SCIENTIFIC ARTICLE

Ultrasound-Assisted Closed Reduction of Distal Radius Fractures

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Purpose To assess the accuracy and ability of ultrasound for monitoring closed reduction for distal radius fractures.

Methods Consecutive patients undergoing ultrasound-guided closed reduction of acute, displaced distal radius fractures between January 2003 and December 2006 at our department were enrolled. The control group was extracted from patients who underwent a closed reduction for similar fractures under fluoroscopy or without any imaging assistance. To confirm the accuracy of the ultrasonography measurements, displacement distance values were compared with those on radiographic imaging before and after reduction. X-ray parameters for pre- and postreduction, reduction time, total cost, and success rate were compared between the ultrasound-guided and the control groups.

Results The ultrasound-guided group consisted of 43 patients (mean age, 68 y) and the control group consisted of 57 patients, which included 35 patients (mean age, 74 y) with fluoroscopic reduction and of 22 patients (mean age, 72 y) with reduction unaided by imaging. There were no significant displacement differences between radiographic and ultrasound measurements. In x-ray parameters for pre- and postreduction, there were no significant differences between the 2 groups. Ultrasound-guided reduction took longer than the other 2 methods. The success rate of the ultrasound and the fluoroscopic groups were similar (95% and 94%, respectively).

Conclusions Our data suggest that ultrasound assistance can aid reduction of distal radius fractures as well as fluoroscopy. *(J Hand Surg Am. 2014;■:■−■. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic II.

Key words Ultrasound examination, distal radius fracture, closed reduction, conservative treatment.

Management of a distal radius fracture, one of the most common fractures encountered by orthopedic surgeons, is extremely variable and includes both surgical and nonsurgical treatment options.[1–3] Although recent development of volar locking plates for unstable or comminuted fractures has widened the surgical indications for internal fixation,[4,5] conservative treatment with closed reduction and cast immobilization remains the most common form of definitive treatment.[6,7] In addition, even when a distal radius fracture requires surgery, successful initial closed reduction and cast immobilization is important to reduce pain and swelling. Thus, accurate primary reduction is valuable for management of a distal radius fracture and essential in nonsurgical cases.

Displaced distal radius fractures are usually managed with closed reduction by manual manipulation or finger

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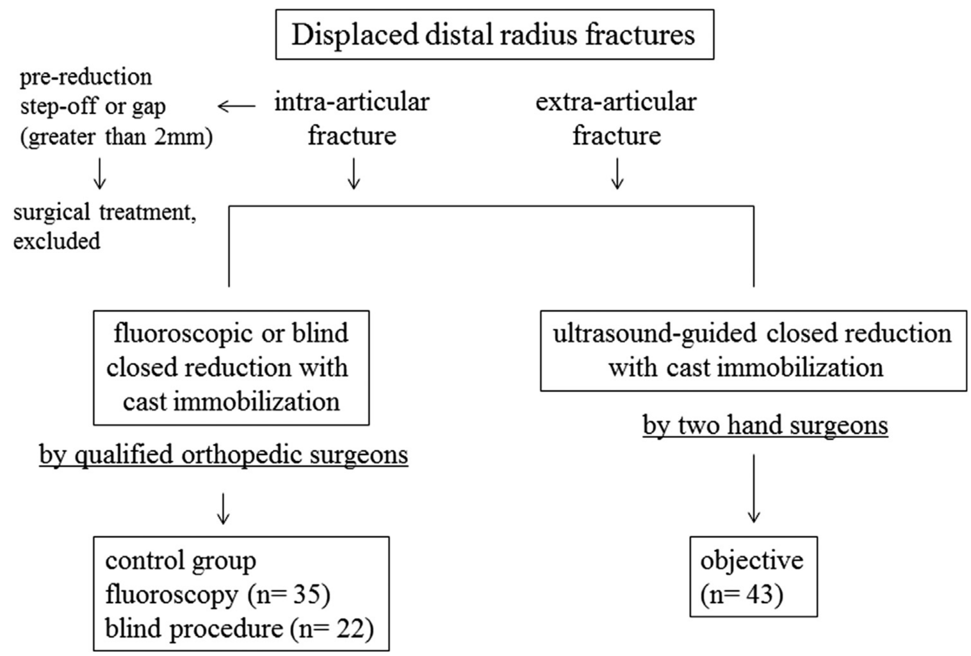

