Sonography for Monitoring Closed Reduction of Displaced Extra-Articular Distal Radial Fractures

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**Background:** Closed reduction and cast immobilization are employed in the primary treatment of most distal radial fractures, and conventional radiographic techniques have been essential and effective in monitoring these reductions. Radiation-free ultrasonography, however, can provide both real-time and dynamic multiple-plane images with a small and simple-to-use transducer that can be operated with only one hand. We therefore wanted to see if the real-time and dynamic multiple-plane observation capabilities of ultrasonography would allow an orthopaedic surgeon to perform a closed reduction without multiple attempts, as are frequently required when only conventional radiographic techniques are used.

**Methods:** Sonographically guided closed reduction was performed in twenty-seven consecutive wrists with an acute distal radial fracture. The efficacy of this method was evaluated and compared with that of conventional radiographic techniques.

**Results:** The sonographic images delineated the fractures as accurately as did the conventional radiographs. All parameters measured on the sonograms and radiographs showed substantial restoration of anatomic alignment after reduction, and all measurements were similar on the two types of images.

**Conclusions:** Sonographically guided monitoring compared well with conventional radiographic techniques during closed reduction of extra-articular distal radial fractures. Sonography is an accurate, simple, and radiation-free tool that provides the substantial benefits of dynamic multiple-plane and real-time observation.

Distal radial fracture is one of the most common injuries treated by orthopaedic surgeons, and one-sixth of all fractures encountered in emergency rooms involve the distal part of the radius. Although various surgical treatments of unstable, comminuted distal radial fractures have demonstrated satisfactory results, closed reduction and cast immobilization has remained the standard for most relatively low-energy fractures. Even when a distal radial fracture requires surgery, a successful initial closed reduction is valuable for controlling pain before the surgery and for facilitating the open reduction. Therefore, accurate primary closed reduction of a distal radial fracture is an important orthopaedic procedure, and an effective technique for monitoring the reduction is needed. Postoperative radiography (and, where available, intraoperative fluoroscopy) is essential for evaluation of closed reduction of all fractures, including distal radial fractures. For the past fifteen to twenty years, fluoroscopic technology (available in the United States and, to a limited extent, in the developing world) has provided high-resolution real-time images and low radiation levels while allowing the surgeon to monitor the reduction process. Radiation-free ultrasonography, however, is widely available and can provide both real-time and dynamic multiple-plane images with a small and simple-to-use transducer that can be operated with only one hand, a major advantage in the acute trauma setting. Sonography has traditionally been used to evaluate soft tissue because bone is a natural barrier to echo. However, because bone has high impedance and reflects strong echoic signals, sonography can clearly illustrate bone alignment. It can also provide continuous information that will allow the surgeon to monitor the reduction in real time.
In this prospective study, we attempted to determine whether the real-time and dynamic multiple-plane observation capabilities of ultrasonography would allow an orthopaedic surgeon to perform a closed reduction without multiple attempts, as are frequently needed when only conventional radiographic techniques are employed. We also evaluated the reliability and accuracy of sonography in comparison with that of conventional radiography.

Materials and Methods

Sonographic monitoring was performed on twenty-seven wrists with an acute displaced distal radial fracture in twenty-five consecutive patients (fourteen male and eleven female) ranging in age from eight to eighty-six years (median age, 48.4 years). All patients underwent immediate closed reduction and cast immobilization between December 1999 and April 2000 in the emergency center of our hospital. These re-
ductions and sonographic monitoring procedures were performed by a qualified orthopaedic surgeon (T.-C.C. or I-M.J.) with the assistance of a resident. Sixteen patients sustained the injury when they stumbled, slipped, or fell; five, in a traffic accident; and four, in a sports accident.

All fractures were classified, with use of the Frykman and AO/ASIF systems, on posteroanterior and lateral radiographs of the wrist made before and after the reduction. There were six Frykman type-I fractures, thirteen type-II, two type-V, five type-VII, and one type-VIII. According to the AO/ASIF classification, fifteen fractures were type A2, six were type A3, two were type B3, and four were type C1. In summary, there were twenty-one displaced extra-articular fractures, four displaced extra-articular and nondisplaced intra-articular fractures, and two displaced intra-articular fractures. Fractures were defined as displaced when there was >3 mm of radial shortening, dorsal or volar angulation, or >2 mm of radial displacement of the distal fragments. We did not perform any detailed bone-mineral assessment, but on the basis of the demographic information and plain radiographs we believed that fourteen patients had a fracture in osteoporotic bone.

