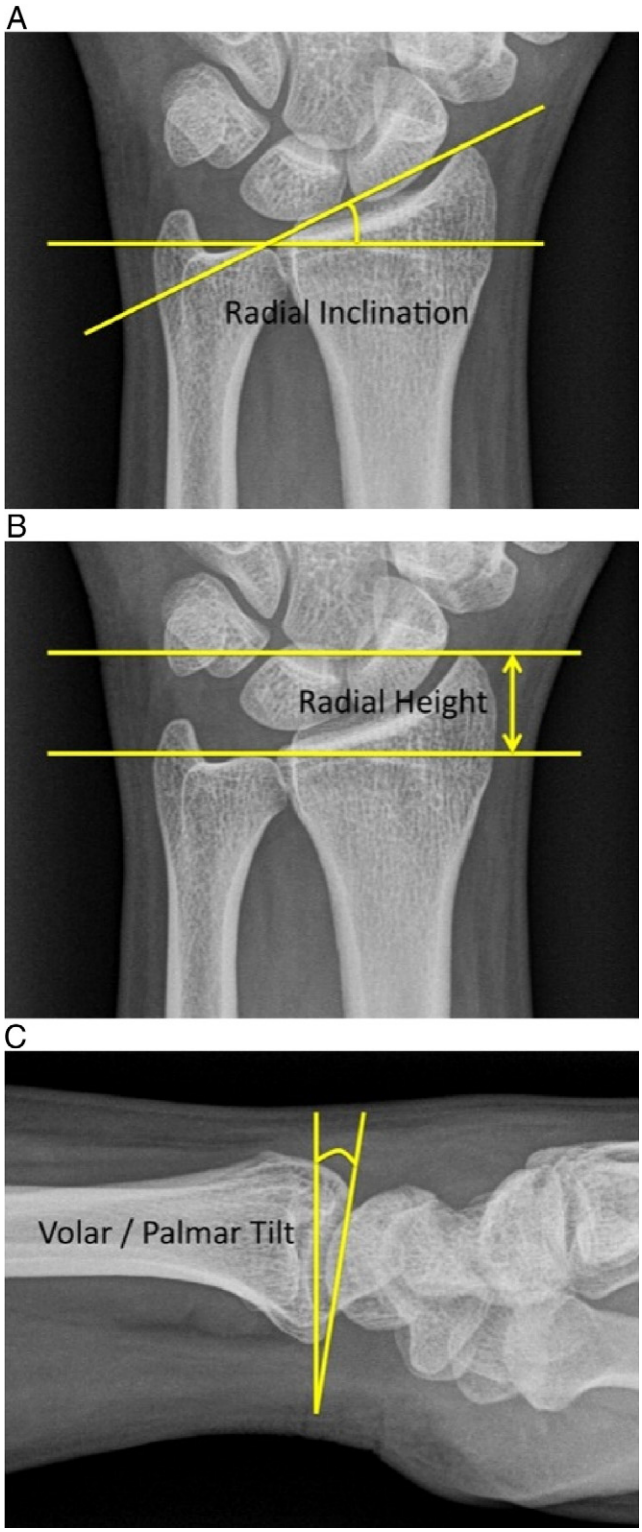


**Fig. 4** A, Radial inclination. B, Radial height. C, Volar tilt.

again unsuccessful, and the patient underwent open reduction and internal fixation.

Of 62 patients from the ultrasound group, 3 (4.9%) ultimately required open reduction and internal fixation for the management of their distal radius fractures, whereas 17 (16.7%) of 102 patients in the control group required open reduction and internal fixation. This was statistically significant with a *P* value of .02 (Table 3).

Next, we looked at the postreduction x-ray characteristics. Comparing the radial inclination, volar tilt and radial height between the 2 groups, both groups had similar overall radiographic indices, the mean of each index lying well within acceptable range. However, the ultrasound group had on average better volar tilt compared with the control group (Table 4).