FIGURE 1: Flowchart representing patient selection. Patients requiring surgical treatment with intra-articular stepoff or gapping (> 2 mm) were excluded. Only cases treated conservatively with cast immobilization were included in this study. The significant displacement was defined as radial shortening > 2 mm, volar tilt < −5°.

trap traction under blind manual palpation or fluoroscopic guidance. Postmanipulation radiographs are then obtained to assess the adequacy of the reduction.[8] However, multiple inadequate reductions under blind manipulation can result in prolonged anesthesia time, increased radiation exposure, and patient discomfort.[9]

Ultrasound examination is widely available in many departments and provides dynamic images in real time. In addition, this method can be easily used in both emergency room and outpatient settings. Recent reports have noted that ultrasound is increasingly used for the detection and management of hand injuries.[10,11] However, few studies have examined ultrasound-guided reduction of displaced distal radius fractures.[12–14]

The purpose of our study was to assess the accuracy of ultrasound in monitoring closed reduction of distal radius fractures.

MATERIALS AND METHODS

Patients

This was a prospective study of a group of patients in whom ultrasound was used to monitor the closed reduction of distal radius fractures and compared with a retrospective control group in whom fracture reduction was performed under fluoroscopic guidance or unassisted by imaging. The present study was undertaken after receiving approval from our institutional review board. Consecutive patients undergoing ultrasound-guided closed reduction of an acute displaced distal radius fracture between January 2003 and December 2006 at our department were enrolled. Adults older than 18 years with displaced distal radius fractures requiring closed reduction were prospectively recruited. The decisions regarding major displacement of each fracture and requirement for closed reduction were made by 2 hand surgeons (N.K. and Y.T.) in our department, both of whom were qualified by the Japanese Society for Surgery of the Hand. Major displacement was defined as radial shortening greater than 2 mm and volar tilt less than -5°. Only cases treated conservatively with cast immobilization were included in this study. In addition, patients with prereduction intra-articular stepoff or gapping greater than 2 mm were excluded. The retrospective control group was extracted from patients who underwent a closed reduction for a similar fracture during the same time period under fluoroscopic guidance or without imaging assistance. All procedures in the control group were performed by orthopedic surgeons (not hand surgeons) qualified by the Japanese Orthopaedic Association. The flowchart representing patient selection is shown in Figure 1.

Methods

All ultrasound-guided closed reduction procedures were performed on an acute displaced distal radius fracture by the 2 hand surgeons (N.K. and Y.T.) in