Reduction and Immobilization Procedure

The reduction was performed with use of established procedures. Briefly, patients were in a supine position under local anesthesia or under anesthesia induced with intravenous methohexital (Brevital; Eli Lilly, Indianapolis, Indiana; 1 mg/kg). There were some minor variations in the reduction technique, but in general we used traction on the fingers and continuous countertraction on the arm with the elbow flexed 90°. The wrist was then carefully manipulated while the manipulation was monitored sonographically. When a patient had a
severely displaced fracture, we released the traction and manipulated the wrist and forearm, using sonographic monitoring to help us to find the best position for alignment of the fracture. Once the reduction of the fracture was confirmed by continuous sonographic observation, an above-the-elbow plaster-of-Paris cast was applied.

**Sonographic Examination and Measurements**

All sonographic examinations in this study were performed with a commercially available real-time scanner (SSD-620; Aloka, Tokyo, Japan) with a 7.5-MHz linear-array transducer. The surgeon viewed the fracture radiographs before performing the fracture reduction, but the surgeon measuring the parameters for the final comparison was blinded to all prior radiographs and sonograms. For comparison of anatomic alignment, the contralateral (uninjured) wrist was also examined in the twenty-three patients without bilateral involvement.

The technique that we used for the sonographic monitoring was simple. After adequate anesthesia administration and positioning of the injured upper extremity, ultrasound coupling gel is placed on the skin over the positions for the dorsal, volar, and radial sections (Fig. 1, a, b, and c). For the dorsal section, because the center of the distal part of the radius falls along the longitudinal line between the index and long fingers, the transducer is placed on the dorsal side of the radius in the parallel space between the index and long fingers. For the volar section, the transducer is placed on the volar side of the radius in the parallel space between the index and long fingers. For the radial section, the transducer is placed near the snuffbox area.

For a detailed comparison of the sonographic and radiographic examinations of these three sections, a pilot study was conducted on the right wrist of one of the authors (T.-C.C.). At the center of each of these three sections, a fine acupuncture needle was inserted perpendicular to the surface and down to the underlying bone surface. Lateral radiographs were then made to verify the cortical surfaces observed on sonographic examination of these sections (Fig. 1, d and e). The dorsal, volar, and radial cortices observed on sonographic examina-
tion of these sections proved to be identical to those observed on conventional radiographs (Fig. 1, f, g, and h).

The alignment of the fracture was shown by the reflection of ultrasound from the volar, radial, and dorsal cortical surfaces of the radius and the corresponding carpal bones. The distance of the displacement and the angulation between the proximal and distal fragments was used to quantify the displacement and to monitor the reduction. When the fracture was too distal or too comminuted, the corresponding carpal bones were used in place of the distal fragment.

After completion of the sonographic monitoring and the recording of the three standard sections before and after the reduction of every fracture, four parameters in each of the three sections were measured. The parameters included the (1) radial displacement distance, (2) volar displacement distance, and (3) dorsal displacement distance, which are the displacement distances between the proximal and distal fragments observed in the standardized radial, volar, and dorsal sections, respectively, and (4) the volar fracture angle, which is formed by a line parallel to the volar cortex of the proximal fragment and a second line along the distal fragment (Fig. 2, a, b, and c).

Radiographic Examination and Measurements
We made plain posteroanterior and lateral radiographs of the injured wrist, with a calibration marker, before and after the reduction and cast immobilization. Because the acutely injured wrist and the long arm cast occasionally interfered with the standard projection directions, one of the authors (T.-C.C.) made plain posteroanterior and lateral radiographs of the injured wrist, with a calibration marker, before and after the reduction and cast immobilization.
achieved standardization and consistency of every radiograph by using different projection techniques in different situations, as described previously. The posteroanterior and lateral radiographs were made with the elbow flexed 90° (or, for some patients wearing a long arm cast, with the elbow in a fixed reduced position of nearly 90°) and the humerus abducted 90°, so that the elbow was at the same height as the shoulder. The posteroanterior radiograph was made with the palm of the hand flat on the film cassette, and the lateral radiograph was made at a right angle to the posteroanterior radiograph.

