Primary Shoulder Hemiarthroplasty: What Can Be Learned From 359 Cases That Were Surgically Revised?

Daniel J. Hackett Jr MD, Jason E. Hsu MD, Frederick A. Matsen III MD

Abstract

Background Primary shoulder hemiarthroplasty is used to address a range of glenohumeral disorders, including fracture, arthritis, avascular necrosis, and capsulorrhaphy arthropathy; some patients with hemiarthroplasties undergo revision surgery for persistent pain or residual shoulder dysfunction. The literature does not clarify the features of the hemiarthroplasties having repeat surgery in a way that can guide surgeons’ efforts to minimize the need for revision. To help address this gap, we analyzed the characteristics of patients from our region for whom we performed surgical revision of a prior humeral hemiarthroplasty.

Questions/Purposes (1) What are the common characteristics of shoulder hemiarthroplasties having a revision? (2) What are the common characteristics of the subset of revised shoulder hemiarthroplasties that were performed for fracture? (3) What are characteristics of the subset of all revised hemiarthroplasties that were associated with glenoid bone erosion?

Methods Data for 983 patients for whom we performed a surgical revision of any type of shoulder arthroplasty between January 1991 and January 2017 were identified in our longitudinally maintained institutional arthroplasty revision database. In each case, revision had been elected by shared patient and surgeon decision-making after consideration of the disorder, degree of compromised comfort and function, treatment alternatives, and the risks of surgery. Of these 983 patients, 359 (37%) had a revision of a prior primary hemiarthroplasty; these patients were the subjects of this investigation. In this group of patients, we investigated the patient demographics, shoulder characteristics, preoperative radiographic findings, and findings at surgical revision. No patients were excluded. The patients having revision of primary hemiarthroplasties had severe loss of self-assessed shoulder comfort and function, with Simple Shoulder Test (SST) scores averaging 2.2 ± 2.2 of the maximum score of 12. The majority of these patients (81%) were women. The medical records of these 359 patients were abstracted to determine the diagnosis for the index primary hemiarthroplasty, clinical characteristics before surgery, and findings at surgical revision. One hundred twelve of the arthroplasties had been performed for fracture-related diagnoses; a subgroup analysis was performed on these patients. Two hundred seventy-three of the 359 patients (76%) had plain radiographs performed within 3 months before revision surgery that were adequate for assessing the radiographic characteristics of the glenoid, humerus, humeral component, and glenohumeral relationships; a subgroup analysis was performed on these patients. The degree of glenoid erosion was measured by a single observer in accordance with established criteria:

Grade 1 is no erosion, Grade 2 is erosion limited to subchondral bone, Grade 3 is moderate erosion with medialization, and Grade 4 is medialization beyond the coracoid.
base. Some patients were included in both of these subgroups.

Results Common characteristics of the revised hemiarthroplasties included female sex (81%), rotator cuff (89 of 359; 25%) or subscapularis (81 of 359; 23%) failure, problems related to prior fracture (154 of 359; 43%), glenoid erosion 125 of 359; 35%), and component malposition (89 of 359; 25%). Hemiarthroplasties performed for fracture-related problems were often associated with tuberosity malunion or nonunion (58 of 79; 73%) and decentering of the humeral component on the glenoid surface (45 of 71; 63%). Major erosion of the bony glenoid (Grade 3 or 4) was more common in decentred hemiarthroplasties (42 of 102; 41%) than for centered hemiarthroplasties (36 of 146; 25%) (Fisher’s exact p = 0.008) and more common for hemiarthroplasties positioned in valgus (28 of 50; 56%) than for those positioned in neutral or varus (40 of 188; 21%) (Fishers’ exact p < 0.0001).

Conclusions These findings suggest that some revisions of primary hemiarthroplasties may be avoided by surgical techniques directed at centering the prosthetic humeral articular surface on the glenoid concavity using proper humeral component positioning and soft tissue balance, by avoiding valgus positioning of the humeral component, and by managing glenoid disorders with a primary glenohumeral arthroplasty rather than a hemiarthroplasty alone. When durable security of the subscapularis, rotator cuff, and tuberosities is in question, the surgeon may consider a reverse total shoulder arthroplasty.

