Hemiartroplasty for Head-split Fractures of the Proximal Humerus

R. Michael Greiwe, MD; Rodrigo Vargas-Ariza, MD; Louis U. Bigliani, MD; William N. Levine, MD; Christopher S. Ahmad, MD

abstract

Hemiartroplasty has been recommended for 3- and 4-part fractures of the proximal humerus. Outcomes are most affected by final implant and tuberosity position. Reports of outcome and management of head-split fractures with humeral head replacement are lacking. The purpose of this study was to report the outcomes after humeral head replacement and the radiographic characteristics identified in head-split fractures. Thirty-five hemiarthroplasties performed for the acute treatment of 3- and 4-part or head-split fractures were retrospectively reviewed in a blinded database. Thirty patients (8 head-split fractures) with a mean age of 67±12 years were followed for a mean of 52±32 months. Clinical, radiographic, and objective outcomes of the head-split fractures were collected at a minimum of 12 months’ follow-up and compared with a control group of 22 three- and 4-part fractures. Radiographs were reviewed to identify characteristic features of the head-split fractures. Head-split fractures demonstrated superior forward elevation (138°±50° vs 106°±54°) but similar American Shoulder and Elbow Surgeons (68±33 vs 63±29) and Simple Shoulder Test (7.4±4.8 vs 7.0±4.0) scores compared with the control group. The pelican sign, a radiographic representation of the tuberosity and attached articular surface, was identified on preoperative radiographs. Head-split fractures are rare and commonly missed on preoperative radiographs. The recognition of the pelican sign improves the detection of head-split fractures. After hemiarthroplasty, forward elevation is improved in patients with head-split fractures compared with other fracture types.

The authors are from the Department of Shoulder Elbow and Sports Medicine (RMG, RV-A), Commonwealth Orthopaedics, Edgewood, Kentucky; and the Department of Orthopaedics (LUB, WNL, CSA), Center for Shoulder, Elbow, and Sports Medicine, Columbia University Medical Center, and the Department of Orthopaedic Surgery, Columbia University, New York-Presbyterian Hospital, New York, New York.

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Correspondence should be addressed to: R. Michael Greiwe, MD, Department of Shoulder Elbow and Sports Medicine, Commonwealth Orthopaedics, 560 South Loop Rd, Edgewood, KY 41017 (mikegreiwe@gmail.com).

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Figure: Anteroposterior radiograph showing the head-split fracture comprising the multiple articular segments and tuberosity segment; in the majority of cases, 1 articular fragment is attached to the tuberosities (A). Anteroposterior radiograph showing the pelican sign in a head-split fracture-dislocation; the white line representing the pelican demonstrates the tuberosity and attached articular segment (B).
Since the 1970s, humeral head replacement has been advocated for treatment of some 3-part and most displaced 4-part proximal humerus fractures and head-splitting fractures. Variable results have been reported following humeral head replacement in the setting of fracture.\(^1\)-\(^10\) Outcome is influenced by patient age,\(^1,3,7\) implant type,\(^11\) surgeon experience,\(^1\) associated neurologic injury,\(^6\) and time from injury to surgery.\(^5\) Recently, studies have demonstrated that outcome is most influenced by final implant position and status of the tuberosities and rotator cuff.\(^5,12\) Fracture type has not been a significant predictor of outcome.

Head-split fractures are rare (less than 5% of all proximal humerus fractures) and difficult to identify on injury radiographs.\(^13,14\) The outcome of head-split fractures, regardless of management, is thought to be worse than nonhead-split fractures because of a perceived higher energy of injury and disruption of the terminal blood supply to the articular fragments.\(^14\) Treatment for head-split fractures in older patients has typically been humeral head replacement due to the disruption of articular surface congruity and vascularity. Only 2 studies have reported on head-split fractures, but outcome scores and satisfaction rates were not reported in either study.\(^1,13\)

The purpose of the current study was to compare head-split fractures with standard 3- and 4-part fractures treated with humeral head replacement to determine head-split fracture prevalence, radiographic features, and outcomes. The authors hypothesized that head-split fractures have superior outcomes compared with standard 3- and 4-part proximal humerus fractures.