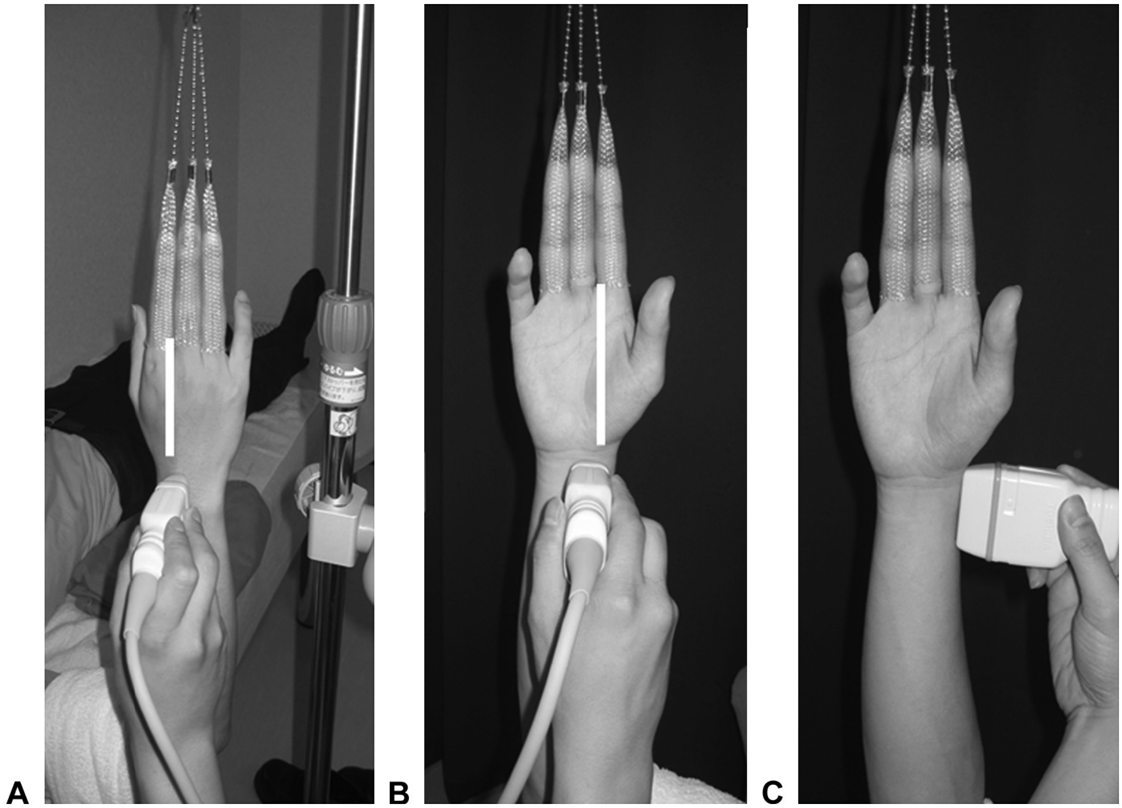

FIGURE 2: Ultrasound-guided reduction of a distal radius fracture. The probe was strictly oriented perpendicular to the longitudinal axis between the index and middle finger in the dorsal **A** and palmar **B** sites and placed perpendicular to the snuffbox in the radial site **C**. The white line shows the longitudinal axis between the index and middle finger.

our department who made the treatment decisions. They were trained to use the 7.5- to 10-MHz linear array ultrasound probe to examine the fracture site by orienting the probe along the longitudinal plane on the dorsal, palmar, and radial aspects of the radius based on the past reports (Fig. 2).[12,13] The present study was begun after each surgeon had performed more than 10 cases of closed reduction with ultrasound monitoring.

Ultrasound-guided closed reduction of displaced distal radius fractures

Posteroanterior and lateral radiographs were initially taken. In the outpatient clinic or emergency room, a closed reduction procedure was performed for displaced distal radius fractures under Bier block anesthesia with 15 to 20 mL of 1% lidocaine or local anesthesia with a hematoma block (injection of 5−10 mL of 1% procaine into the hematoma around the fracture site under ultrasound control). After anesthesia, the condition of the fracture site was initially examined under ultrasound monitoring with an Aloka SSD-500 (Aloka Co, Tokyo, Japan) real-time scanner equipped with a 7.5- to 10-MHz linear array transducer. Three plain views of the dorsal, palmar, and radial sites before reduction were delineated during the ultrasound examination. In order to precisely represent the condition of the fracture, the probe was strictly oriented perpendicular to the longitudinal axis between the index and the middle finger on the dorsal and palmar sites and was placed perpendicular to the snuffbox on the radial site (Fig. 2). The alignment of the fracture was shown by the ultrasound reflection from the dorsal, volar, and radial cortical surfaces of the radius and carpal bones (Figs. 3−5). Next, the fracture was reduced by Chinese finger-trap traction with additional manual manipulation. The fracture condition was evaluated in real time under ultrasound examination during the reduction. During the reduction procedure, the ultrasound view could be repeated as often as necessary until acceptable alignment was obtained. Acceptable alignment as viewed by ultrasound was defined as aligning the proximal and distal bone cortex into as straight a line as possible. When acceptable alignment was obtained, external immobilization was performed using sugar-tong orthosis or short-arm casting. Pre- and postreduction ultrasound images were recorded and printed. After immobilization, a follow-up