Level of Evidence Level III, therapeutic study

Introduction

Primary shoulder hemiarthroplasty is a commonly used procedure for the treatment of various shoulder disorders [9, 11, 12, 14, 17, 18, 26, 28, 32, 33, 35, 42, 45]. In the treatment of a proximal humeral fracture, primary hemiarthroplasty is considered when displaced fracture fragments cannot be treated with internal fixation or when there is concern regarding head collapse. In the treatment of shoulder arthritis, capsulorrhaphy arthropathy, or avascular necrosis, a primary hemiarthroplasty may be performed if there is minimal glenoid disorder, if the shoulder is too tight to admit a glenoid component, if there is insufficient bone stock to support a prosthetic glenoid, if the patient wishes to avoid the risks and limitations associated with a glenoid component, or if the surgeon is not comfortable with performing another type of shoulder arthroplasty. In some cases, hemiarthroplasty may not provide the comfort and function desired by the patient. Unsatisfactory outcomes can be associated with pain and stiffness, rotator cuff or tuberosity failure, weakness, component loosening, instability, or erosion of the bony glenoid surface—any of which may cause sufficient symptoms to indicate revision surgery. Much of the available information regarding surgical revisions comes from published case series of hemiarthroplasties from the practices of experienced surgeons [2, 3, 7, 19-21, 25, 27, 30, 34, 37, 43, 50]. These series point to the problem of glenoid bone erosion after hemiarthroplasty, but do not provide information regarding the factors associated with it. These publications also point to the difficulty in using hemiarthroplasty in the management of fracture-related problems, but do not provide detailed information regarding the characteristics of shoulders having revision of a primary hemiarthroplasty for fracture. Given the widespread use of hemiarthroplasty [46], it is important to identify the characteristics of revised hemiarthroplasties to help guide efforts to improve the clinical outcomes of this procedure and to minimize the need for hemiarthroplasty revision. To complement publications reporting outcomes of case series of primary hemiarthroplasties performed at individual centers, we studied patients having revisions at a regional referral center of some of the hemiarthroplasties performed by the surgeons in our region. In that the characteristics of the population of hemiarthroplasties from which the revisions were drawn are not known, such an investigation cannot provide odds or risk ratios for different possibly contributing factors; however, it can reveal the demographic, clinical, radiographic and surgical characteristics typical of shoulders having surgical revision of a primary hemiarthroplasty.

We asked: (1) What are the common characteristics of shoulder hemiarthroplasties having a revision? (2) What are the common characteristics of the subset of all revised shoulder hemiarthroplasties that were performed for fracture? (3) What are characteristics of the subset of all revised hemiarthroplasties that were associated with glenoid bone erosion?

Methods

In our practice, the indications for revision of a prior arthroplasty are (1) shoulder comfort and function that are unsatisfactory to the patient, (2) a mechanical problem that potentially could be addressed by revision surgery, (3) sufficient patient physical and emotional health for repeat surgery, and (4) consent by the patient to proceed with revision surgery after discussion with the surgeon of the risks and alternatives. Between January 1991 and January 2017, 983 patients had surgical revision at our center for shoulder arthroplasties performed by surgeons in our region. In each of these cases, revision was elected by shared patient-surgeon decision-making after consideration of the disorder, degree of compromised comfort and function,
treatment alternatives, and risks of surgery. Of these 983 patients, 359 (37%) patients had previously undergone primary hemiarthroplasty; these patients were the subjects of this investigation. This retrospective observational study was approved by our institutional review board (#STUDY00001281).

The intent of this study was to identify the characteristics of shoulders with primary hemiarthroplasties undergoing surgical revision. It was not intended to evaluate the rate of hemiarthroplasty revision, the technique of revision, or the outcomes of surgical revision. Surgical revision was considered when a potentially treatable mechanical cause of unsatisfactory shoulder comfort and function could be identified and when the patient desired to proceed after a thorough discussion of the risks and alternatives. Surgical revision was not considered if a treatable mechanical cause of shoulder dysfunction could not be identified, if the patient was not understanding and accepting of the risks, or if the patient was not in sufficiently robust emotional and physical health to undergo a major surgical revision.