**Materials and Methods**

Between January 2001 and January 2009, seventy-four consecutive patients who underwent humeral head replacement for 3- and 4-part proximal humerus fractures were identified via retrospective review. Institutional review board approval was obtained for a review of patient records and radiographs, and informed consent was obtained from all patients in the final study group. Patients were included if they had received acute treatment (less than 28 days) for a Neer 3- or 4-part proximal humerus fracture. Patients were excluded if they had a preoperative diagnosis of fracture nonunion or malunion (n = 14), pathological fracture (n = 2), or previous surgical treatment for the fracture (n = 8); were unable to participate due to death or psychiatric impairment (n = 12); or refused participation (n = 3). Thirty-five patients met the inclusion criteria, and 5 patients had incomplete records, leaving 30 (86%) patients for review in the study.

Mean patient age was 67±12 years. Eighteen women and 12 men followed up at a mean of 52±32 months. The mechanism of injury was a fall in 25 patients, a motor vehicle/motorcycle/all-terrain vehicle accident in 4, and a bicycle accident in 1. Mean time to operative treatment was 2.8±1.3 days for the head-split group and 6.2±6.3 days for the control group. All surgeries were performed by fellowship-trained surgeons at the authors’ institution.

Two independent observers analyzed preoperative radiographs and computed tomography scans and the operative findings to determine fracture type based on the Neer classification.\(^15\) Eight patients sustained a head-split fracture. Of these, 4 had concomitant fracture-dislocations and the other 4 did not. In the comparison group, 22 patients were identified who sustained 3- or 4-part fractures, and 12 had associated anterior fracture-dislocations.

**Surgical Technique**

Patients were placed in the beach-chair position, and a standard deltopectoral approach was used. In the case of head-split fractures, rotator interval release allowed access to the joint and identification of articular fragments and tuberosity attachments. The head was osteotomized with a microsagittal saw or an osteotome to separate the head from the tuberosities. Bone graft was routinely collected from the head fragments. Sutures were then placed at the bone-tendon junction of the lesser and greater tuberosity fragments, and the humerus was prepared. All surgeons used either a smooth stem Bigliani/Flatow (Zimmer, Warsaw, Indiana) or Trabecular Metal (Zimmer).

Sutures were then passed between the tuberosity and shaft using the described suturing techniques. The stem was placed in 30° of retroversion. Cancellous bone graft was placed in between the tuberosity fragments and the shaft to improve healing. The stem was cemented at the predetermined height, and the tuberosity sutures were tied, reducing the tuberosities to the shaft and the prosthesis.

Postoperatively, the shoulder was immobilized in a sling. Physical therapy was started allowing gentle pendulum exercises and passive range of motion exercises for 2 weeks. For postoperative weeks 2 to 6, active assisted motion was allowed. When clinical and radiographic healing was evident, active motion was allowed and strengthening was started.

**Clinical and Radiographic Follow-up**

Patients were followed clinically and radiographically at 2 and 6 weeks, 3 and 6 months, 1 year, and yearly thereafter. At these time periods, clinical and radiographic follow-up, charts, operative reports, and radiographs were reviewed by 2 observers. Study questionnaires included the Simple Shoulder Test (SST), the American Shoulder and Elbow Surgeons (ASES) questionnaire, and the validated self-assessment range of motion form (4 patients).\(^16\)

Follow-up radiographs taken at least 4 months postoperatively were used to assess tuberosity healing by 2 independent observers. Tuberosities were classified as healed, completely resorbed, or partially resorbed. The greater tuberosity was considered healed if it was visible in either the anteroposterior or axillary views. If no
tuberosity was visible and the radiographs initially showed tuberosity fixation, it was considered completely resorbed. If some tuberosity—less or greater—was visible at follow-up, resorption had occurred in comparison with postoperative radiographs, it was considered partially resorbed.