The surgeon performing the measurements was blinded to the previous radiographs and the sonograms. The assessment of the radiographs included measurement of the four parameters (radial, volar, and dorsal displacement distances and volar fracture angle), identical to those measured on the sonographic studies. The three conventional measurements of accurate treatment and sufficient radiographic follow-up (radial shortening distance, radial inclination angle, and palmar tilting angle), which could not be determined with the sonography (one of the limitations of a sonographic examination), were also evaluated (Fig. 2, d) and correlated with the sonographic changes.

**Statistical Analysis**

Data were analyzed statistically with a Student paired t test, with p < 0.05 considered significant. In addition to the data obtained by the authors of the present study, the data obtained by an invited observer blinded to the patients’ previous radiographs and sonographic images were analyzed.

**Results**

**Characteristic Sonographic Findings**

All sonographic and radiographic images were evaluated by three orthopaedic surgeons and a radiologist who had experience with ultrasonography. Distinct presentation of homogeneous, strong, bright reflective echoes with dorsal acoustic shadowing was the characteristic feature of the bone border in all patients. A longitudinal examination across the fracture site revealed a clear disruption of the continuous reflection of
the radius; furthermore, the displacement between the fracture fragments and the angle formed by the fracture fragments could be observed and measured easily in every case (Figs. 3 and 4). If the fracture was located in a juxta-articular or intra-articular area, the corresponding carpal bone (usually the scaphoid or lunate) could be used in place of the distal radial fragment (Figs. 5 and 6).

**Adequacy of Reduction**

Traction and manipulation monitored by sonographic examination successfully reduced all of the fractures to normal or nearly normal anatomic alignment. Despite successful primary treatment, surgical intervention with various methods of internal and/or external fixation was indicated, and was performed within one week, in six wrists with an unstable fracture pattern.

**Results of Measurements**

Sonographic and Radiographic Measurements at the Fracture Site

A comparison of the sonographic and radiographic measurements of the volar, dorsal, and radial displacement distances as well as of the volar fracture angle is shown in Table I. Both modalities showed a significant decrease in the displacement distances and a significant correction of the fracture angle ($p < 0.05$). Anatomic or nearly anatomic alignment of both fragments was achieved in every reduction, as demonstrated by the almost completely reduced translation in all three planes and the correction of the volar fracture angle to a value comparable with that on the normal, contralateral side. In addition, the paired $t$ test analysis showed a close and significant association between the sonographic and radiographic measurements of all of these.
parameters both before and after the reduction (p < 0.05).

Radiographic Measurements of
Conventional Parameters of Reduction
Table II shows the means and standard deviations for the palmar tilting angle, radial inclination angle, and radial shortening distance, before and after the reduction and cast immobilization, as measured on the radiographic studies. The palmar tilting angle averaged −18.5° (range, 25° of volar tilt to −67° of dorsal tilt) on the initial lateral radiographs. The angle was significantly decreased, to an average of 6.1° (range, 20° of volar tilt to −5° of dorsal tilt), on the radiographs made immediately after the reduction and cast application (p < 0.05). There was also a significant increase in radial inclination (p < 0.05), from 14.8° (range, −5° to 45°) on the initial radiographs to 24.6° (range, 18° to 30°) on the postreduction radiographs, and a significant decrease in the radial shortening (p < 0.05), from 3.4 mm (range, 0 to 12 mm) to 0.0 mm (range, −2 to 1 mm). Overall, the results of the closed reductions in this series were successful according to generally accepted criteria; a palmar tilting angle between 0° and 22°, a radial inclination angle between 16° and 28°, and radial shortening of <2 mm.

