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Coronal Shear Fractures of the Distal End of the Humerus*

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Investigation performed at Massachusetts General Hospital, Boston, and Grandview Hospital, Ohio University, Dayton

ABSTRACT: We identified a shear fracture of the distal articular surface of the humerus, with anterior and proximal displacement of the capitellum and a portion of the trochlea, in six patients (five female and one male). The average age of the patients was thirty-eight years (range, ten to sixty-three years). Each fracture was the result of a fall from a standing height. A characteristic radiographic abnormality, which we have termed the double-arc sign, was seen on the lateral radiograph of each patient and represented the subchondral bone of the displaced capitellum and the lateral trochlear ridge. All patients were managed with open reduction, internal fixation, and early motion of the elbow.

The average duration of follow-up was twenty-two months (range, eighteen to twenty-six months). The fracture united in all patients at an average of six weeks (range, four to nine weeks), without radiographic evidence of osteonecrosis of the fracture fragment. Flexion of the elbow averaged 141 degrees (range, 130 to 150 degrees), with an average flexion contracture of 15 degrees (range, 0 to 40 degrees). Pronation of the forearm averaged 83 degrees, and supination averaged 84 degrees. All patients had a good or excellent functional result, according to the elbow-rating scale of Broberg and Morrey.

Osteochondral shearing fractures of the distal end of the humerus may be difficult to assess accurately on standard radiographs. The operative treatment of these fractures may be equally difficult, given the limited amount of subchondral bone available for stable internal fixation of the fracture fragment.

The most common pattern of osteochondral fractures of the distal part of the humerus involves the capitellum. Such fractures have been classified into three groups: type 1 (the Hahn-Steinthal fracture), which involves most of the capitellum, with little or no extension into the lateral aspect of the trochlea; type 2 (the Kocher-Lorenz fracture), which involves only the anterior cartilage of the capitellum, with a thin layer of subchondral bone; and type 3, described by Broberg and Morrey, which is a comminuted fracture of the capitellum. The results of treatment of these capitellar fractures with manipulative reduction and immobilization in a cast are unpredictable, leading many investigators to recommend operative reduction.

The purpose of this retrospective review was to evaluate the operative results for six patients who had a shear fracture of the distal end of the humerus that extended in the coronal plane across the capitellum to include most of the lateral trochlear ridge and the lateral half of the trochlea. To our knowledge, this type of injury has not been described before.

Materials and Methods

Between 1990 and 1993, six patients who had a coronal shear fracture of the distal end of the humerus were managed at Massachusetts General Hospital, Boston, or at Grandview Hospital, Ohio University, Dayton (Table I). During this time, ninety patients who had an intra-articular fracture of the distal end of the humerus were managed at these two institutions. The diagnosis of a coronal shear fracture was made by computed tomographic scanning preoperatively in two patients and by direct visualization at the time of the operation in the remaining four. There were five female patients and one male patient; the average age was thirty-eight years (range, ten to sixty-three years). All of the fractures were closed and were the result of a fall from a standing height. All patients recalled striking the ground with the hand and wrist in the extended position. Each fracture was an isolated injury, with no associated neurovascular injury. The dominant arm was involved in four patients. At the time of the injury, three patients were employed as clerical workers, one was a homemaker, and one (who was developmentally handicapped) was unemployed. The sixth patient was a ten-year-old girl.
TABLE I

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex, Age (Yrs.)</th>
<th>Initial Treatment</th>
<th>Duration of Follow-up (Mos.)</th>
<th>Accuracy of Reduction</th>
<th>Result</th>
<th>Range of Motion (Degrees)</th>
<th>Post-Traumat. Osteoarth. (Grade)</th>
<th>Elbow Rating (Points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M, 63</td>
<td>Open reduct. &amp; int. fixat., Herbert screws</td>
<td>26</td>
<td>Near-anatomical</td>
<td>Good</td>
<td>35/135</td>
<td>50/55</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>F, 10</td>
<td>Open reduct. &amp; int. fixat., Kirschner wires</td>
<td>18</td>
<td>Anatomical</td>
<td>Excellent</td>
<td>0/130</td>
<td>90/90</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>F, 45</td>
<td>Open reduct. &amp; int. fixat., screws &amp; plate</td>
<td>24</td>
<td>Near-anatomical</td>
<td>Good</td>
<td>40/140</td>
<td>90/90</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>F, 49</td>
<td>Open reduct. &amp; int. fixat., Herbert and small-fragment screws</td>
<td>18</td>
<td>Anatomical</td>
<td>Good</td>
<td>15/145</td>
<td>90/90</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>F, 33</td>
<td>Open reduct. &amp; int. fixat., Herbert screws</td>
<td>22</td>
<td>Anatomical</td>
<td>Excellent</td>
<td>0/145</td>
<td>90/90</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>F, 25</td>
<td>Open reduct. &amp; int. fixat., screws &amp; plate</td>
<td>24</td>
<td>Anatomical</td>
<td>Excellent</td>
<td>0/150</td>
<td>90/90</td>
<td>0</td>
</tr>
</tbody>
</table>

The initial anteroposterior and lateral radiographs of the elbow were re-evaluated for the purpose of this study. In each patient, the fracture fragment of the capitellum and trochlea was seen to be rotated and displaced in a proximal direction.

