The Effect of Greater Tuberosity Placement on Active Range of Motion After Hemiarthroplasty for Acute Fractures of the Proximal Humerus

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Abstract

Union of the greater tuberosity to the humeral shaft after hemiarthroplasty for acute fractures of the proximal humerus is a critical factor in the restoration of glenohumeral function. A retrospective review was undertaken to examine 23 consecutive patients who underwent hemiarthroplasty for the treatment of acute three- and four-part fractures of the proximal humerus. The study was conducted to examine the relationship between the position of the healed greater tuberosity and postoperative range of motion. The average age of the patients was 66.5 years. The average follow up was 3.8 years with a range of 24 to 108 months. Active range of motion was measured in forward elevation, external rotation, and internal rotation. Postoperative radiographs were examined to determine the position of the united greater tuberosity in relation to the top of the replaced humeral head. The tuberosity was fixed at an average of 15.4 mm below the top of the humeral head (range: 3 to 26 mm). A radiographic assessment of a control population of 50 normal proximal humeri demonstrated an average tuberosity position of 6.7 mm (range: 2 to 12 mm) below the superior aspect of the humeral head. Polynomial regression analysis demonstrated a polynomial relationship for active range of motion and tuberosity height. ANOVA testing demonstrated statistically significant differences in all ranges of motion. Active forward elevation for Group I (3 to 9 mm) was 88°, Group II (10 to 16 mm) was 126°, and Group III (17 to 26 mm) was 85° (p = 0.04). Active external rotation for Group I was 19°, Group II was 48°, and Group III was 29° (p = 0.01). Active internal rotation for Group I was to L2, Group II was to T10, and Group III was to L2 (p = 0.01). Although many factors affect the final ranges of motion in patients who undergo prosthetic replacement for acute proximal humeral fractures we believe that placement of the greater tuberosity 10 to 16 mm below the humeral head will assist in the maximum recovery of glenohumeral motion.

Hemiarthroplasty is a commonly employed technique in the treatment of complex fractures of the proximal humerus. Although humeral head replacement usually provides for adequate pain relief, the literature defines quite varied results with respect to functional outcomes. Numerous factors have been reported to contribute to diminished functional results, including nerve damage, infection, concomitant injury, and inadequate rehabilitation. Although many clinical factors are beyond the surgeon’s control, many failures result from technical errors. It has been demonstrated that restoration of humeral length is an important factor in maximizing functional outcome. A loss of humeral offset with prosthetic reconstruction can lead to a shortened lever arm for the deltoid and supraspinatus muscles, often resulting in diminished forward elevation. Excessive retroversion, which commonly results from a desire to ensure anterior stability, often results in increased tension in the greater tuberosity and its attachments. Tuberosity nonunion or malunion is one of the more common complications associated with hemiarthroplasty for acute fractures and can lead to significant losses in active range of motion. Many investigators stress the importance of adequate fixation of the tuberosities and note the importance of proper placement of the greater tuberosity in an anatomic position.
approximately 5 mm beneath the most superior projection of the humeral head. This study is designed to determine whether the healed position of the greater tuberosity could affect the functional outcome of patients treated with hemiarthroplasty for acute fractures of the proximal humerus.

**Materials and Methods**

Twenty-three consecutive patients who had undergone humeral head arthroplasty for acute three- and four-part fractures of the proximal humerus were included in this retrospective study. All procedures were performed by one surgeon using a standard technique. In all cases, a modular prosthesis was used (Cofield-Smith and Nephew). All of the patients underwent surgery within 3 weeks of injury. There were 19 females and 4 males. The average age at surgery was 66.8 years (range: 34 to 81 years). The average follow-up was 3.8 years (range: 2 to 9 years). At the time of follow-up, all patients completed a questionnaire regarding pain, function, and satisfaction.

A full history was obtained and a physical examination was conducted to assess active range of motion in forward elevation, external rotation with the arm at the side, and internal rotation. For statistical purposes, internal rotation was translated into a numeric scale (side = 1, iliac crest = 2, S1 = 3, L5 = 4, and so forth). Radiographs were obtained in three planes (scapular AP in neutral rotation, scapular lateral, and axillary projections).