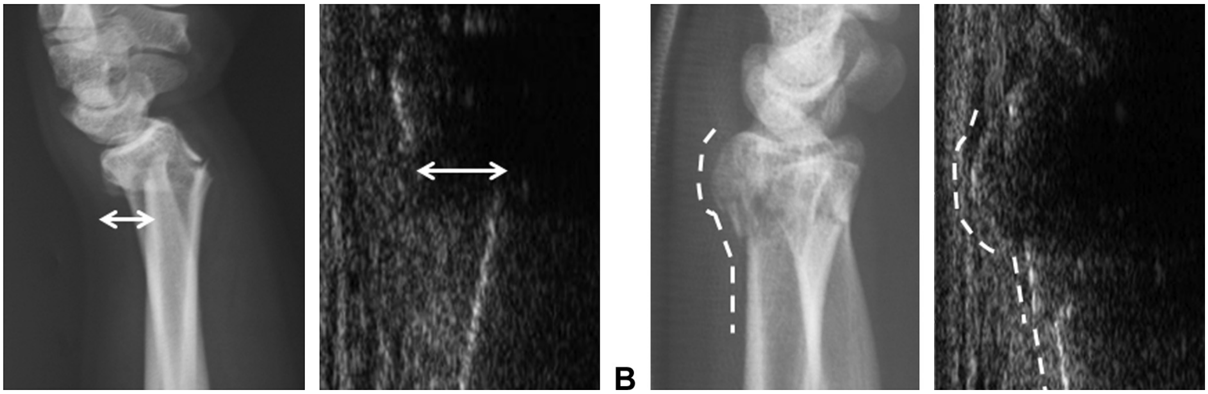

FIGURE 3: Radiographic and ultrasound views of the dorsal site of the fracture. **A** Prereduction. The white arrow shows the displacement distance of the dorsal site. **B** Postreduction. The dotted white line shows alignment of the dorsal cortex.

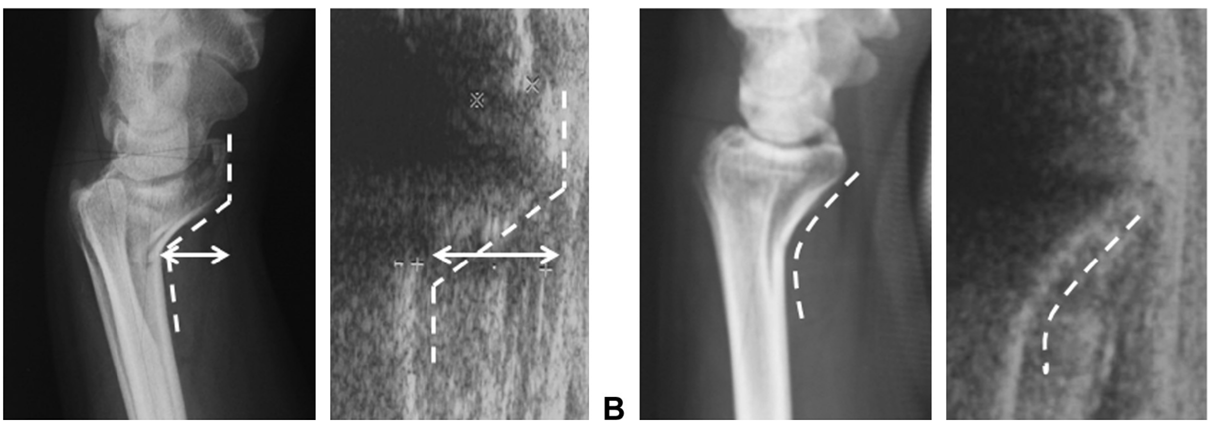

FIGURE 4: Radiographic and ultrasound views of the volar site of the fracture. **A** Prereduction. The white arrow shows the displacement distance of the volar site. **B** Postreduction. The dotted white line shows alignment of the volar cortex.