The medical records of these patients were reviewed to collect demographic information including age, sex, date of index arthroplasty, diagnosis at index surgery, prerevision Simple Shoulder Test (SST) scores, date of revision arthroplasty, and findings at revision surgery. The SST was used as a validated tool enabling patients to self-report their shoulder’s loss of comfort and function before revision surgery [23].

Of the 359 patients who underwent revision arthroplasty, 290 (81%) were women and 69 (19%) were men (Table 1). These patients had very low self-assessed shoulder comfort and function, with average SST scores of 2.2 ± 2.2; the maximum score on the SST is 12. The average age of the patients at index surgery was 56.9 ± 13.5 years (range, 17-87 years), and the average age at revision surgery was 60.4 ± 12.7 years (range, 22-88 years). The average interval from index arthroplasty to revision was 3.4 ± 4.6 years. The majority (55%) presented earlier than 2 years from the date of the index hemiarthroplasty. The most common diagnoses for the index hemiarthroplasty were proximal humeral fracture, malunion, or nonunion, glenohumeral arthritis, capsulorrhaphy arthropathy, cuff tear arthropathy, and avascular necrosis (Table 1).

From a longitudinally maintained single-center database of shoulder arthroplasty revisions performed for patients from our region, the preoperative clinical evaluation and the surgical findings for those having revision of a primary hemiarthroplasty were abstracted to identify patient (Table 1) and shoulder characteristics (Table 2).

Two hundred seventy-three of the patients (76%) had radiographs performed within 3 months before revision surgery that were adequate for assessing the radiographic characteristics of the glenoid, humerus, humeral component, and glenohumeral relationships. The degree of glenoid erosion was measured on plain films by an individual observer (JEH) in accordance with the criteria described by Sperling et al. [45]. Grade 1 is no erosion, Grade 2 is erosion limited to subchondral bone, Grade 3 is moderate erosion with medialization, and Grade 4 is medialization beyond the coracoid base.

The status of the greater tuberosity was assessed as intact, malunited (>1 cm displacement from anatomic position [5]), nonunited, or absent. The angle of the neck of the humeral component with reference to the axis of the humeral canal was measured as described by Herschel et al. [20]. The humeral component was considered to be in varus if the angle was less than 40° and valgus if the angle was greater than 50°. Components between 40° and 50° are

### Table 1. Demographics for 359 patients*

| Characteristic                        | Number | % of total |
|---------------------------------------|--------|------------|
| Sex                                   |        |            |
| Men                                   | 69     | 19%        |
| Women                                 | 290    | 81%        |
| Laterality                            |        |            |
| Right                                 | 224    | 62%        |
| Left                                  | 135    | 38%        |
| Interval after index surgery (mean)   | 3.4 ± 4.6 years |            |
| Less than 2 years                     | 178    | 55%        |
| 2 to 5 years                          | 88     | 27%        |
| 5 to 10 years                         | 35     | 11%        |
| More than 10 years                    | 24     | 7%         |
| Index hemiarthroplasty date           |        |            |
| Before 2000                           | 98     | 30%        |
| From 2000 to 2005                     | 73     | 22%        |
| From 2005 to 2010                     | 84     | 26%        |
| After 2010                            | 71     | 22%        |
| Diagnosis at index surgery            |        |            |
| Proximal humerus fracture             | 99     | 32%        |
| Glenohumeral arthritis                | 94     | 30%        |
| Capsulorrhaphy arthropathy            | 35     | 11%        |
| Cuff tear arthropathy                 | 30     | 10%        |
| Avascular necrosis                    | 18     | 6%         |
| Other                                 | 14     | 5%         |
| Posttraumatic                         | 13     | 4%         |
| Inflammatory arthropathy              | 11     | 4%         |
| Humeral stem                          |        |            |
| Cemented                              | 72     | 26%        |
| Noncemented                           | 206    | 74%        |

*Every characteristic was not available for every shoulder; some of the percents do not add to 100% because of rounding.
considered to be in neutral. Humeral stem radiolucencies were graded in the seven Gruen zones adapted for the shoulder [29, 38]: proximal lateral metaphysis, proximal lateral diaphysis, mid-lateral diaphysis, prosthetic tip, mid-medial diaphysis, proximal medial diaphysis, proximal medial metaphysis. A humeral component was considered loose if there was obvious subsidence [39, 48] or presence of radiolucent lines greater than 2 mm in three or more of these zones [31].

