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This information is current as of July 22, 2008

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Publisher Information
The Journal of Bone and Joint Surgery
20 Pickering Street, Needham, MA 02492-3157
www.jbjs.org
Percutaneous Pinning of the Proximal Part of the Humerus

AN ANATOMIC STUDY

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Background: Closed reduction and percutaneous pinning of unstable proximal humeral fractures is a well-described technique with some theoretical advantages over open techniques. To our knowledge, the risk of injury to neurovascular structures from percutaneous pinning of the proximal part of the humerus has not been studied. We sought to quantify this risk using a cadaveric model.

Methods: In ten fresh-frozen cadaveric shoulders, the intact proximal part of the humerus was pinned under fluoroscopic guidance with use of an identical published technique. A total of five 2.5-mm terminally threaded AO pins, including two lateral, one anterior, and two greater tuberosity pins, were used in each shoulder. The specimens were then dissected to determine the distance of each pin from adjacent neurovascular structures as well as key anatomic relationships.

Results: The proximal lateral pins were located at a mean distance of 3 mm from the anterior branch of the axillary nerve. Four of the twenty lateral pins were noted to penetrate the articular cartilage of the humeral head. The anterior pins were located at a mean distance of 2 mm from the tendon of the long head of the biceps (perforating the tendon in three specimens) and of 11 mm from the cephalic vein (perforating the vein in one specimen). The proximal tuberosity pins were located at a mean distance of 6 and 7 mm from the axillary nerve and the posterior humeral circumflex artery (tenting the structures in two specimens with internal rotation), respectively. These pins moved away from the nerve with external rotation of the humerus.

Conclusions: The technique used in this study may be associated with a risk of injury to important anatomic structures about the shoulder. Lateral pins should be distal enough to avoid injury to the anterior branch of the axillary nerve, and multiple fluoroscopic views should be obtained to avoid penetration of the humeral head cartilage. There may be a risk of injury to the cephalic vein, the biceps tendon, and the musculocutaneous nerve with use of anterior pins, and these pins should be employed with caution. Greater tuberosity pins should be placed with the arm in external rotation, should be aimed for a point ≥20 mm from the inferior aspect of the humeral head, and should not overpenetrate the cortex.

Closed reduction and percutaneous pinning of unstable fractures of the proximal part of the humerus is a well-described technique that minimizes soft-tissue dissection and may reduce operative morbidity. To our knowledge, the risk of injury to neurovascular structures from percutaneous pinning of the proximal part of the humerus has not been studied. The purpose of the present study was to define quantitatively the risk of injury to neurovascular structures about the shoulder with use of a published technique of percutaneous pinning of the proximal part of the humerus and to recommend modifications of the technique as necessary to improve clinical safety.

Materials and Methods

Percutaneous pinning of ten fresh-frozen human cadaveric shoulders was performed with the technique described by Jaberg et al. (Fig. 1). The specimens had previously been disarticulated through the scapulothoracic joint. The proximal part of the humerus was left intact as it was thought that creating a fracture was unnecessary for the purposes of this study and that it might compromise additional anatomic dissections. An identical pinning technique was utilized for each specimen, and every effort was made to insert all pins in a reproducible fashion.

With use of c-arm fluoroscopy, five 2.5-mm terminally threaded AO pins were advanced into each specimen. Standardized fluoroscopic views of the shoulder, including a true anteroposterior view of the shoulder perpendicular to the scapular plane and a transscapular lateral view of the humerus that was oriented 90° to the anteroposterior view, were used during placement of the pins. Two lateral pins were placed, from distal to proximal, through the lateral aspect of the humeral shaft into the humeral head; two greater tuberosity pins were placed, from proximal to distal, through the greater tuberosity, engaging the medial aspect of the humeral neck; and one anterior pin was placed, from distal to proximal, entering
the anterior midline of the humerus and aiming for the posterior aspect of the humeral head. The anterior pin was placed perpendicular to the scapular plane with the shoulder in neutral rotation, and the two lateral pins and the two greater tuberosity pins were placed parallel to the scapular plane. The lateral pins were advanced to within 5 mm of the articular surface of the humeral head. The position of the tips of the pins was evaluated with anteroposterior fluoroscopic views with the shoulder in two, three, or four positions of rotation. Every effort was made to avoid overpenetration of the humeral head and shaft medially, as would be the case during an actual procedure. In addition, satisfactory positioning of all pins was confirmed with use of both anteroposterior and lateral fluoroscopic images, as described above.

