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## Recommended Citation

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# Intermediate Outcomes Following Percutaneous Fixation of Proximal Humeral Fractures

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*Investigation performed at the Mount Sinai School of Medicine, New York, NY, Barnes-Jewish Hospital, St. Louis, Missouri, and the University of Pennsylvania Health System, Philadelphia, Pennsylvania*

**Background:** Mini-open reduction and percutaneous fixation of proximal humeral fractures historically results in good outcomes and a low prevalence of osteonecrosis reported with short-term follow-up. The purpose of this study was to determine the midterm results of our multicenter case series of proximal humeral fractures treated with percutaneous fixation.

**Methods:** Between 1999 and 2006, thirty-nine patients were treated with percutaneous reduction and fixation for proximal humeral fractures at three tertiary shoulder referral centers. Twenty-seven of these patients were available for intermediate follow-up at a minimum of three years (mean, eighty-four months; range, thirty-seven to 128 months) after surgery; the follow-up examination included use of subjective outcome measures and radiographic analysis to identify osteonecrosis and posttraumatic osteoarthritis on radiographs.

**Results:** Osteonecrosis was detected in seven (26%) of the total group of twenty-seven patients at a mean of fifty months (range, eleven to 101 months) after the date of percutaneous fixation. Osteonecrosis was observed in five (50%) of the ten patients who had four-part fractures, two (17%) of the twelve patients who had three-part fractures, and none (0%) of the five patients who had two-part fractures. Posttraumatic osteoarthritis, including osteonecrosis, was present on radiographs in ten (37%) of the total group of twenty-seven patients. Posttraumatic osteoarthritis was observed in six (60%) of the ten patients who had four-part fractures, four (33%) of the twelve patients who had three-part fractures, and none (0%) of the five patients who had two-part fractures.

**Conclusions:** Intermediate follow-up of patients with percutaneously treated proximal humeral fractures demonstrates an increased prevalence of osteonecrosis and posttraumatic osteoarthritis over time, with some patients with these complications presenting as late as eight years postoperatively. Development of osteonecrosis did not have a universally negative impact on subjective outcome scores.

**Level of evidence:** Therapeutic <u>Level IV</u>. See Instructions for Authors for a complete description of levels of evidence.

Despite the frequency of proximal humeral fractures, debate persists over the ideal treatment of these fractures, with little intermediate or long-term data substantiating superiority of one treatment method over another. The decision-making process with regard to treatment is affected by many variables; specifically, these variables include fracture pattern, degree of comminution, bone quality, surgeon-preferred technique, and the age and activity level of the patient. For fractures with an indication for surgical treatment, operative procedures include interfragmentary suture, locking and nonlocking plates, percutaneous pins, intramedullary rods, and humeral head replacement[1-7].

Increasingly, humeral head preservation, rather than arthroplasty reconstruction, has been popularized as advances have been made in fracture fixation. However, the reported complication rates remain high, even with advanced fixation options such as locking plates[8-10]. Furthermore, even modern joint-preserving techniques fail to modify the incidence of

osteonecrosis. Minimally invasive surgical techniques, including percutaneous pinning, have recently received increased attention[11-18]. Surgeons advocating this technique have reported good results, citing the advantages of limited soft-tissue dissection during fracture management[19]. In addition, the technique is associated with decreased scar formation, which may allow for easier postoperative rehabilitation and make future shoulder surgery easier. However, percutaneous fixation remains a technically demanding procedure and requires careful assessment of fracture patterns to ensure that the technique is appropriate for the particular injury.

With any humeral-head-preserving technique, osteonecrosis is an important postoperative concern. Previous studies have suggested that by minimizing the stripping of soft tissue, percutaneous fixation may decrease the rate of osteonecrosis in patients who have sustained a proximal humeral fracture. Osteonecrosis rates reported in percutaneous pinning studies have ranged from 4% to 16%[12,15,17,20], which compares favorably with the 12.5% to 71% range reported with the use of other techniques[3,21,22]. The present case series was in part previously reported at a short-term follow-up with an osteonecrosis rate of 3.7%[20]. However, the involved surgeons noted that some patients returned later with evolving radiographic changes, providing the impetus for a longer term follow-up of these patients.

The purpose of this study is to report on the midrange clinical and radiographic outcomes of patients who were treated for displaced two, three, and four-part fractures of the proximal part of the humerus with minimally invasive reduction and percutaneous fixation.