In order to determine the normal anatomic relationship of the greater tuberosity to the articular surface of the humeral head, radiographs of 50 normal humeral heads were assessed. The AP view in neutral rotation was used. A line was first drawn down the midline of the shaft of the humerus. Two lines were then drawn perpendicular to the initial line. The first was placed at the most superior point of the articular surface and the second at the most superior point of the greater tuberosity (Fig. 1). The difference between these two lines was then calculated. This figure was determined to be the normal anatomic position of the greater tuberosity on the external rotation radiograph. Within the study group, full-length radiographs of the humeri were obtained for both the surgical and nonsurgical extremities. The difference in humeral length, if any, was determined for each patient. The position of the surgically repaired greater tuberosity in relation to the articular surface of the prosthesis was determined in the same manner as in the normal subjects. ANOVA testing was used to determine whether a statistical relationship existed between the height of the greater tuberosity in relation to the articular surface and the active range of motion obtained at follow-up examinations.

**Results**

Fifty AP radiographs in neutral rotation were used to determine the normal anatomic position of the greater tuberosity. The most superior aspect of the greater tuberosity was found to be an average of 6.7 mm (range: 2 mm to 12 mm) below the most superior aspect of the articular surface of the humeral head. Of the 28 surgical patients examined in this study, the average height of the greater tuberosity was noted to be 15.4 mm below the top of the humeral head (range: 3 mm to 26 mm). None of the patients were noted to have the greater tuberosity above the articular surface.

A polynomial regression analysis demonstrated a relationship between the heights of the tuberosities and the achieved ranges of motion. The patients were subsequently categorized into three groups. Group I (four patients) consisted of those patients with a tuberosity placed between 3 and 9 mm below the articular surface; Group II (8 patients) between 10 and 16 mm; and Group III (11 patients) between 17 and 26 mm.

There were no statistically significant differences in

![Figure 1 Diagram describing the method of measuring the position of the greater tuberosity in relation to the articular surface for the intact humerus (A) and the operated humerus (B). Line A is drawn in line with the longitudinal axis at the humeral shaft. Line B is drawn at the most superior point of the articular surface and perpendicular to Line A. Line C is drawn at the most superior point of the greater tuberosity and perpendicular to Line A. The distance between Line B and Line C represents the position of the greater tuberosity in relation to the articular surface.](image-url)
age, gender, fracture pattern, or delay to surgery between the three groups. ANOVA testing demonstrated statistically significant differences in the final ranges of motion in all three groups (Table 1). Active forward elevation averaged 88° in Group I (range: 30° to 150°), 126° in Group II (range: 20° to 170°), and 85° in Group III (range: 30° to 160°) (p = 0.04). Active external rotation was 19° for Group I (range: 15° to 60°), 48° for Group II (range: 25° to 65°), and 29° for Group III (range: 15° to 70°) (p = 0.01). Active internal rotation was to L2 in Group I (range: L5 to T9), T10 in Group II (range: L5 to T8), and L2 in Group III (range: L5 to T8) (p = 0.01).

### Discussion

Hemiarthroplasty has an important role in the treatment of three- and four-part fractures of the proximal humerus. Following this procedure patients are consistently comfortable, however significant variations occur with respect to final ranges of motion. Limited recovery of active range of motion can result in significant functional compromise. A previous study at our institution correlated reduced range of motion in patients over seventy, a surgical delay of more than two weeks after fracture, female gender, and following four-part fractures. Surgical technique has always stressed the importance of anatomic restoration. Humeral length must be reproduced to restore proper tension in the rotator cuff and deltoid. The prosthesis should recreate the normal retroversion to provide sufficient anterior stability while avoiding excessive tension on the tuberosities and the attached tendons. The tuberosities must be adequately secured to the prosthesis, the shaft, and to each other to ensure that healing results in a stable construct capable of withstanding the stresses of active motion.