Each specimen was then dissected to determine the distance of each pin from adjacent neurovascular structures, including the cephalic vein, musculocutaneous nerve, axillary nerve (main trunk and anterior branch), and posterior humeral circumflex artery. The distance of the anterior pins from the tendon of the long head of the biceps was also determined. Fine-point engineering calipers were used to measure the shortest perpendicular distance between the pins and the adjacent structures. Overlying muscles and soft tissues were dissected when necessary to explore anatomic structures for measurements. The means and ranges for these distances were then calculated and recorded.

Other anatomic relationships that were measured included the length of each humerus, the distance between the inferior aspect of the articular cartilage of the humeral head and the axillary nerve, the distance from the top of the humeral head to the cephalic vein at the anterior midline of the humeral shaft, the distance along the lateral aspect of the humeral shaft from the deltoid tuberosity to the radial nerve distally, and the distance between the anterior branch of the axillary nerve and the tip of the greater tuberosity laterally. The humeral heads were inspected for any evidence of pin penetration.

### Results

The distances of each pin from selected anatomic structures are presented in Table I.

#### Lateral Pins

The distal lateral pins were located at a mean distance of 19 mm (range, 10 to 25 mm) from the cephalic vein and a mean distance of 17 mm (range, 13 to 25 mm) from the anterior branch of the axillary nerve.

The proximal lateral pins were located at a mean distance of 21 mm (range, 14 to 27 mm) from the cephalic vein and a

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### Table I Closest Perpendicular Distance Between Pins and Adjacent Anatomic Structures*

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Distal lateral</td>
<td>18.7 (10-25)</td>
<td>NA</td>
<td>NA</td>
<td>17.2 (13-25)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Proximal lateral</td>
<td>20.6 (14-27)</td>
<td>NA</td>
<td>1.6 (0-7)</td>
<td>16.7 (9-35)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Anterior</td>
<td>10.5 (0-19)</td>
<td>7.1 (0-21)</td>
<td>7.8 (0-19)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Distal greater tuberousity</td>
<td>3.9 (0-11)</td>
<td>6.6 (1-10)</td>
<td>5.0 (1-2)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Proximal greater tuberousity</td>
<td>NA</td>
<td>10.6 (6-16)</td>
<td>2.5 (0-10)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

*The values represent the mean distance, in millimeters, with the range in parentheses. Each pin was used in ten specimens. NA = not applicable.

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Fig. 1
Anteroposterior radiograph of a cadaveric shoulder, demonstrating percutaneous pin placement according to the technique of Jaberg et al.3.
The mean distance of the anterior branch of the axillary nerve from the superiormost aspect of the greater tuberosity, mean distance of 3 mm (range, 1 to 10 mm) from the anterior branch of the axillary nerve. In seven of the ten specimens, the proximal lateral pin was <2 mm from the anterior branch of the axillary nerve (Fig. 2). Four of the twenty lateral pins were noted to penetrate the articular cartilage of the humeral head.

**Anterior Pins**
The anterior pins were located at a mean distance of 11 mm (range, 0 to 19 mm) from the cephalic vein. One pin perforated the vein. The anterior pins were also located at a mean distance of 2 mm (range, 0 to 7 mm) from the tendon of the long head of the biceps muscle. In two specimens the pin perforated the tendon, and in one specimen the pin passed between an anomalous bifurcation of the tendon. The anterior pins were all located lateral to the musculocutaneous nerve, at a mean distance of 17 mm (range, 9 to 35 mm).

**Greater Tuberosity Pins**
Distances were measured between the main trunk of the axillary nerve and the posterior humeral circumflex artery and the tips of the pins as they penetrated the medial aspect of the humeral neck (Fig. 2). These distances were measured with the shoulder in neutral rotation as well as in internal and external rotation. In general, internal rotation of the shoulder tightened the axillary nerve and the posterior humeral circumflex artery and brought these structures closer to the tips of the pins, whereas external rotation relaxed these structures and tended to move them farther away.