AP and superoinferior glenohumeral relationships were measured on standardized axillary and Grashey view radiographs as described previously [22]. On each of these radiographic projections, a circle was constructed congruent to the articular surface of the humeral head component. We then measured the shortest distance between this circle’s center and the perpendicular bisector of a line segment connecting the edges of the bony glenoid (anterior and posterior edges in the axillary view; superior and inferior edges in the Grashey view). This distance was divided by the diameter of the circle; this ratio was converted to a percentage. Humeral head decentering was defined as any value greater than 5%.

The answers to Question 1 were derived from all 359 cases. The answers to Question 2 were derived from the 112 of the 359 revisions that were performed after primary hemiarthroplasty for fracture or fracture sequelae. The answers to Question 3 were derived from the 273 of the 359 revisions with preoperative radiographs adequate for analysis of glenoid erosion. Some shoulders were included in the analysis for Questions 2 and 3.

### Statistical Analysis

Descriptive statistics were used to describe the characteristics of these shoulders; means and SDs were presented for continuous variables, and frequencies were tabulated for categorical variables. Fishers’ exact test was used to test the relationship of major (Grades 3 and 4) glenoid erosion with humeral centering in the glenoid and valgus positioning.

### Results

#### Common Characteristics of Revised Primary Hemiarthroplasties

Of the 359 patients, the most common characteristics of the revised hemiarthroplasties included superior or anterior cuff failure (170 of 359 patients; 47%), persistent fracture sequelae (154 of 359 patients; 42.9%), severe glenoid erosion (125 of 359 patients; 34.8%), improper component positioning (89 of 359 patients; 24.8%), and improper component positioning (81 of 359 patients; 22.6%).

### Table 2. Characteristics of revised primary hemiarthroplasties

| Characteristic | Number | % of total |
|---------------|--------|------------|
| Cuff failure  | 170    | 47.4%      |
| Superior cuff failure* | 89    | 24.8%      |
| Anterior cuff failure§ | 81    | 22.6%      |
| Fracture sequelae¶ | 154   | 42.9%      |
| Severe glenoid erosion¶ | 125   | 34.8%      |
| Improper component positioning¶ | 89    | 24.8%      |
| Dislocation/instability | 33    | 9.2%       |
| Head contact with glenoid suture anchors | 9     | 2.5%       |
| Obvious infection | 8     | 2.2%       |
| Periprosthetic fracture | 5     | 1.4%       |

*Not every characteristic was available for every shoulder; some of the percents do not add to 100% because of rounding.

* tendon defect involving at minimum most of the supraspinatus.
§ tendon defect involving most of the subscapularis.
¶ proximal humeral deformity, tuberosity nonunion, malunion or absence.
† erosion obviously involving the subchondral bone.
‡ head height > 5 mm above or below the desired level, rotational malposition > 20° from the desired rotation.

### Table 3. Radiographic characteristics of failed primary hemiarthroplasties

| Characteristic                        | Number | % of total |
|--------------------------------------|--------|------------|
| Glenoid erosion                      |        |            |
| Grade 1                              | 118    | 43%        |
| Grade 2                              | 70     | 26%        |
| Grade 3                              | 75     | 28%        |
| Grade 4                              | 10     | 4%         |
| Glenohumeral centering               |        |            |
| Centered                             | 148    | 59%        |
| Decentered                           | 104    | 41%        |
| Superior                             | 82     | 30%        |
| Anterior                             | 42     | 17%        |
| Posterior                            | 22     | 9%         |
| Inferior                             | 5      | 2%         |
| Tuberosity status                    |        |            |
| Intact                               | 207    | 76%        |
| Malunion/nonunion/absent             | 67     | 25%        |
| Humeral stem loosening               |        |            |
| Not loose                            | 271    | 98%        |
| Loose                                | 6      | 2%         |
| Varus/varus angle (°)                |        |            |
| < 40°                                | 28     | 12%        |
| 40° to 50°                           | 164    | 68%        |
| > 50°                                | 51     | 21%        |