At the time of the operation, the fracture line was observed to extend in the coronal plane across the capitellum, to include most of the lateral trochlear ridge and the lateral half of the trochlea (Figs. 1-A and 1-B). In the child (Case 2), this represented a Salter-Harris type-4 injury, with separation of the anterolateral portion of the distal humeral epiphysis. The extent of involvement of the trochlea was not accurately depicted on the preoperative radiographs of any patient. A pathognomic radiographic feature of these injuries is the so-called double-arc sign, best seen on the lateral radiograph of the elbow for all of the patients in this series. This represents the subchondral arc of bone of the capitellum, and the lateral trochlear ridge, rotated and displaced in a superior direction (Fig. 2). The extension of the coronal fracture line to include a large portion of the trochlea, the subchondral bone of which comprises the second arc of the double-arc sign, distinguishes these injuries from simple capitellar fractures. Lateral and anteroposterior tomography was performed for three patients, but it also did not accurately represent the fracture pattern. Computed tomography was performed in the axial or transverse plane at the level of the distal end of the humerus for two patients, and the images of the coronal fracture line provided an accurate representation of the operative findings (Fig. 3). Sagittal reconstructions of the computed tomographic scans also were helpful in demonstrating the posterior extent of the fracture line.

Because of the inherent difficulties encountered with accurate representation of the fracture on preoperative radiographs, the classification of the fractures was based primarily on the observations made during the operation. These fractures most closely resembled AO/ASIF type-B3.3 fractures of the distal end of the humerus14,15. However, the fractures in this series lacked the sagittal split seen in such fractures; most of the anterior articular surface displaced as one fragment.

Operative Technique

The six operative procedures were performed an average of three days (range, zero to seven days) after the injury, with the patient under general or axillary block anesthesia. With use of pneumatic tourniquet
control, the fracture was approached through an extended lateral Kocher approach. The common extensor origin, including the origin of the extensor carpi radialis longus, was elevated anteriorly. Particular care was taken to identify and protect the origin of the lateral collateral ligamentous complex on the lateral epicondyle. In three patients, it was necessary to reflect the ligament to obtain sufficient exposure of the fracture. A suture placed in the ligament facilitated accurate reattachment through drill-holes in the lateral epicondyle after fixation of the fracture.

The operative exposure was extended both proximally, along the lateral humeral ridge between the biceps and the triceps, and distally, between the anconeus and the extensor carpi ulnaris. The extensor carpi ulnaris was elevated anteriorly, with care being taken to protect the posterior interosseus nerve by keeping the forearm pronated. In this fashion, a long, thick anterior soft-tissue flap was created. By elevating the anterior portion of the elbow capsule, retractors could be placed over the medial column of the distal end of the humerus, and the entire anterior articular surface of the distal end of the humerus could be visualized.

In each patient, the consistent intraoperative finding was separation of the entire capitellum and most of the lateral trochlear ridge as a single osteochondral fragment, with extension of the fracture line to or across the midline of the trochlea. This fragment was displaced proximally and internally rotated in all of the patients. In three patients, slight comminution of the fracture laterally was observed. The fracture could be accurately reduced in each patient by reducing the clearly visible fracture line at the superior portion of the capitellum and then checking across the front of the joint to ascertain accurate reduction of the trochlear extension. After irrigation and débridement of the joint, the articular fragment was reduced into an anatomical position. The extensile lateral exposure was necessary to visualize adequately the extension of the fracture across the trochlea.

Provisional fixation was performed with smooth Kirschner wires, directed transarticularly from anterior to posterior in the distal end of the humerus. The definitive fixation was then performed with standard (non-cannulated) Herbert screws (Zimmer, Warsaw, Indiana) placed in an anterior-to-posterior fashion through the articular surface anteriorly. Alternatively, in two patients in whom the fracture line exited more posteriorly, it was judged that there was sufficient subchondral bone in the anterior shear fragment to accommodate the threaded portion of a partially threaded 4.0-millimeter cancellous-bone AO screw (Synthes USA, Paoli, Pennsylvania). These screws were inserted from the posterior aspect of the lateral condyle, to obtain interfragmentary compression across the fracture site in a posterior-to-anterior fashion. In two patients in whom the fracture line exited more posteriorly into the lateral condyle, a short (four or five-hole) plate was added along the posterolateral aspect of the condyle. Although the primary orientation of the fracture was in the coronal plane, the fracture line in these two patients angled slightly posteriorly at the lateral condyle. Placement of the screws from posterolateral to anteromedial through the plate enhanced fixation. Intraoperative radiographs were made to confirm the position and orientation of the internal fixation. The fracture in the child was treated with smooth Kirschner wires, which were removed four weeks postoperatively.