## Materials and Methods

A retrospective, multicenter case series review evaluated the midterm results of percutaneous reduction and fixation of displaced proximal humeral fractures. Subjects were included from the practices of fellowship-trained shoulder and elbow specialists at three institutions: Barnes-Jewish Hospital (St. Louis, Missouri), University of Pennsylvania Health System (Philadelphia, Pennsylvania), and Mount Sinai Medical Center (New York, NY). Between 1999 and 2006, thirty-nine patients from these institutions underwent closed reduction and percutaneous fixation for treatment of a displaced proximal humeral fracture. Twenty-seven patients were available for a minimum three-year follow-up (mean, eighty-four months; range, thirty-seven to 128 months). Patients were evaluated with radiographs and physical examinations at the time of their latest follow-up. American Shoulder and Elbow Surgeons (ASES) scores were also completed at the latest follow-up.

The indication for operative intervention was determined by the treating surgeon. In general, fractures were assessed with use of radiographs (four views: anteroposterior, true anteroposterior, outlet, and axillary) without tertiary imaging. Surgical neck fractures were considered displaced when there was >45° of angulation. Tuberosity displacement was diagnosed when there was >5 mm of displacement on orthogonal radiographs. Suitability of the patient for percutaneous pinning was determined by the senior surgeon on the basis of radiographic and patient characteristics. Fractures were treated with other fixation methods during the study period, at the discretion of the surgeon. Indications for percutaneous reduction and pinning included adequate bone quality, absence of calcar comminution, and stability of the fracture after reduction and fixation. Patients with severe osteopenia, severe comminution, or tuberosity fragmentation were not considered candidates for percutaneous fixation. Fractures with marked displacement, such as fracture-dislocations, were not considered for percutaneous reduction and fixation.

### Surgical Technique and Postoperative Care

The surgical technique and postoperative care used by the participating centers has been previously reported in a similar patient series[20].

The surgical procedures were performed with the patient in a modified beach-chair or supine position. Fluoroscopy was utilized to obtain orthogonal imaging of the proximal part of the humerus during fracture reduction and implant placement. Displaced surgical neck fractures were reduced as described by Jaberg et al.[12] When anatomic reduction could not be obtained with a closed reduction maneuver, a small (1 to 2-cm) portal incision was made, through which a blunt elevator was introduced to manipulate the fragments. This reduction portal is located inferior to the anterolateral corner of the acromion at the level of the surgical neck. After an adequate reduction was confirmed fluoroscopically, two or three 2.8-mm terminally threaded pins were placed in a retrograde fashion, starting from the lateral and anterior aspect of the humeral shaft. Tuberosity displacement was reduced with use of a dental pick, bone hook, or pins. Most tuberosity fragments were also secured with cannulated small-fragment screws or with pins that were cut to allow them to be subcutaneous. No bone graft was added primarily.

Patients had shoulder immobilization for three to four weeks. Protected passive shoulder range of motion was initiated after three to four weeks in all patients following removal of the terminally threaded pins. Pin removal was performed in the operating room with the patient under sedation with local anesthesia and with use of fluoroscopic guidance. Initial exercises included passive motion of the shoulder into forward elevation and external rotation with the arm at the side, as well as pendulum exercises. Active motion was initiated at six weeks, provided that healing was demonstrated on postoperative radiographs, and this was followed by strengthening as tolerated at two to three months postoperatively.

### Follow-up Evaluation

Radiographs were made at the latest follow-up and included anteroposterior, true anteroposterior, outlet, and axillary views. These studies were evaluated by a group of fellowship-trained surgeons (A.K.H., B.O.P., J.K., K.I.G., and several surgeons who were not authors of this paper, but not the senior authors) for evidence of posttraumatic osteoarthritis of the glenohumeral joint or osteonecrosis of the humeral head. Osteonecrosis was diagnosed if radiographs demonstrated focal articular surface collapse within the humeral head. At the latest follow-up, patients completed questionnaires regarding pain and shoulder function and underwent a thorough physical examination by a fellowship-trained surgeon (A.K.H., B.O.P., J.K., K.I.G., or one of several surgeons who were not authors of this paper) independent of the operating surgeon who documented shoulder motion. Overall shoulder function was objectively assessed with ASES scores.

## Results

Thirty-nine patients met our criteria for this study. One patient died of unrelated causes during the follow-up period. One could not be located or contacted for follow-up, and ten patients were contacted but refused participation in the study. Of the twenty-seven patients who agreed to participate, nineteen represent a subset of patients whose short-term outcome has been previously reported[20].