With the shoulder in neutral rotation, the distal tuberosity pins were located at a mean distance of 8 mm (range, 1 to 18 mm) from the posterior humeral circumflex artery and 10 mm (range, 0 to 22 mm) from the axillary nerve. These distances decreased with internal rotation, to a mean of 7 mm (range, 0 to 21 mm) from the posterior humeral circumflex artery and 8 mm (range, 0 to 19 mm) from the axillary nerve, and increased with external rotation, to a mean of 14 mm (range, 4 to 25 mm) from the posterior humeral circumflex artery and 15 mm (range, 4 to 26 mm) from the axillary nerve. In one specimen, the tip of the distal pin touched the axillary nerve slightly with neutral rotation and tented the nerve with internal rotation. Likewise, in an additional specimen the tip of the distal pin was found to be immediately adjacent to the posterior humeral circumflex artery and to tent the artery with internal rotation.

With the shoulder in neutral rotation, the proximal tuberosity pins were located at a mean distance of 7 mm (range, 1 to 10 mm) from the posterior humeral circumflex artery and 6 mm (range, 2 to 12 mm) from the axillary nerve. These distances decreased with internal rotation, to a mean of 4 mm (range, 0 to 11 mm) from the posterior humeral circumflex artery and 3 mm (range, 0 to 10 mm) from the axillary nerve, and increased with external rotation, to a mean of 11 mm (range, 6 to 16 mm) from the posterior humeral circumflex artery and 11 mm (range, 5 to 15 mm) from the axillary nerve. In two specimens, the pin was noted to be immediately adjacent to the artery and nerve and to tent these structures with internal rotation of the shoulder.

**Other Measurements and Observations**
The mean distance of the anterior branch of the axillary nerve from the superiormost aspect of the greater tuberosity, mea-

![Fig. 2](image-url)

Photograph displaying a proximal lateral pin (solid arrow) passing adjacent to the anterior branch of the axillary nerve. Also displayed are the proximal and distal greater tuberosity pins, which pass closely by the main trunk of the axillary nerve in this specimen (open arrows).

![Fig. 3](image-url)

Illustration of the proposed starting point for placement of the lateral pins and the end point for the greater tuberosity pins. The starting point for the proximal lateral pin should be at or distal to a point twice the distance from the superior aspect of the humeral head to the inferiormost margin of the humeral head. The greater tuberosity pins should engage the cortex of the humeral neck ≥20 mm from the inferiormost aspect of the humeral head.
sured along the lateral aspect of the humerus, was 50 mm (range, 43 to 57 mm). The main trunk of the axillary nerve was located along the medial aspect of the humeral neck at a mean distance of 10 mm (range, 7 to 14 mm) from the inferiormost extent of the humeral head cartilage. In all specimens, the posterior humeral circumflex artery coursed parallel and distal to the axillary nerve. Measured at the anterior midline of the humeral shaft, the distance from the superiormost aspect of the humeral head to the cephalic vein averaged 80 mm (range, 72 to 96 mm). The radial nerve was found in the spiral groove, distal to the deltoid tuberosity by a mean of 31 mm (range, 28 to 35 mm) as measured directly lateral on the humeral shaft. The mean length of the ten humeri in this study was 329 mm (range, 275 to 350 mm).

Discussion

The majority of proximal humeral fractures are inherently stable and are readily treated with closed means. Internal fixation is indicated for displaced two-part fractures of the surgical neck when acceptable reduction cannot be achieved or maintained with closed methods, and in select three and four-part fractures when the chances for fracture union and humeral head salvage are reasonable. While hemiarthroplasty is generally preferred for head-splitting fractures and for four-part fracture-dislocations, especially in older, low-demand patients, internal fixation for complex proximal humeral fractures is being increasingly recommended by some authors.