Radiographs were measured for indices and markers that predicted clinical success in previous reports on hemiarthroplasty for fracture. Specifically, authors have reported the head-to-tuberosity distance (HTD), presence or absence of proximal migration, and tuberosity healing or resorption to be associated with outcome following hemiarthroplasty.\textsuperscript{1,5,7,17,18}

Each index was measured on immediate postoperative and final radiographs. For each case in which a head-split fracture was identified intraoperatively, radiologist reports were examined to identify whether the head-split fracture had been identified. Finally, preoperative radiographs and computed tomography scans were reviewed for characteristic features of a head-split fracture.

**Statistical Analysis**

Student’s $t$ test was used to compare longitudinal demographic and outcome variables between the head-split fracture and control groups. Fisher’s exact test was used to compare binary demographic and outcome variables.

**RESULTS**

**Demographics**

When demographic, mechanism of injury, and surgical variables were used to compare the 2 groups via Student’s $t$ test, a statistical difference was only identified with regard to time to operation after injury. After being controlled, operative time was observed not to have an effect on postoperative outcome (Table 1).

**Range of Motion**

At most recent follow-up, average active forward elevation for the entire group was $122\pm53^\circ$. Average forward elevation for the head-split group was $138\pm50^\circ$, which was greater than the control group ($106\pm54^\circ$) ($P=.15$). Table 2 shows the differences between the 2 groups in forward elevation, external rotation, and internal rotation.

**Complications and Reoperations**

None of the 8 head-split fractures required a reoperation. Three of 22 patients in the control group required a reoperation, but this difference was not statistically significant (Table 3). Two patients required revision with conversion to a reverse total shoulder arthroplasty. The first patient developed proximal humeral migration with pseudoparalysis and tuberosity resorption 1 year following the initial hemiarthroplasty.

The second patient was complicated by a postoperative brachial plexopathy that slowly resolved over 1 year. Radiographs 2 years postoperatively showed loosening of the humeral prosthesis, tuberosity resorption, and poor range of motion. A reverse total shoulder arthroplasty was performed. Three and a half years later, the patient reported dissatisfaction with her result and poor shoulder function.

The final patient who required a reoperation had an uncomplicated hemiarthroplasty for a 4-part proximal humerus fracture. At 2 weeks postoperatively, the patient reported wound breakdown. He was evaluated and it was noted that the wound was dehisced at the superior aspect. Therefore, the patient underwent wound exploration and irrigation and debridement. On exploration, no evidence...
existed of deeper wound breakdown, and the wound was primarily closed. Six years later, the patient reported almost full motion, no pain, and an excellent result.

In the control group, 1 incident of preoperative and 2 incidents of postoperative nerve injury occurred (Table 3); none occurred in the head-split group. Aside from these complications, a 52-year-old man in the control group was placed in a significant amount of retroversion (60°), but the patient had no difficulty with range of motion (140° forward flexion, 40° external rotation, and internal rotation to L5) and good functional scores (ASES=68 and SST=8). Four other patients had isolated proximal humeral migration, and proximal migration accompanied resorption in every case. Ten patients in the control group had 13 total complications, including 4 rotator cuff failures, 4 tuberosity resorptions, 1 prosthesis placed in 60° of retroversion, 1 superficial infection, and 2 postoperative neurologic injuries. In the head-split group, 1 patient had partial resorption and proximal humeral migration.