The mean age of the participating patients at the time of injury was 58.8 years (range, forty-two to seventy-six years). The average follow-up was eighty-four months (range, thirty-seven to 128 months). There were fifteen women and twelve men. The right extremity was injured in fourteen patients, and the left, in thirteen patients. Fractures were classified according to the Neer classification system[23]. There were five two-part fractures, twelve

| TABLE I Rate of Osteonecrosis and Posttraumatic Osteoarthritis by Fracture Type | | |
|---|---|---|
| Fracture Pattern (No. of Patients) | Osteonecrosis (%) | Posttraumatic Osteoarthritis (%) |
| Two-part (5) | 0 | 0 |
| Three-part (12) | 17 | 33 |
| Four-part, all valgus-impacted (10) | 50 | 60 |

three-part fractures, and ten four-part fractures. All ten of the four-part fractures demonstrated a valgus-impacted pattern.

### Radiographic Evaluation

The radiographs of all of the patients demonstrated fracture-healing. No patient had a nonunion or failure, loosening, or complications regarding the implant. Radiographic review at the time of the last follow-up demonstrated osteonecrosis in seven (26%) of the twenty-seven patients. Osteonecrosis was diagnosed, on the average, fifty months after the date of the original percutaneous fixation, with a range of eleven to 101 months after the time of fixation. Four patients were diagnosed with osteonecrosis more than two years after fracture fixation. One patient in whom osteonecrosis was diagnosed ninety-eight months after injury had last been evaluated twenty-four months after injury, at which time there were no clinical or radiographic findings of osteonecrosis. He reported minimal symptoms and chose not to return. Osteonecrosis was found in three other patients at thirty-two, seventy-five, and 101 months. Two of these patients had not returned for follow-up since their one-year postoperative evaluation and, even after their recent diagnosis of osteonecrosis, remained asymptomatic. The other patient

had also not returned since the one-year postoperative visit and developed mild shoulder pain only six months prior to the diagnosis of osteonecrosis.

Osteonecrosis rates varied for different fracture patterns. The highest rate occurred in patients who had four-part fractures, with five (50%) of the ten patients developing osteonecrosis. All of these fractures were four-part, valgus-impacted patterns. Osteonecrosis was seen in two (17%) of the twelve patients who had three-part fractures, and in none (0%) of the five patients who had two-part fractures. On radiographs, the highest rate of posttraumatic osteoarthritis was in valgus-impacted, four-part fractures. Posttraumatic osteoarthritis developed in six (60%) of the ten patients who had four-part fractures, four (33%) of the twelve patients who had three-part fractures, and none (0%) of the five patients who had two-part fractures (Table I).

### Outcomes Evaluation

The average ASES score for all patients with a minimum three-year follow-up was 82. Of the patients originally described in a previous report by Keener et al.[20], nineteen patients were reevaluated with use of ASES scores at the time of the latest follow-up. The average ASES score for this subset of patients was 78.5 in the earlier study, and 80.8 at the time of the latest follow-up. The ASES scores for all patients with osteonecrosis (average ASES score = 77) in the present study were lower as compared with the scores for patients without osteonecrosis (average ASES score = 84), but this was not significant (p = 0.26) in an intention-to-treat analysis. In the present study, the average ASES score for those patients without posttraumatic osteoarthritis was 87 as compared with an average ASES score of 74 for those with posttraumatic osteoarthritis, which was significant (p = 0.046) in an intention-to-treat analysis.

| TABLE II Comparison of Patients with and without Osteonecrosis* | | | |
|---|---|---|---|
| | Patients with Osteonecrosis | Patients without Osteonecrosis | P Value |
| Average age (yr) | 54.4 | 60.4 | 0.13 |
| Average ASES† score (points) | | | |
| At latest follow-up | 77 | 84 | 0.26 |
| Prior to arthroplasty | 65 | 84 | 0.02‡ |
| Range of motion (deg) | | | |
| Forward elevation | | | |
| At latest follow-up | 129 | 144 | 0.08 |
| Prior to arthroplasty | 125 | 144 | 0.01‡ |
| External rotation | | | |
| At latest follow-up | 33 | 44 | 0.32 |
| Prior to arthroplasty | 23 | 44 | 0.02‡ |
| Internal rotation | L2 level | L2 level | 0.65 |

*Comparison data are from the latest follow-up as well as prior to the arthroplasty revision, where variable (i.e., for the patients who had better scores at the time of the latest follow-up as a result of having undergone arthroplasty). †ASES = American Shoulder and Elbow Surgeons. ‡Significant value.