The results of this study indicate that subtle differences in the placement of the greater tuberosity can have a significant impact on postoperative recovery of active range of motion. Since a nonunion of the greater tuberosity can have severe functional consequences, we have always attempted to secure the greater tuberosity in a position that allows it to heal to both the shaft and to the lesser tuberosity. We have accomplished this with large nonabsorbable sutures placed around both tuberosities, the prosthesis, and the shaft. The goal is to establish a stable construct capable of maintaining passive motion as a single unit until union occurs. The desire to maximize boney contact can result in placement of the tuberosity in a slightly more distal position, often overlapping the shaft. However, distal positioning may result in excess tension in the rotator cuff, thereby compromising the ability to regain range of motion.

Our measurements of humeral height of the operative and nonoperative extremities did not show a significant difference. Restoration of humeral height is an important factor. Proper tension in the deltoid must be re-established for normal shoulder function. This is best accomplished through a careful reapproximation of humeral height. With the prosthesis cemented in place at its correct height, the tuberosities can then be addressed. For the acute fractures in this series in which there was no significant retraction of the rotator cuff and tuberosity, restoration of humeral height should allow for the tuberosities to be fixed to both the shaft and to each other (based on the lateral fin of the prosthesis). If humeral length is too long, it might be difficult to approximate the tuberosity to the shaft. A correspondingly short humerus might allow the surgeon to place the tuberosities in a more distal position. In either situation, alterations in humeral length may prevent the surgeon from placing the tuberosities in their ideal locations, leading to increased difficulties either achieving union, range of motion, or both.

In this study the greater tuberosity was 6.7 mm lower than the most superior portion of the articular surface in intact humeri. The Group II patients (10 to 16 mm) had significantly greater ranges of motion than either Group I (3 to 9 mm) or Group III (17 to 28 mm). Based upon this data, placement of the greater tuberosity in a slightly more distal position is desirable. We believe it is probably necessary because the prosthetic construct most likely results in less lateral offset of the humeral head than the pre-fracture anatomy. Further study is warranted to determine the significance of this loss. A slight distal advancement of the greater tuberosity may address this loss of offset and restore the proper tension to the rotator cuff. Placing the tuberosity in the range of the Group III patients appears to leave the patient with too much tension in the rotator cuff, resulting in a similar loss of range of motion.

### Conclusion

Many factors may play a role in the functional outcome of patients treated with hemiarthroplasty for complex fractures of the proximal humerus. A number of these factors, such as age, fracture pattern, tissue quality, and the patient’s ability to comply with rehabilitation pro-

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**Table 1** Postoperative Range of Motion for Three Groups

<table>
<thead>
<tr>
<th></th>
<th>Active Forward Elevation</th>
<th>Active External Rotation</th>
<th>Active Internal Rotation</th>
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<tbody>
<tr>
<td>Group I 3-9 mm</td>
<td>88</td>
<td>19</td>
<td>L2</td>
</tr>
<tr>
<td>Group II 10-16 mm</td>
<td>126</td>
<td>48</td>
<td>T10</td>
</tr>
<tr>
<td>Group III 17-28 mm</td>
<td>85</td>
<td>29</td>
<td>L2</td>
</tr>
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* p = 0.04, p = 0.01, p = 0.01
Protocols are often beyond the surgeon’s control. However, technical aspects of the procedure are under the surgeon’s control. In addition to restoration of humeral height and retroversion, proper placement of the tuberosities can impact on the recovery of postoperative ranges of motion. It is critical to place the greater tuberosity in a position that allows for union while restoring proper tension in the rotator cuff. For the prostheses used in this study, we found it advantageous to place the greater tuberosity in a slightly more distal position, located 10 mm to 16 mm below the most superior aspect of the humeral head. We believe that this position adjusts for subtle losses of lateral offset, thereby improving the tension in the rotator cuff. Insufficient or excessive advancement of the greater tuberosity (less than 10 mm or greater than 16 mm) can lead to compromise of recovery of range of motion.

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References