*Not every characteristic was available for every shoulder; some of the percents do not add to 100% because of rounding.
sequelae, including tuberosity malunion and nonunion (154 of 359 patients; 43%), and glenoid erosion (125 of 359 patients; 35%) (Table 2). Other features included improper component positioning (89 of 359 patients; 25%), instability (33 of 359 patients; 9%), head contact with suture anchors (nine of 359 patients; 3%), obvious infection (8 of 359 patients; 2%), and periprosthetic fracture (five of 359 patients; 1%). Some shoulders had more than one of these features. Of the 273 patients with acceptable radiographs, glenoid erosion was present in 155 of 273 patients (57%); Grade 2 in 70 of 273 patients (26%), Grade 3 in 75 of 273 patients (28%), and Grade 4 in 10 of 273 patients (3%) (Table 3; Fig. 1). One hundred four of the 273 patients (41%) showed glenohumeral decentering, with the most common direction of decentering being superior (82 of 273 patients; 30%) (Fig. 2). Malunion, nonunion, or absent tuberosities was present in 67 of 273 patients (25%). Humeral component loosening was present in six of 273 patients (2%).

Features of Revised Hemiarthroplasties Initially Performed for Fracture

Revised primary arthroplasties performed for fracture-related diagnoses were predominantly in women. Revision typically was performed 3 years after the index procedure; the humeral component was commonly cemented (Table 4). These shoulders frequently showed failure of the tuberosity and superior or anterior decentering (Table 5).

Fig. 1 Grade 3 glenoid erosion associated with superior malposition of the humeral head is shown.

Features of revised hemiarthroplasties with glenoid bone erosion

Most of the characteristics of revised primary hemiarthroplasties were not strongly associated with glenoid erosion (Table 6). However, major erosion of the bony glenoid (Grade 3 or 4) was more common in decentered hemiarthroplasties (42 of 102; 41%) than for centered hemiarthroplasties (36 of 146; 25%) (Fisher’s exact p = 0.008) and more common for hemiarthroplasties positioned in valgus (28 of 50; 56%) than for those positioned in neutral or varus (40 of 188; 21%) (Fishers’ exact p < 0.0001). Major erosion was seen in 23% (18 of 77) of revised hemiarthroplasties performed for arthritis and 29% (19 of 66) of revised hemiarthroplasties performed for fracture (Fisher’s exact p = 0.566).

Discussion

Hemiarthroplasty is a commonly performed procedure for shoulder disorders, including glenohumeral arthritis, avascular necrosis, capsulorrhaphy arthropathy, avascular necrosis, and proximal humeral fractures [11, 12, 14, 17, 24, 26, 28, 44, 45]. While often successful, this procedure can result in shoulders that are painful, stiff, weak or unstable [10, 41, 49]. These outcomes can cause the patient to consider revision surgery. As indicated by their SST scores.
at the time of presentation for revision surgery, patients who underwent revision of their hemiarthroplasties had very poor shoulder comfort and function. Our goal was to review a large number of patients from our region having revision surgery to seek modifiable factors that may enhance the outcome for primary hemiarthroplasty.

Table 4. Patient characteristics for fracture and nonfracture diagnoses*

| Characteristic                                      | Proximal humerus fracture and sequelae | Nonfracture diagnoses |
|-----------------------------------------------------|---------------------------------------|-----------------------|
| Sex                                                 |                                       |                       |
| Men                                                 | 17/112 (15%)                          | 52/247 (21%)          |
| Women                                               | 95/112 (85%)                          | 195/247 (79%)         |
| Age at index surgery (mean ± SD)                    | 58.5 ± 13.9                           | 56.2 ± 13.2           |
| Age at revision surgery (mean ± SD)                 | 61.9 ± 12.6                           | 59.6 ± 12.8           |
| Interval between index and revision surgeries (mean ± SD) | 3.4 ± 4.8                            | 3.4 ± 4.5             |
| Index hemiarthroplasty date (number; %)              |                                       |                       |
| Before 2000                                         | 47/107 (44%)                          | 51/219 (23%)          |
| From 2000 to 2005                                   | 24/107 (22%)                          | 49/219 (22%)          |
| From 2005 to 2010                                   | 25/107 (23%)                          | 59/219 (27%)          |
| After 2010                                          | 11/107 (10%)                          | 60/219 (27%)          |
| Humeral cementing (number; %)                        |                                       |                       |
| Cemented                                            | 53/79 (67%)                           | 19/199 (10%)          |
| Noncemented                                         | 26/79 (33%)                           | 180/199 (90%)         |

*Not every characteristic was available for every shoulder; some of the percents do not add to 100% because of rounding.