**Table 1** Baseline characteristics between the ultrasound and control group

| | Ultrasound group, no. (%) | Control group, no. (%) |
|---|---|---|
| Age | | |
| Mean | 61.8 | 61.2 |
| Median | 62.5 | 59.0 |
| Sex | | |
| Male | 18 (29) | 29 (28.4) |
| Female | 44 (71) | 73 (71.6) |
| Side of fracture | | |
| Left | 35 (56.5) | 53 (52) |
| Right | 27 (43.5) | 49 (48) |
| Age of fracture | | |
| < 1 day | 56 (90.3) | 86 (84.3) |
| >1 to <5 days | 5 (8.1) | 12 (11.8) |
| >5 days | 1 (1.6) | 4 (3.9) |
| Fracture classification (universal) | | |
| Class II (extra-articular, displaced) | 43 (69.4) | 73 (71.6) |
| Class IV (intra-articular, displaced) | 19 (30.6) | 29 (28.4) |
| Anesthesia | | |
| Regional (Bier block) | 57 (91.9) | 92 (90.2) |
| Procedural sedation | 2 (3.2) | 4 (3.9) |
| Regional + Parenteral analgesia | 3 (4.8) | 4 (3.9) |
| Regional + Procedural sedation | 0 | 2 (2.0) |
| Physicians who performed the M&R | | |
| Junior physicians | 52 (83.9) | 75 (73.6) |
| Senior EPs | 10 (16.1) | 27 (26.4) |

**Table 2** Comparing rates of M&R

| No. of attempts at M&R | Ultrasound group, no. (%) | Control group, no. (%) | *P* |
|---|---|---|---|
| One attempt | 61 (98.4) | 93 (91.2) | .056 |
| More than one attempt (in the ED or during hospital admission) | 1 (1.6) | 9 (8.8) | |

**Table 3** Comparing rates of surgical intervention

| Rate of ORIF | Ultrasound group, no. (%) | Control group, no. (%) | *P* |
|---|---|---|---|
| No. of patients requiring ORIF | 3 (4.9) | 17 (16.7) | .019 |
| No. of patients not requiring ORIF | 59 (95.1) | 85 (83.3) | |

ORIF indicates open reduction and internal fixation.

### 3.1. Limitations

In a preliminary review of our ED's retrospective data, our repeat M&R rate was approximately 10%. To test a difference of more than 5%, a single-tail study with a power of 90% would require a sample size of 96 patients. Our study was stopped after recruiting 62 patients. The reduced numbers were due to the following reasons: (1) we had exceeded the proposed time frame of the study and (2) eligible cases not recruited due to lack of resources. We have only one ultrasound machine; in busy periods, priority of machine use was given to patients with major trauma or illness. At these times, EPs usually fall back to using blind manual palpation rather than wait for ultrasound availability. An interim analysis has shown that we had already achieved our target reduction of more than 50% in the repeat M&R rate (8.8% to 1.6%), in spite of a reduced sample size. Although anatomical radiographic reduction was defined, we left it to the discretion of the senior EP to determine acceptability of reduction. No attempt was made to measure interrater reliability of their assessments. This model best fits the practice that was carried out in the retrospective cohort and would help reduce intervention bias in the prospective cohort that underwent ultrasound-guided M&R.

## 4. Discussion

In our study, we have shown that with the use of ultrasound guidance, repeated attempts at M&R were significantly reduced. Although postreduction x-ray characteristics between the 2 groups were similar, a better overall volar tilt was achieved in the ultrasound group. Restoring the volar angle itself has been shown to reduce radial shortening, independent of other indices [10]. Obviously, ultrasound cannot directly measure radial height, radial inclination, or volar tilt, but alignment of the distal and proximal bony fragments of the radius in 2 planes is a sufficient surrogate index. Reduction based on the 2 basic types of displacements (radial and dorsal) has also been shown to result in satisfactory reduction [10]. Of note, visual judgment of bony alignment on the ultrasound screen is enough, and no measurements need be made on the ultrasound images. Another advantage of ultrasound guidance over blind manual reduction is that swelling of the fracture site is often encountered, and this decreases sensitivity of palpation. Ultrasound then gives immediate visual feedback on bony alignment.