There were two patients with symptomatic osteonecrosis, diagnosed at twenty-one months and one year after surgery, respectively, who underwent revision to a hemiarthroplasty (see Appendix). The outcome scores, obtained immediately prior to hemiarthroplasty, averaged 65 and were significantly lower in these two patients than in patients in whom osteonecrosis did not develop (average outcome score = 84; p = 0.02).

### Physical Examination

Overall, at the time of the latest follow-up, patients had an average forward elevation of the shoulder of 140° (range, 90° to 160°), an average external rotation of 41° (range, 0° to 90°), and an average internal rotation to the level of L2 (range, gluteal level to the level of T7) (Table II). The average forward elevation for patients without osteonecrosis was 144° and, for patients with osteonecrosis, 129°. Average external rotation for patients without osteonecrosis was 44° and, for those with osteonecrosis, 33°. The average internal rotation was to the level of L2 for patients with and patients without osteonecrosis. None of these differences were significant.

When evaluating the average shoulder motion prior to hemiarthroplasty for the two patients who had symptomatic osteonecrosis, the average forward elevation was 125°, the average external rotation was 23°, and the average internal rotation was to the level of L2. In this analysis, both forward elevation (p = 0.01) and external rotation (p = 0.02) were significantly poorer in patients who had osteonecrosis as compared with those who did not have osteonecrosis.

### Discussion

This study revealed two important points with regard to minimally invasive proximal humeral fixation: (1) Osteonecrosis occurs at a higher prevalence than previously reported with longer follow-up, and (2) There are significant differences between asymptomatic osteonecrosis and symptomatic osteonecrosis that require revision surgery. In this series, osteonecrosis occurred in 26% of patients overall and in 50% of the patients with valgus-impacted proximal humeral fractures. This is a much higher rate than that seen in the same patient group at a shorter-term (thirty-five months) follow-up, in which the incidence was 4%. This highlights the fact that, similar to what is true for reconstructive procedures, longer-term follow-up may be necessary to determine the final radiographic and functional outcome after proximal humeral fracture fixation. There were differences between the two patients who had symptomatic osteonecrosis that required revision to hemiarthroplasty and the asymptomatic patients who had osteonecrosis that was found at later follow-up.

Previous studies have reported varying but relatively low rates of osteonecrosis with a percutaneous fracture fixation technique. In a series of forty-eight patients who were followed for an average of three years, Jaberg et al. found osteonecrosis in ten patients (21%); in eight of these patients (17% of the forty-eight), they described "transient osteosclerosis" involving only a portion of the humeral head, which resolved in many[12]. In the study by Keener et al., which includes a subset of patients from the present study, the osteonecrosis rate was 4%[20]. Only one of twenty-seven patients followed for an average of thirty-five months developed osteonecrosis. Fenichel et al. reported no cases of osteonecrosis in fifty patients who were followed for an average of 2.5 years[24].

In contrast, Herscovici et al. found a higher rate of osteonecrosis, primarily in four-part fractures[25]. In thirty-seven fractures followed for forty months, osteonecrosis was found in three of the four four-part fractures, leading the authors to propose that percutaneous fixation not be used for this fracture pattern. We also had a significantly higher rate of osteonecrosis (50%) in valgus-impacted four-part fractures in our study.

Although the overall rate of osteonecrosis in this series is higher than previously reported, the length of follow-up in this study is notably longer, with a minimum of three years and average of eight-four months. Osteonecrosis was diagnosed, on the average, fifty months from the time of initial fixation. The primary orthopaedic trauma publication requires at least one year of follow-up in the evaluation of post-fracture sequelae such as posttraumatic osteoarthritis or osteonecrosis, but most recommend a two-year clinical follow-up[26]. Our data suggest that osteonecrosis can be an even later finding, as four patients with no findings for osteonecrosis developed radiographically evident osteonecrosis at one year and two years, and the osteonecrosis in one of them was discovered more than eight years after the index procedure. The true rate of osteonecrosis that develops after percutaneous fixation may therefore be higher than previously believed.