Table 5. Radiographic characteristics for fracture and nonfracture diagnoses*

| Characteristic                                      | Proximal humerus fracture and sequelae | Nonfracture diagnoses |
|-----------------------------------------------------|---------------------------------------|-----------------------|
| Glenoid erosion                                     |                                       |                       |
| Grade 1                                             | 30/77 (39%)                           | 88/196 (45%)          |
| Grade 2                                             | 25/77 (32%)                           | 45/196 (23%)          |
| Grade 3                                             | 20/77 (26%)                           | 55/196 (28%)          |
| Grade 4                                             | 2/77 (3%)                             | 8/196 (4%)            |
| Tuberosity status                                   |                                       |                       |
| Intact                                              | 21/79 (27%)                           | 186/195 (95%)         |
| Malunited                                           | 15/79 (19%)                           | 2/195 (1%)            |
| Nonunited                                           | 18/79 (23%)                           | 2/195 (1%)            |
| Absent                                              | 25/79 (32%)                           | 5/195 (3%)            |
| Glenohumeral centering                               |                                       |                       |
| Centered                                            | 26/71 (37%)                           | 122/181 (67%)         |
| Decentered                                          | 45/71 (63%)                           | 59/181 (33%)          |
| Superior                                            | 36/71 (51%)                           | 46/181 (25%)          |
| Anterior                                            | 21/71 (30%)                           | 21/181 (12%)          |
| Posterior                                           | 5/71 (7%)                             | 17/181 (9%)           |
| Inferior                                            | 2/71 (3%)                             | 3/181 (2%)            |
| Humeral stem loosening                              |                                       |                       |
| Not loose                                           | 74/79 (94%)                           | 197/198 (99%)         |
| Loose                                               | 5/79 (6%)                             | 1/198 (1%)            |

*Not every characteristic was available for every shoulder; some of the percents do not add to 100% because of rounding.
Table 6. Patient characteristics associated with different grades of glenoid erosion*