Many techniques have been described for fixation of unstable proximal humeral fractures. The theoretical advantages of closed reduction and percutaneous pinning include avoidance of devascularization of fracture fragments, minimization of the risk of injury to the blood supply of the humeral head, and reduced operative morbidity by avoidance of an open procedure. Disadvantages of this technique include the potential for pin migration, loss of reduction, and pin-site infection. Injury to important anatomic structures about the shoulder is also a potential concern with this technique. The published technique used in the current study may be associated with a risk of injury to important anatomic structures about the shoulder girdle. Particularly at risk are the main trunk of the axillary nerve and the posterior humeral circumflex artery from the greater tuberosity pins, the anterior branch of the axillary nerve from the proximal lateral pin, and the cephalic vein, biceps tendon, and musculocutaneous nerve from the anterior pin. Although the risk of injury to these structures may be reduced by making a small skin incision and bluntly dissecting to bone prior to pin placement, the proximity of some of these structures to the pins in the current study suggests that certain alterations in pin placement should be considered.

To avoid injury to the anterior branch of the axillary nerve, the starting point for all lateral pins should be at or distal to a point along the lateral aspect of the shaft equal to twice the distance from the top of the humeral head to a line perpendicular to the shaft at the inferiormost margin of the articular cartilage of the humeral head (Fig. 3). On the basis of the dissections performed in the current study, a safe zone was found between this point and the deltoid tuberosity distally. The technical difficulty associated with pin insertion increases as the starting point is moved distally along the humeral shaft, and there is a risk of injury to the radial nerve when pins are inserted distal to the deltoid tuberosity. The lateral pins should be advanced no closer than 10 mm from the articular surface of the humeral head. Despite our attempt to avoid humeral head penetration in the current study by using two, three, or four rotational fluoroscopic views, the articular cartilage was penetrated slightly in two of the specimens. Therefore, multiple fluoroscopic views of the glenohumeral joint should be used to ensure that no pin has penetrated the joint surface.

The addition of an anterior pin has been shown to increase the rigidity of fixation with percutaneous pinning. Which structures can be injured by an anterior pin depends on the location of the pin relative to a plane that bisects the humerus longitudinally and is perpendicular to the scapular plane. Pins lateral to this plane can potentially injure the cephalic vein, pins in this plane can potentially injure the long head of the biceps, and pins medial to this plane can potentially injure the musculocutaneous nerve. Thus, there is no truly safe zone anteriorly. While penetration of the cephalic vein or the biceps tendon would not necessarily lead to substantial functional loss, the surgeon must weigh the potential biomechanical advantages of adding an anterior pin against the substantial risk of vein or tendon perforation.

We recommend initial fixation of the humeral head fragment to the shaft with lateral distal-to-proximal pins. Following this fixation, the shoulder may be externally rotated during placement of greater tuberosity pins to move the axillary nerve and the posterior humeral circumflex artery farther away from the humeral neck. When the greater tuberosity pins are inserted, great care must be exercised to avoid overpenetration of the medial cortex, and the surgeon should aim for a point ≥20 mm from the inferior extent of the humeral head to reduce the risk of injury to the axillary nerve and the posterior humeral circumflex artery.

Potential weaknesses of this study bear mentioning. The cadaveric specimens had been previously disarticulated through the scapulothoracic joint. Theoretically, this may decrease tension in the brachial plexus and vascular tree. However, because there was adequate tissue proximal to the glenohumeral joint to tether the posterior cord and the posterior humeral circumflex artery, we do not think that the pertinent anatomic relationships measured in this study were compromised substantially. The fact that we pinned intact rather than fractured humeri may also be perceived as a weakness of the current study because the actual clinical setting was not replicated. We believe that it was important to leave the humeri intact for two reasons. First, creating reproducible fracture patterns would have required soft-tissue dissection and direct osteotomies of the proximal part of the humerus. This may have distorted local anatomy and limited
the validity of subsequent anatomic measurements. Second, it is generally assumed that displaced fractures will be reduced prior to percutaneous pinning, thus restoring local anatomic relationships to a nearly normal state. The presence of fracture hematoma or markedly displaced fracture fragments may also alter the anatomic relationships of the neurovascular structures studied in the current report. However, it seems reasonable to conclude that the magnitude of such alteration is likely to be small. Finally, while the modifications of the pin positions suggested by this study are not dramatic, it should be emphasized that these modifications were based only on anatomic considerations. In vitro biomechanical studies and in vivo clinical testing were not performed.

Percutaneous pinning of unstable fractures of the proximal part of the humerus remains a viable technique. With slight modifications in surgical technique, based on a knowledge of local anatomy, the risk of iatrogenic injury to important anatomic structures about the shoulder can be reduced.

References