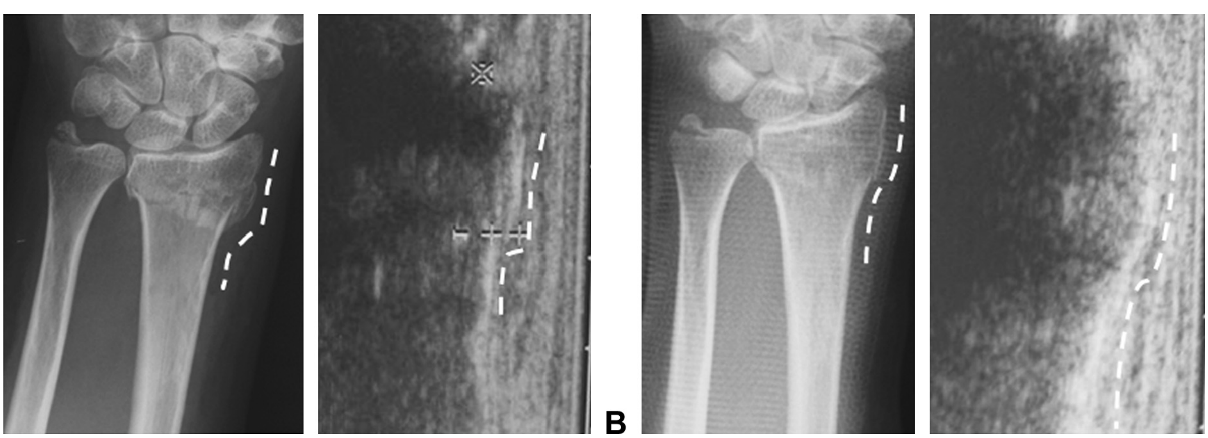

FIGURE 5: Radiographic and ultrasound views of the radial site of the fracture. **A** Prereduction. **B** Postreduction. The dotted white line shows alignment of the radial cortex.

plain radiograph was taken in the posteroanterior and lateral views to confirm adequate reduction.

Evaluation of ultrasonography measurements

In order to confirm the accuracy of the ultrasonographic measurements, displacement distance values obtained with volar, dorsal, and radial ultrasound views were compared with those on the radiographic images before and after reduction. Prereduction characteristics and x-ray parameters for pre- and postreduction were compared among the 3 groups: the ultrasound-guided, fluoroscopic, and non–image-assisted reduction groups.

TABLE 1. Prereduction Patient Characteristics

Prereduction Characteristics	Ultrasound Group (n = 43)	Fluoroscopy Group (n = 35)	Image-Unassisted Group (n = 22)*
Age (y), mean (range)†	68 (30−92)	74 (23−93)	72 (27−89)
Sex			
Male	11	5	4
Female	32	30	18
Side of fractures			
Right/left	15/28	18/17	12/10
AO classification	A2:10, A3:24 B2:1 C2:5, C3:3	A2:8, A3:20 C1:1, C2:4, C3:2	A2:6, A3:13 C1:2, C2:1
X-ray parameters†			
VT (°)‡	−16 ± 10	−17 ± 7	−18 ± 5
RI (°)‡	14 ± 5	14 ± 4	14 ± 5
RS (mm)‡	5 ± 2	5 ± 2	5 ± 2

RI, radial inclination; RS, radial shortening; VT, volar tilt.
*Image-unassisted: closed reduction without any imaging assistance.
†There were no significant differences among the 3 groups in age and x-ray parameters.
‡The values are given as mean and SD.