Radiographic Analysis

Immediate postoperative radiographs demonstrated a well-positioned greater tuberosity in 23 of 30 patients, defined by a head-to-tuberosity distance (HTD) of 5 to 20 mm.¹ In 5 shoulders, the greater tuberosity was malpositioned, as defined by a HTD distance of greater than 20 mm. Two patients had HTD distances less than 5 mm, indicating a superiorly malpositioned greater tuberosity. The change in tuberosity height from initial to final radiographs was 2.7±3.8 mm. The initial HTD was 13±7.8 mm in the head-split group and 17±1.4 mm in the control group. The change in HTD on final radiographic evaluation was 2±4 mm in the head-split group and 3.5±4.3 mm in the control group. Tuberosity resorption was identified in 5 cases in the control group and 1 case in the head-split group. Rotator cuff failure, as measured by proximal humeral migration, was noted in 8 patients in the control group and 1 in the head-split group. Average tuberosity HTD was 22±4.1 mm for patients with proximal humeral migration and 15±8.5 mm for those without proximal humeral migration over both groups (P=.047). At final radiographic follow-up, 3 cemented humeral components demonstrated loosening group. The lucent lines were 1 mm and incomplete for 2 patients, and 4 mm and complete for another patient who required later revision to a reverse total shoulder arthroplasty. Tuberosity union was achieved in 27 of 30 shoulders; 3 healed in a malunited position and 3 went on to nonunion or tuberosity resorption. For all of the measured parameters, no statistically significant difference existed between the head-split group and the control group (Table 4).

Outcome Measurements

At final follow-up, average ASES score was 67±28 over both groups. Table 5 summarizes the ASES and SST scores of the 2 groups. In each of the groups studied, ASES and SST scores were similar. Average ASES score was 68±33 in the head-split group and 63±29 in the control group.

<table>
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<th>Head-split Group (n=8)</th>
<th>Control Group (n=22)</th>
<th>P</th>
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<tr>
<td>Complications</td>
<td>1 (13)</td>
<td>10 (45)</td>
<td>.20</td>
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<tr>
<td>Reoperations</td>
<td>0 (0)</td>
<td>3 (14)</td>
<td>.54</td>
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<tr>
<td>Patient satisfaction</td>
<td>6 (75)</td>
<td>15 (68)</td>
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| Abbreviation: HTD, head-to-tuberosity distance.

<table>
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<td>17±1.4</td>
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<td>Mean±SD change in HTD, mm</td>
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<td>Proximal migration, No. (%)</td>
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<tr>
<td>Nonunion, No. (%)</td>
<td>1 (13)</td>
<td>3 (14)</td>
<td>1.00</td>
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| Abbreviations: ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test.

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<th>Control Group (n=22)</th>
<th>P</th>
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<td>Mean±SD ASES score</td>
<td>68±33</td>
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<td>Mean±SD SST score</td>
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<tr>
<td>Patient satisfaction</td>
<td>6 (75)</td>
<td>15 (68)</td>
<td>1.00</td>
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</table>

| Abbreviations: ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test.
group. Average SST score was 7.4±4.8 in the head-split group and 7.0±4.0 in the control group (Table 5).

**Subjective Satisfaction**

Results were excellent in 8 patients, satisfactory in 14, and unsatisfactory in 8. In those with unsatisfactory ratings, 2 were unsatisfied due to residual problems from neurologic injury following the index operation. Two (25%) patients in the head-split group and 7 (32%) patients in the control group were unsatisfied (P=1.00). Two patients in the control group were unsatisfied because they required a revision surgery and lacked adequate postoperative function. The others who had unsatisfactory ratings were due to pain or lack of motion postoperatively.

**Radiographic Assessment**

A head-split fracture was identified on preoperative radiographs in 3 (37.5%) patients. Computed tomography revealed the fracture pattern in 4 cases.

In 7 (87.5%) of 8 patients, an arc-shaped double density, called the pelican sign, was identified in patients with a head-split fracture on anteroposterior radiographs (Figure). In each case, the sign signified a radiographic density corresponding with the cortex of the greater tuberosity fragment and the subchondral bone of the attached articular segment.

The pelican sign is present when the articular surface of the humeral head remains attached to the greater or lesser tuberosity and is identified by inspecting the tuberosity and its articular surface attachment. The tuberosity (lesser or greater) begins as a well-defined cortical density and arcs to the footprint of the rotator cuff. This is best seen on the anteroposterior view for the greater tuberosity and the axillary view for the lesser tuberosity. The second arc of the pelican sign represents the articular surface. The cortex of the tuberosity and the subchondral bone of the articular segment represent the 2 wings of the pelican, and the nadir between the 2 (the rotator cuff insertion) represents the body of the pelican. Occasionally, due to rotation from the pull of the rotator cuff, the 2 arcs overlap. In all cases reviewed, the greater tuberosity was found attached to a piece of the articular segment.