While the etiology of the osteonecrosis is likely related to the type of trauma that was sustained or to the type of fracture fixation that was used, alternative etiologies cannot be excluded, particularly in cases involving later onset. It is possible that medical comorbidities may have contributed to the development of osteonecrosis. One of the patients had a history of Crohn disease and treatment with oral corticosteroids. For the other patients (i.e., those without comorbidities known to cause osteonecrosis), there was no identifiable alternative assumption regarding what caused the osteonecrosis.

Our patients with osteonecrosis had average ASES scores that were lower than the average score for patients without osteonecrosis, although only two patients with osteonecrosis were symptomatic enough to pursue additional surgery. This finding is consistent with other recent studies, thus suggesting that osteonecrosis may not represent a catastrophic failure. Wijgman et al. reported that although 37% of sixty patients undergoing nonlocking fixation of complex proximal humeral fractures developed osteonecrosis, 77% of these patients had a good or an excellent result[27]. One explanation for well-tolerated osteonecrosis after percutaneous fixation is that there are no protruding implants damaging the glenohumeral joint, as is the case with locking plates. Removal of implants may allow percutaneously treated patients to better tolerate osteonecrosis. Another possible explanation is that the tuberosities heal in anatomic position after fixation of valgus-impacted four-part fractures, enabling near normal rotator cuff function. Tuberosity malunion is a common cause of pain and dysfunction after proximal humeral fractures.

The two patients in this study who underwent revision to hemiarthroplasty to treat osteonecrosis had excellent results,

with ASES scores of eighty-three and ninety-three, and recovery of functional shoulder motion (see Appendix). Although this involved only two patients in our series, these results are superior to other reported results of humeral head replacement after failed fracture fixation. In one study, only 22% of patients undergoing arthroplasty for failed primary fixation had a good result, compared with 60% good and excellent results for acute arthroplasty[28]. Higher complication rates have been seen in patients who underwent arthroplasty after failure of initial fracture fixation than in those who underwent humeral head replacement as the primary fracture treatment[29]. However, poor results are also seen in patients who undergo primary arthroplasty for the treatment of proximal humeral fractures[30,31], particularly with regard to tuberosity malunion or nonunion[32,33]. Percutaneous pinning may offer the advantages of excellent reduction and union rates, preservation of rotator cuff function, and a lack of intra-articular destruction, allowing better results after revision surgery.

Patient outcomes after percutaneous fixation are durable over time. Despite the onset of asymptomatic osteonecrosis, measurable patient outcomes remain stable[20]. In the previous paper by Keener et al., the average ASES score was found to be 83.4, with a mean forward elevation of 142° at a minimum of one year of follow-up[20]. These results have been relatively durable, with no significant change in ASES scores and little change in shoulder motion with a much longer follow-up.

The limitations of this study include the challenges inherent in a retrospective study. Twelve patients from the original group of thirty-nine patients were not available for the longer-term follow-up. However, even under the best of circumstances, if none of the twelve developed osteonecrosis, the overall rate of osteonecrosis in this series would be 18% (i.e., seven of the original thirty-nine patients), which is still significantly higher than reported in our previous study and higher than reported in most other studies of this technique. Our results therefore, may underestimate the true prevalence for the following three reasons. First, this study comprises a group with the longest follow-up currently reported in the literature, although the numbers are small for statistical analysis and the conclusions drawn from these numbers are limited. Second, these patients were not followed serially over the study period, but rather were recalled for study purposes. Therefore, the exact time of onset of osteonecrosis cannot be determined. Regardless of that fact, the late onset osteonecrosis was largely asymptomatic and would have otherwise gone undetected, at least in the immediate future. The natural history of asymptomatic osteonecrosis remains unknown. Third, a number of patients refused participation in the study.

In conclusion, this case series revealed higher osteonecrosis rates than those previously reported, especially in valgus-impacted proximal humeral fractures, in what, to our knowledge, is currently the longest follow-up study after minimally invasive fracture fixation. Differences exist between patients with symptomatic and asymptomatic osteonecrosis; specifically, our two patients with symptomatic osteonecrosis had earlier onset of articular surface collapse and presented earlier with painful shoulders. Percutaneous pinning results in durable, good results for treatment of carefully selected patients and may provide distinct advantages for later revision surgery.

## Appendix

(eA) Figures showing the case of a patient who underwent hemiarthroplasty to treat osteonecrosis after percutaneous fixation are available with the online version of this article as a data supplement at jbjs.org. ∎

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