TABLE 2. Ultrasound and Radiographic Measurement of Displacement Distances Before Reduction and Immediately After Closed Reduction

	Before Reduction			After Reduction		
	Ultrasound	Radiography	Statistics	Ultrasound	Radiography	Statistics
Dorsal displacement (mm)*	4.2 ± 3.4	4.4 ± 3.6	P = .86 NS	1.6 ± 1.9	1.6 ± 2.2	P = .82 NS
Volar displacement (mm)*	2.4 ± 1.5	2.5 ± 1.8	P = .73 NS	0.7 ± 0.8	0.9 ± 1.0	P = .54 NS
Radial displacement (mm)*	2.0 ± 1.4	2.1 ± 1.7	P = .76 NS	0.2 ± 0.3	0.2 ± 0.4	P = .85 NS

NS, not significant ($P < .05$).
*The values are given as mean and SD.

The x-ray parameters for pre- and postreduction included volar tilt, radial shortening, and radial inclination. Reduction time (from anesthesia to cast immobilization); total cost (which included pre- and postreduction posteroanterior and lateral x-rays, closed reduction, and cast immobilization); and successful reduction rate were compared among the 3 groups. The criteria for successful reduction were defined as radial shortening less than 1 mm and volar tilt of 0° or greater when reviewing postreduction radiographs.

Statistical analysis

Data are shown as the mean and SD. Statistical analyses for significance were performed using Student *t*-tests for unpaired continuous variables and multiple comparison test. The level of significance was set at *P* less than .05.

RESULTS

Prereduction characteristics are listed in Table 1. There were no significant differences between the groups in regard to age and x-ray parameters.

The accuracy of ultrasonography measurements are demonstrated in Tables 2 and 3. Table 2 presents the displacement distances of the distal radius fractures measured by radiography and ultrasonography, which were determined from the dorsal, volar, and radial views before and immediately after reduction.

TABLE 3. Comparison of X-Ray Parameters Between Ultrasound and Control Groups Before Reduction and Immediately After Closed Reduction

	Before Reduction				After Reduction			
X-Ray Parameters	Ultrasound Group	Fluoroscopy Group	Blind Procedure Group*	Statistics	Ultrasound Group	Fluoroscopy Group	Blind Procedure Group*	Statistics
Volar tilt (°)†	−16 ± 10	−17 ± 7	−18 ± 5	P = .71 NS	5 ± 6	5 ± 3	5 ± 4	P = .99 NS
Radial inclination (°)†	14 ± 5	14 ± 4	14 ± 5	P = .96 NS	16 ± 4	18 ± 3	18 ± 4	P = .53 NS
Radial shortening (mm)†	5 ± 2	5 ± 2	5 ± 2	P = .78 NS	0.9 ± 0.9	0.5 ± 0.4	0.8 ± 0.8	P = .18 NS

NS, not significant (P <.05).
*Blind procedure: closed reduction without any imaging assistance.
†The values are given as mean and SD.

TABLE 4. Comparison of Time for Closed Reduction, Total Cost, and Success Rates for Closed Reduction Among the 3 Groups

	Ultrasound Group (n = 43)	Fluoroscopy Group (n = 35)	Blind Procedure Group (n = 22)
Time (min)*	18 (11−21)	14 (10−18)	10 (5−12)
Cost†	$371	$382	$337
Success rate (%) (cases)‡	95 (41/43)	94 (33/35)	68 (15/22)

*Time (mean, range): time for closed reduction from anesthesia to cast immobilization.
†Cost: total cost of pre- and postreduction x-rays, closed reduction under each procedure, and cast immobilization. (Exchange rate, $1.00 = 102 yen.)
‡Success rate: successful reduction criteria were defined as radial shortening, < 1 mm; volar tilt ≥ 0°.

No significant differences were found between the groups. X-ray parameters (volar tilt, radial inclination, and radial shortening) improved significantly between pre- and postreduction in 3 groups (Table 3). There were no significant differences between the groups in any of the 3 parameters, which were measured before and immediately after reduction.