**DISCUSSION**

Head-split fractures of the proximal humerus are rare fractures that usually require hemiarthroplasty due to a high incidence of osteonecrosis. Due to the rarity of head-split fractures, their outcomes have only been reported in a single case series or as a part of a larger study. These studies lacked comparison groups for head-split fractures and did not report key findings, such as radiographic outcome, range of motion, satisfaction, or clinical outcome. The current study compared the outcomes (range of motion, ASES and SST scores, complications, and satisfaction) of patients who underwent hemiarthroplasty for head-split fractures to those with standard 3- and 4-part fractures of the proximal humerus. In addition, a high percentage of head-split fracture patterns are not identified on initial radiographs. The pelican sign in the current small series is a reliable feature that indicates a head-split fracture pattern.

In the current series, head-split fractures demonstrated improved range of motion, complication rate, and revision rate compared with standard fractures. Patients with head-split fractures had an average active forward elevation of 138°, a complication rate of 12.5%, and revision rate of 0 at an average 3.6 years postoperatively, which compared favorably with the 3- and 4-part fracture group, which had an average active forward elevation of 106°, a complication rate of 36%, and a revision rate of 14%. Despite these differences, range of motion, patient satisfaction, and ASES and SST scores were not significantly different. However, due to the rarity of head-split fractures, the power of the study is limited. Similar to other studies, patient age, presence of neurologic injury, and implant positioning were more important predictors of outcome.

Antuña et al reported an average forward elevation of their patients with head-split fractures to be 146°±34°. They did not explain why favorable range of motion was observed following head-split fractures or report on their radiographic parameters or outcome scores. The current authors believe that head-split fractures have features that offer surgical benefit compared with other standard fracture patterns requiring humeral head replacement. First, the energy of injury is distributed through the

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**Figure:** Anteroposterior radiograph showing the head-split fracture comprising the multiple articular segments and tuberosity segment; in the majority of cases, 1 articular fragment is attached to the tuberosities (A). Anteroposterior radiograph showing the pelican sign in a head-split fracture-dislocation; the white line representing the pelican demonstrates the tuberosity and attached articular segment (B).
The hallmark of the pelican sign are the easily identified on standard radiographs. Defined the pelican sign, which can be expected. If left untreated, poor outcomes can be expected. Several factors influenced outcome in patients who did not fare well. Age older than 70 years, neurologic status, and final HTD greater than 20 mm were predictive of outcome. These factors have been shown by other authors to influence final range of motion and outcome scores. Age was influential in the head-split fractures group; the only poor result occurred in the most elderly patient: an 81-year-old woman.

The fact that age, neurologic status, and final HTD is predictive of outcome is not surprising because of the importance of healing potential, postoperative rehabilitation, and surgical technique. Neer emphasized the importance of proper patient selection and surgical technique when performing humeral head replacement for fractures of the proximal humerus. Bigliani et al. reported that although multiple reasons exist for failure following hemiarthroplasty for fracture, the most frequent problem was greater tuberosity displacement. Except in cases of neurologic injury, greater tuberosity problems were again seen as the most important single cause of poor outcome in the current series.

This study has several limitations, including the retrospective study design and the low number of patients with head-split fractures. However, head-split fractures are rare, and, to the authors’ knowledge, this study is the first to focus on the outcomes of hemiarthroplasty for head-split fractures of the proximal humerus.

**CONCLUSION**

Head-split fractures are often missed on initial plain radiographs, and identification can be improved when looking for the pelican sign. Hemiarthroplasty for head-split fractures is an acceptable treatment that may offer better results compared with other fracture patterns.

**REFERENCES**