### Discussion

This study was a prospective review of the findings in twenty-seven consecutive wrists with various types of acute displaced distal radial fractures treated primarily with sonographically guided closed reduction and cast immobilization. With the real-time guidance and confirmation of the sonographic examination, we were able to achieve anatomic or nearly anatomic alignment in every closed reduction in this study. These results were verified by radiographs made immediately after each reduction and cast application. A comparison of radiographs made before and after the reduction and immobilization revealed the restoration of normal bone alignment, normal radial inclination and palmar tilting angles, and preservation of radial length in every wrist immediately after treatment. The sonographic observations were identical to the radiographic findings. This similarity supports the hypothesis that sonographic monitoring can provide real-time observation that can guide and confirm the closed reduction of extra-articular distal radial fractures.

Sonography for the diagnosis of disorders in the musculoskeletal system has been found to be especially useful for the detection and characterization of soft-tissue abnormalities. Only a few studies have shown that sonography can be a useful adjunct to routine radiography for the diagnosis of fractures—e.g., the early diagnosis of stress fractures; the detection of occult fractures in children; and the identification of some fractures, including those of the scaphoid, sternum, rib, greater tuberosity of the humerus, orbital floor, and radial neck, that are poorly delineated by conventional radiographs. Sonography, however, is not yet frequently used. All of the above reports also concluded that sonography is not the method of choice for detecting and diagnosing bone fractures. One major reason for this conclusion is the basic technical dif-

### TABLE I Comparison of Sonographic and Radiographic Measurements of Displacement Distances and Angulation Angle at the Time of Injury and Immediately After Closed Reduction and Cast Immobilization*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Treatment</th>
<th>After Treatment</th>
<th>Statistical Findings†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sonography (1)</td>
<td>Radiography (2)</td>
<td>Sonography (3)</td>
</tr>
<tr>
<td>Volar displacement (mm)</td>
<td>3.0 ± 2.8</td>
<td>3.0 ± 2.6</td>
<td>0.07 ± 0.42</td>
</tr>
<tr>
<td>Volar fracture angle (deg)</td>
<td>−6.7 ± 31.9</td>
<td>−7.0 ± 33.3</td>
<td>19.70 ± 8.70</td>
</tr>
<tr>
<td>Dorsal displacement (mm)</td>
<td>4.0 ± 4.0</td>
<td>4.1 ± 4.1</td>
<td>0.07 ± 0.26</td>
</tr>
<tr>
<td>Radial displacement (mm)</td>
<td>3.3 ± 3.1</td>
<td>3.4 ± 3.3</td>
<td>0.04 ± 0.28</td>
</tr>
</tbody>
</table>

*The values are given as the mean and the standard deviation. †NS = not significant.

### TABLE II Radiographic Measurements of Anatomic Deformity Associated with Distal Radial Fracture at the Time of Injury and Immediately After Closed Reduction and Cast Immobilization*

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Before Treatment</th>
<th>After Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmar tilting angle (deg)</td>
<td>−18.5 ± 25.7</td>
<td>6.1 ± 7.0†</td>
</tr>
<tr>
<td>Radial shortening distance (mm)</td>
<td>3.4 ± 3.0</td>
<td>0.0 ± 0.8†</td>
</tr>
<tr>
<td>Radial inclination angle (deg)</td>
<td>14.8 ± 9.6</td>
<td>24.6 ± 2.4†</td>
</tr>
</tbody>
</table>

*The values are given as the mean and the standard deviation. †P < 0.05, compared with the value before treatment.
Sonography is an effective tool for real-time monitoring of the reduction of distal radial fractures. It is noninvasive, produces no morbidity, is highly accurate, is easy to use, and can sometimes be more useful in closed reduction than conventional radiography. While sonography has some limitations that prevent it from completely replacing conventional radiography, it can facilitate the reduction and prevent repeated reduction attempts.

In summary, sonography is an effective tool for real-time monitoring of the reduction of distal radial fractures. It is noninvasive, produces no morbidity, is highly accurate, is easy to use, and can sometimes be more useful in closed reduction than conventional radiography. While sonography has some limitations that prevent it from completely replacing conventional radiography, it can facilitate the reduction and prevent repeated reduction attempts.

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