Reduction time, total cost, and successful reduction rate of the 3 groups are shown in Table 4. Ultrasound-guided reduction took the longest time, and image-unassisted closed reduction took the shortest time. The cost included the pre- and postreduction x-rays (US $44, exchange rate, US $1.00 = 102 yen), closed reduction under fluoroscopy/ultrasound/image-unassisted procedure ($220/$209/$175), and cast immobilization ($118). Fluoroscopic reduction cost the most ($382), and image-unassisted closed reduction cost the least ($337). Ultrasound guided-reduction cost $371. The success rate of the ultrasound group was 95%. Although the ultrasound views showed good alignment, 2 of the 43 cases (5%) had an unsuccessful x-ray reduction. The success rate for the fluoroscopic group was 94% and for the image-unassisted group was 68%.

DISCUSSION

Most patients with a displaced distal radius fracture are initially managed with closed reduction under fluoroscopy or without imaging assistance in the emergency room.[8,15] Even when surgery is indicated, a closed reduction is often performed to reduce pain and swelling. However, these methods have some problems. Fluoroscopy is not immediately available in the emergency room in Japan and many other countries. The patient and physician are exposed to radiation with its use. Although minifluoroscopy units avoid these disadvantages, most emergency departments do not own the units. In contrast, imaged-unassisted closed manipulation can include repeated efforts and multiple postmanipulation radiographs. This increases patient discomfort, treatment time in the emergency room, and radiation exposure. Thus, we considered it important to find another procedure for

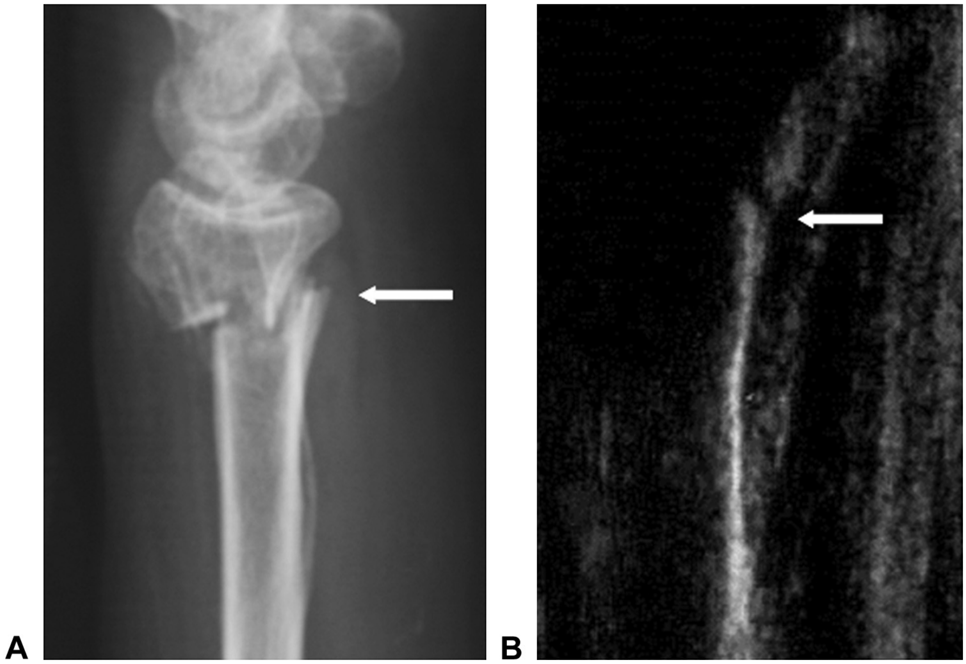

FIGURE 6: Inconsistencies between radiographic and ultrasound views. The white arrows reveal that the cortical discontinuity of the fracture site **A** sometimes appears to have good alignment in the ultrasound view **B**.

visualizing closed reduction of a displaced distal radius fracture.