| Characteristic                                      | Grade 1 | Grade 2 | Grade 3 | Grade 4 |
|-----------------------------------------------------|---------|---------|---------|---------|
| Sex (number; %)                                      |         |         |         |         |
| Men                                                 | 29/118 (25%) | 16/70 (23%) | 15/75 (20%) | 1/10 (10%) |
| Women                                               | 89/118 (75%) | 54/70 (77%) | 60/75 (80%) | 9/10 (90%) |
| Age at index surgery (years, SD)                    | 55.1 ± 12.2 | 59.6 ± 12.0 | 53.6 ± 13.5 | 54.5 ± 16.3 |
| Age at revision surgery                             | 57.8 ± 11.9 | 62.9 ± 11.2 | 58.4 ± 12.6 | 60.6 ± 17.1 |
| Interval from index to revision (years, SD)          | 2.7 ± 4.5 | 3.3 ± 3.6 | 4.8 ± 5.6 | 6.1 ± 6.4 |
| Index hemiarthroplasty date (number; %)              |         |         |         |         |
| Before 2000                                          | 8/101 (8%) | 16/70 (23%) | 12/70 (17%) | 2/8 (25%) |
| From 2000 to 2005                                    | 16/101 (16%) | 21/70 (30%) | 25/70 (36%) | 3/8 (38%) |
| From 2005 to 2010                                    | 34/101 (34%) | 23/70 (33%) | 20/70 (29%) | 3/8 (38%) |
| After 2010                                           | 43/101 (43%) | 10/70 (14%) | 13/70 (19%) | 0/8 (0.0%) |
| Diagnosis at index surgery (number, %)               |         |         |         |         |
| Glenohumeral arthritis                               | 45/101 (45%) | 14/61 (23%) | 16/62 (26%) | 2/9 (22%) |
| Proximal humerus fracture                            | 24/101 (24%) | 23/61 (38%) | 17/62 (27%) | 2/9 (22%) |
| Capsulorrhaphy arthropathy                           | 13/101 (13%) | 9/61 (15%) | 8/62 (13%) | 2/9 (22%) |
| Cuff tear arthropathy                                | 6/101 (6%) | 6/61 (10%) | 8/62 (13%) | 1/9 (11%) |
| Inflammatory arthropathy                             | 2/101 (2%) | 3/61 (5%) | 3/62 (5%) | 0/9 (0%) |
| Posttraumatic                                        | 6/101 (6%) | 2/61 (3%) | 3/62 (5%) | 0/9 (0%) |
| Avascular necrosis                                   | 3/101 (3%) | 2/61 (3%) | 2/62 (3%) | 1/9 (11%) |
| Other                                               | 2/101 (2%) | 2/61 (3%) | 5/62 (8%) | 1/9 (11%) |
| Humeral stem (number; %)                             |         |         |         |         |
| Cemented                                            | 23/117 (20%) | 20/70 (29%) | 23/75 (31%) | 4/10 (40%) |
| Noncemented                                         | 94/117 (80%) | 50/70 (71%) | 52/75 (69%) | 6/10 (60%) |
| Tuberosity status (number, %)                        |         |         |         |         |
| Intact                                              | 91/118 (77%) | 50/70 (71%) | 56/71 (79%) | 7/10 (70%) |
| Malunion/nonunion/absent                             | 27/118 (23%) | 2070 (29%) | 15/71 (21%) | 3/10 (30%) |
| Glenohumeral centering (number; %)                   |         |         |         |         |
| Centered                                            | 77/108 (71%) | 33/62 (53%) | 32/69 (46%) | 4/9 (44%) |
| Decentered                                          | 31/108 (29%) | 29/62 (47%) | 37/69 (54%) | 5/9 (56%) |
| Superior                                            | 19        | 24     | 33     | 5     |
| Inferior                                            | 3         | 1      | 0      | 1      |
| Anterior                                            | 16        | 14     | 9      | 2      |
| Posterior                                           | 6         | 9      | 7      | 0      |
| Humeral stem loosening (number; %)                   |         |         |         |         |
| Not loose                                           | 115/117 (98%) | 70/70 (100%) | 73/75 (97%) | 8/10 (80%) |
| Loose                                               | 2/117 (2%) | 0/70 (0%) | 2/75 (3%) | 2/10 (20%) |
| Varus/valgus angle (number; %)                       |         |         |         |         |
| < 40° (varus)                                       | 11/107 (10%) | 13/63 (21%) | 4/64 (6%) | 0/8 (0.0%) |
| 40° to 50° (neutral)                                | 89/107 (83%) | 35/63 (56%) | 35/64 (55%) | 5/8 (63%) |
| > 50° (valgus)                                      | 7/107 (7%) | 15/63 (24%) | 25/64 (39%) | 3/8 (38%) |

*Not every characteristic was available for every shoulder; some of the percents do not add to 100% because of rounding.
The results of this study should be viewed in light of some important limitations. First, this was a retrospective study of patients presenting for revision surgery to a regional shoulder center; therefore, our results may be different from those of studies of other patient groups. Specifically, the patients in this series were selected for revision because the surgeons in our center believed that there was a surgically manageable mechanical issue with the shoulder and that the patient was a good candidate for revision surgery. In that each shoulder was revised only after surgeon-patient shared decision-making, it is quite possible that different selections would be reached in other practices. While this study focused on patients having primary hemiarthroplasties who underwent revision surgery, it is likely that a substantial number of patients having primary hemiarthroplasties with poor clinical outcomes do not undergo revision surgery because of patient or surgeon disinclination for a second procedure; information regarding these hemiarthroplasties could not be included in our study [15]. Second, because we do not have the data on the population from which these patients were drawn, the study does not allow us to report the rates of revision or the relative risk associated with the characteristics of the patient or shoulder. Third, we did not have the opportunity to evaluate the glenoid bone quality, greater tuberosity integrity, and glenohumeral relationships before or immediately after the primary hemiarthroplasty [20]. Fourth, 24% (86 of 359) of our patients lacked prerevision radiographs of adequate quality for analysis; we do not, however, have reason to believe that this loss was selective in a way that would bias the results. Fifth, while some designs of humeral prostheses might be more prone to problems of component positioning, tuberosity stability, or glenoid erosion, we were unable to document the effect of different component designs on the nature of hemiarthroplasty revision.