If the ultrasound images show good alignment, it may even be possible to cut out the postreduction x-rays and only have the x-rays done upon review in the fracture clinic (usually at 1 week). However, a possible concern is that after application of plaster splint, the window for ultrasound beam is lost. In the uncommon event that the distal fragment slips during the application of the splint (either through inadequate traction or excessive movement), only x-rays can identify such occurrences. In this case, fluoroscopy is superior. Fortunately, this was not a problem encountered in our study. Another possible approach is using ultrasound alone to detect and assess distal radius fractures, guide its reduction, and then have the postreduction x-rays done.

Although this article did not set out to achieve a reduction in the rate of open reduction and internal fixation as one of its primary objectives, it was nevertheless an interesting observation made during the study. Three patients from the ultrasound group required open reduction and internal fixation: one of them had M&R repeated (see above); 2 other patients had only one M&R attempt, but the senior EPs felt the fractures were unstable and patients were admitted for open reduction and internal fixation. All 3 patients had intra-articular (class IV) distal radius fractures. Seventeen patients from the control group underwent open reduction and internal fixation. Only 1 of 17 patients had a repeated M&R attempt, which was still unsatisfactory postreduction; 8 of them had extra-articular fractures (class II), and 9 of them had intra-articular fractures (class IV). Because decisions for open reduction and internal fixation will depend on several factors, the attending orthopedic surgeon, desired functional outcome of the patient and other patient factors like comorbidities and fitness for surgery. At this point, we do not conclude that ultrasound guidance will lead to a reduced operative rate.

**Table 4** Comparing radial inclination, volar tilt, and radial height between ultrasound and control groups

| Radiographic measurements | Ultrasound group, mean (SD) | Control group, mean (SD) | Mean difference (95% confidence interval) | *t* test |
|---|---|---|---|---|
| Radial inclination (°) | 19.42 (4.83) | 20.21 (5.15) | 0.79 (−0.80 to 2.39) | 0.330 |
| Palmar/Volar tilt (°) | 5.93 (9.62) | 2.61 (10.71) | 3.31 (0.34 to 6.59) | 0.048 |
| Radial height (mm) | 9.09 (3.38) | 10.00 (3.43) | 0.92 (−0.16 to 2.01) | 0.096 |

## 5. Conclusion

Soft tissue ultrasound has seen wide spread applications in the ED, and using ultrasound to guide fracture reductions is but one good example. Ultrasound-guided M&R is effective, reduces repeated M&R attempts, and should be used routinely in distal radius fracture reduction.

## References

[1] Lee SMK, et al. Safety and effectiveness of portable fluoroscopy in the emergency department for the management of distal extremity fractures. Ann Emerg Med 1994;24:725-30.
[2] Hubner U, et al. Ultrasound in the diagnosis of fractures in children. Br Editor Soc Bone Joint Surg 2000;82-B(8):1170-3.
[3] Durston W, et al. Ultrasound guided reduction of pediatric forearm fractures in the ED. Am J Emerg Med 2000;18:72-7.
[4] Chen L, et al. Diagnosis and guided reduction of forearm fractures in children using bedside ultrasound. Pediatr Emerg Care 2007;23(8): 528-31.
[5] Chern TC, et al. Sonography for monitoring closed reduction of displaced extra-articular distal radial fractures. J Bone Joint Surg 2002;84-A(2):194-203.
[6] Video courtesy of HCMC Department of Emergency Medicine. Website, http://www.hqmeded.com/blogs/page5/page5.html.
[7] Marshburn TH, et al. Goal-directed ultrasound in the detection of long-bone fractures. J Trauma 2004;57:329-32.
[8] Jaremko JL, et al. Do radiographic indices of distal radius fracture reduction predict outcomes in older adults receiving conservative treatment? Clin Radiol 2007;62:65-72.
[9] Cooney WP. Fractures of the distal radius. A modern treatment based classification. Orthop Clin North Am 1993;24(2):211-6.
[10] van der Linden W, Ericson R. Colle's fracture. How should its displacement be measured and how should it be immobilised. J Bone Joint Surg Am 1981;63:1285-8.