Ultrasound examination is typically used to evaluate soft tissue conditions in orthopedics. However, bone alignment is also easily represented, because bone has high impedance and reflects strong echoic signals. Superficial bone is notably illustrated with this method. Previous studies have reported the ultrasound visualization of rib and orbital floor fractures.[16,17] Jenkins and Thuau[17] reported that ultrasound detected the presence of an orbital floor fracture with an overall accuracy of 86% and a sensitivity of 85% compared with computed tomography or direct surgical exploration of the orbital floor. Senall et al[18] reported that ultrasound was effective for early diagnosis of scaphoid fractures with a sensitivity of 78% and specificity of 89%. Conversely, there are few reports about ultrasound-guided reduction for distal radius fractures. Chern et al[13] reported the usefulness of ultrasonographic monitoring of 27 wrists with extra-articular distal radius fractures. Chinnock et al[12] reported that ultrasound examination was highly sensitive in detecting of a successful reduction when used in the emergency department. However, they did not address the pitfalls of ultrasound-guided reduction, and they did not compare this procedure with fluoroscopic control or image-unassisted reduction in detail.

This procedure of ultrasound monitoring for closed reduction of distal radius fractures has several advantages. The ability to assess fracture condition in multiple planes is as good as fluoroscopic examination. The examiners and patients are not exposed to x-rays. Furthermore, the closed reduction procedure can be performed in the outpatient clinic or the emergency room rapidly and easily. Ultrasound examination can be used to evaluate not only bone alignment but also soft tissue injuries, such as tendon injury and hematoma accompanying such fractures. Ultrasound is also slightly cheaper than fluoroscopy in Japan.

Ultrasound examination also has some disadvantages because of its inability to penetrate bone. The articular surface cannot be visualized, so any stepoff or gap in the radial articular surface cannot be evaluated. Consequently, ultrasound-guided reduction is most useful for extra-articular fractures. However, we often have cases managed conservatively even with stepoff and gap of 1 to 2 mm, even when the fracture type is AO C type. Thus, conservative treatment with initial closed reduction is also important for AO C type fractures. In addition, ultrasonography is potentially unable to present the 3-dimensional assessment available with fluoroscopy, meaning that it is unable to directly measure radial shortening, radial inclination, and volar tilt. Although the ultrasound images arrange the contours of the distal radius on the volar, dorsal, and radial surfaces, aligning the 3 surfaces visualized in ultrasound images can lead to improvements in the radiographic parameters, achieving a reasonable reduction of the articular surface. However, slight displacement on the radiographic image is sometimes difficult to represent by ultrasonography because of artifacts. It is therefore necessary to consider the pitfall that inadequate reduction may occur even when the ultrasound view shows good alignment in some cases (Fig. 6). Bone alignment using ultrasound may look collinear when the distal and proximal cortices overlap. In our study, 2 of the 43 cases in the ultrasound group had an unsuccessful reduction. These results could presumably be operator dependent or related to the position of the transducer. We advise repeat, careful examinations with ultrasound to properly reduce the fractures.

Our study has some limitations. We investigated the accuracy of ultrasound-guided reduction prospectively on 43 consecutive patients compared with a retrospective control group who underwent the procedure under fluoroscopy or without imaging assistance. An ideal study would be prospective and randomized to compare ultrasound, fluoroscopy, and image-unassisted procedures. Furthermore, only 2 hand surgeons (N.K. and Y.T.) performed the ultrasound examinations in the present study. To standardize this procedure, additional physicians should participate after receiving training in performing ultrasound-assisted closed reduction. In future, we will study these meaningful comparisons based on the level of training and prior ultrasound examination experience of the attending physicians.

Although ultrasound-guided reduction took longer than fluoroscopic or image-unassisted procedures, it was easy to perform and generally presented clear images of the fracture condition in real time and in a dynamic manner. Our practitioners experienced no problem with the learning curve of the ultrasound examination technique, and we consider that all physicians can become proficient with their own wrists after only several sessions. Although ultrasound cannot directly measure the same parameters as x-ray images, real-time images showing alignment of the distal and proximal bony fragments in 3 planes provided a sufficient surrogate index. The excellent correlation of postreduction ultrasound findings with radiographic findings allows us to recommend that this procedure should be considered for real-time monitoring of the closed reduction of distal radius fractures.

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