**Postoperative Management**

The postoperative dressing and splint were removed within twenty-four hours. A lightweight, removable thermoplastic orthosis, which held the elbow in 90 degrees of flexion, was made for the patient's comfort and
Figs. 4-A through 4-D: Case 4.
Fig. 4-A: Preoperative lateral radiograph showing the so-called double-arc sign (arrow).

was worn for the first four to six weeks. Active motion was initiated on the first postoperative day. The patient was instructed to lie supine and to forward-flex the involved shoulder to bring the elbow overhead. With the uninjured arm supporting the involved forearm, gravity was used to assist flexion of the elbow. A similar approach was used for elbow-extension exercises, except that the patient was instructed to sit and the uninjured arm assisted the forearm into extension. With the exception of the child, who was managed with a cast, the patients were instructed about performing the exercises on their own, with a physiotherapist functioning primarily as a monitor of their progress. Muscle-strengthening and endurance exercises were initiated twelve to sixteen weeks postoperatively.

The patients were seen in the fracture clinic every two weeks until union had occurred, and then every four weeks for the first three months.

Follow-up Examination

The most recent follow-up evaluation was performed by the three of us and consisted of a history, physical examination, radiographs, and assessment of elbow function. The physical examination consisted of manual testing of mediolateral and anteroposterior stability and testing of muscular strength against the examiner's resistance, and both were graded according to the scale established by Broberg and Morrey.

Anteroposterior, oblique, and lateral radiographs were made to assess the accuracy of the reduction and the presence or absence of osteonecrosis or post-traumatic osteoarthrosis. The accuracy of the initial reduction was judged at the time of the operation, and follow-up radiographs were used to assess any loss of fixation or reduction. The radiographic evaluation scale of Knirk and Jupiter was used to grade post-traumatic degenerative changes in the elbow joint. According to this scale, grade 0 indicates no degenerative changes; grade 1, slight narrowing of the joint space; grade 2, marked narrowing of the joint space, with formation of osteophytes; and grade 3, bone on bone, with formation of osteophytes and cysts.

The most recent results were assessed with use of the objective functional elbow index rating scale of Broberg and Morrey. Points were allocated, on a weighted scale, for strength, motion, stability, and pain. The results were then rated, with a total score of 95 to 100 points considered excellent; 80 to 94 points, good; 60 to 79 points, fair; and 59 points or less, poor.

Results

All fractures united at an average of six weeks (range, four to nine weeks). There were no operative complications. The average duration of follow-up was twenty-two months (range, eighteen to twenty-six months). Four of the six patients had no pain; the two remaining patients reported pain with strenuous activity, although neither used analgesic medication. Three of the five adults returned to their pre-injury occupation, and three patients reported a full return to recreational sports activity. The patient who was developmentally handicapped (Case 4) remained unemployed, and another patient (Case 1) undertook a preplanned retirement after the injury.

No patient reported difficulty with any functional activity of daily living or had any subjective complaints consistent with instability of the elbow. Flexion of the elbow averaged 141 degrees (range, 130 to 150 de-
CORONAL SHEAR FRACTURES OF THE DISTAL END OF THE HUMERUS

Figs. 4-C and 4-D: Postoperative lateral and anteroposterior radiographs showing the anatomical reduction and internal reduction obtained with Herbert and 4.0-millimeter AO screws. The patient had a good result, with an elbow score of 92 points at the one-year follow-up evaluation.

Discussion

While the coronal shear fracture may appear to resemble the well recognized type-I capitellar (Hahn-Steinthal) fracture\(^1\), the distinguishing feature in our patients was extension of the fracture across much of the trochlea. Failure to reduce this injury anatomically may adversely affect not only the arc of flexion and extension of the elbow but also the intrinsic stability of the elbow provided by the trochlea-olecranon articulation\(^2\).

Although this fracture pattern has been previously described as part of more complex fractures of the distal end of the humerus\(^6\) or fracture-dislocations of the elbow\(^7\), it has not been reported as an isolated injury, to our knowledge. While type B3.3 of the AO/ASIF classification represents a coronal fracture of the articular surface involving both the capitellum and the trochlea, it includes a second fracture in the sagittal plane that was not found in the fractures that we described in this report.

Recognition of the extent of articular involvement that distinguishes this fracture from one of the capitellum or the lateral condyle is important for preoperative planning and operative exposure. The use of Herbert screws, which can be countersunk beneath the chondral surface, aided in the treatment of these articular injuries (Figs. 4-A through 4-D). There was a need for a more extensive exposure than is ordinarily recommended for capitellar or condylar fractures.

Despite the limited soft-tissue attachments on these displaced articular fracture fragments, avascular necrosis was not observed on any of the follow-up radiographs in this series. Although the average duration of...
follow-up was only twenty-two months, the literature on the results of operative treatment of capitellar and lateral fractures suggests that avascular necrosis is unlikely to occur\(^6\). Although these fractures are difficult to recognize and to reduce accurately, rigid fixation and early motion of the joint reliably restored function of the elbow in our patients.

References