Despite these limitations, this study suggests that there are at least three issues that surgeons can consider in striving for improved outcomes from primary shoulder arthroplasty: the problem of cuff failure, the special features of arthroplasty for fractures, and the problem of glenoid erosion.

Many of the revised hemiarthroplasties in this series were associated with rotator cuff deficiency noted at the time of revision. It cannot be determined with certainty whether these cuff deficiencies existed at the time of the primary hemiarthroplasty or developed subsequently owing to tissue quality rendered tenuous by subsequent age-related degeneration or injury. However, in performing a hemiarthroplasty the surgeon is in a position to directly assess the quality of the cuff tendons and their attachment to the greater tuberosity. When the cuff appears frail at the time of the primary procedure, the surgeon may consider an alternative procedure, such as a reverse total shoulder arthroplasty [50].

As observed by previous authors, a large proportion of unsatisfactory hemiarthroplasties were performed initially for fracture-related diagnoses [4, 7, 16, 36]; such cases often showed nonunited or malunited tuberosities, glenohumeral decentering, and humeral loosening. These observations indicate the difficulty of prosthetic reconstruction for a fractured proximal humerus. In this setting, implantation of the body of a hemiarthroplasty prosthesis can limit the amount of bone available for tuberosity fixation and bone-to-bone healing. The loss of the tuberosities removes important support for the humeral component and the landmarks for humeral component positioning [6, 7]. Proximal humeral fractures often are sustained by elderly women with poor bone quality [8]. Tuberosity healing problems have been associated with superior migration, stiffness, and pain [7]. Unless the tuberosities can be secured in contact with solid proximal humeral bone, the surgeon may decide to immobilize the shoulder in the hope of improving the chances for healing; this delay in mobilization may further compromise the functional outcome. These challenges of anatomic prosthetic reconstruction suggest consideration of the reverse total shoulder arthroplasty, rather than hemiarthroplasty, in the treatment of proximal humeral fractures that cannot be securely managed with internal fixation [1, 13, 40, 47].

Erosion of the glenoid bone was a prominent feature among the revised hemiarthroplasties. The presence and severity of glenoid erosion was associated with humeral head decentering and valgus positioning of the humeral component, but not with the diagnosis before the index hemiarthroplasty. Decentering may contribute to glenoid erosion by giving rise to eccentric bone loading with diminished contact area to support the humeral head force, resulting in increased glenoid bone wear. Decentering may result from implantation of a humeral hemiarthroplasty prosthesis in a shoulder with uncorrected posterior glenoid erosion—a common finding in osteoarthritis and in capsulorrhaphy arthropathy [25]. Decentering also may result from technical factors, such as inadequate soft tissue balancing or humeral component malpositioning. At the time of surgery, centering can be optimized by managing glenoid surface biconcavity, by properly orienting the humeral component, by assuring cuff integrity, by soft tissue balancing, and by the use of humeral sided balancing measures, such as an eccentric humeral head component [22]. Valgus positioning of the humeral component in the humeral shaft was associated with increased glenoid erosion as reported by Herschel et al. [20]. A valgus component position may give rise to locally increased joint pressure when the arm is in an adducted position where the inferior corner of the humeral head is pressed into the glenoid bone surface. Surgical attention to centering the humeral...
component in the medullary canal may help minimize valgus positioning, especially in fracture cases or in cases where a short humeral component stem is used.

Conclusions

The results of this study suggest that surgical attention to the challenge of cuff integrity and to achieving proper and secure humeral component positioning with centering of the humeral head in the glenoid are important for successful shoulder hemiarthroplasty. Some revisions of primary hemiarthroplasties may be avoided by surgical techniques directed at centering the prosthetic humeral articular surface on the glenoid concavity using proper humeral component positioning and soft tissue balance, by avoiding valgus positioning of the humeral component, and by managing glenoid disorders with a primary glenohumeral arthroplasty rather than a hemiarthroplasty alone. When durable security of the subscapularis, rotator cuff, and tuberosities is in question, the surgeon may consider a reverse total shoulder arthroplasty.

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