Preoperative Factors Associated with Improvements in Shoulder Function After Humeral Hemiarthroplasty

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PREOPERATIVE FACTORS ASSOCIATED WITH IMPROVEMENTS IN SHOULDER FUNCTION AFTER HUMERAL HEMIARTHROPLASTY

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Background: The relationship between the characteristics of the shoulder that can be determined before humeral hemiarthroplasty and the functional improvement after surgery is not known. The goal of this study was to test the hypothesis that the functional outcome of this procedure correlated significantly with factors that are identifiable preoperatively.

Methods: The study group included seventy-one shoulders in sixty-eight patients undergoing hemiarthroplasty, performed by the same surgeon, for diagnoses other than acute fracture. The mean age of the patients was sixty-one years (range, thirty to eighty-three years). The results were characterized in terms of the change in self-assessed shoulder function and general health status at an average of forty-nine months (range, twenty-four to 142 months) after surgery.

Results: The preoperative absence of erosion of the glenoid was associated with greater improvement in shoulder function and level of comfort after hemiarthroplasty ($p < 0.001$). Shoulders that had not had previous surgery had greater functional improvement than did those that had previous surgery ($p = 0.012$). Shoulders with an intact rotator cuff showed significantly ($p < 0.5$) greater improvement in the ability to lift weight above shoulder level after hemiarthroplasty ($p < 0.5$). With regard to diagnoses, shoulders with rheumatoid arthritis, capsulorrhaphy arthropathy, and cuff tear arthropathy had the least functional improvement, whereas those with osteonecrosis ($p = 0.0004$) and with primary ($p = 0.02$) and secondary degenerative joint disease ($p = 0.03$) had the greatest improvement. Patient age and gender did not significantly affect the outcome.

Conclusions: These results suggest that the functional improvement following humeral hemiarthroplasty is related to factors that are identifiable before surgery. These data may be of benefit in preoperative discussions with patients who have a shoulder disorder and are considering treatment with hemiarthroplasty.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

Because of concerns about the longevity of glenoid prostheses, humeral hemiarthroplasty continues to be used for patients with primary glenohumeral arthritis[1-9], secondary degenerative joint disease[10], osteonecrosis of the humeral head[2,11], and a combined loss of the glenohumeral joint surface and rotator cuff[3,12-17]. Published reports have indicated a large variation in the benefits of this procedure from patient to patient. For example, in a recent series of thirty-three shoulders treated with hemiarthroplasty because of cuff tear arthropathy, eleven had unsatisfactory results[15]. In a recent long-term study of seventy-four hemiarthroplasties in young patients, thirty-five had an unsatisfactory result after a minimum follow-up period of five years (mean, twelve years)[18].

While it is recognized that factors observed at the time of surgery, such as the quality of the cartilage, bone, and rotator cuff, may influence the result of arthroplasty, we were critically interested in what preoperative information may be associated with greater improvement in patient-assessed function after this procedure and we believed that preoperative decision-making by patients and their surgeons could be better informed if such factors were identified. The purpose of this study was to test the hypothesis that the functional improvement following humeral hemiarthroplasty is related to factors that can be identified before surgery, such as a pre-

TABLE I Characteristics of Shoulders Treated with Hemiarthroplasty

Diagnosis	No. of Shoulders/ No. of Patients	No. of Female Patients	Age* *(yr)*	No. of Shoulders with Glenoid Erosion/No. of Radiographs	No. of Shoulders with Cuff Tear	Duration of Follow-up* *(mo)*
Posttraumatic arthritis	7/7	5	59 ± 13	1/5	1	33.9
Osteonecrosis	11/9	7	43 ± 18	0/11	1	50.6
Cuff-tear arthropathy	23/23	11	69 ± 6	23/23	23	49.0
Degenerative joint disease	8/8	3	61 ± 15	2/5	0	54.4
Secondary degenerative joint disease	12/12	5	54 ± 16	4/4	1	54.8
Capsulorrhaphy arthropathy	3/3	1	48 ± 19	1/3	1	46.6
Rheumatoid arthritis	7/6	6	62 ± 8	4/5	3	43.2
Entire group	71/68	38	61 ± 16 (30-83)	35/56	30	49.0 ± 24 (24-142)

*The values are given as the average and the standard deviation, with the range in parentheses.

vious operation, the status of the cuff and glenoid, and the specific diagnosis.

Materials and Methods

With the exclusion of procedures for the management of acute fractures and nonunions, eighty-six primary shoulder hemiarthroplasties were performed by the senior author (F.A.M. III) between January 1, 1990, and October 1, 1999. Each patient was invited to complete and submit a follow-up self-assessment questionnaire, which was mailed to his or her home as a part of our quality assurance program. Our institutional review board approved our use of these data for research. This report concerns the seventy-one shoulders in sixty-eight patients who provided follow-up data at least twenty-four months (mean, forty-nine months; range, twenty-four to 142 months) after surgery.

The preoperative characteristics assessed for each shoulder were (1) patient age, (2) patient gender, (3) diagnosis, (4) the presence or absence of a full-thickness rotator cuff tear as assessed by tendon imaging, (5) a previous operation, (6) a standardized and validated shoulder function questionnaire, the Simple Shoulder Test, completed before surgery[19-34], and (7) the general health status as assessed by the Short Form-36 (SF-36)[25,32,35-39]. The importance and validity of patient self-assessents, including the Simple Shoulder Test and the SF-36, in this type of clinical research have been described[40,41].

The preoperative appearance of the glenoid on standardized anteroposterior and axillary radiographs was characterized on the basis of previously described methods[5,42-44]. The classification was initially conducted independently by three of the authors who were asked to classify each glenoid as uneroded, superiorly eroded, posteriorly eroded, medially eroded, or anteriorly eroded according to the dominant direction of the erosion. As the preoperative radiographs of fifteen of the seventy-one shoulders had been lost or destroyed, fifty-six glenoids were included in the analysis. All three authors agreed in the assessment of forty-eight of the fifty-six glenoids. One disagreed in the assessment of six of them, and all three disagreed in the assessment of two. The disagreement in these eight cases was resolved by discussion among the three reviewers so that each shoulder could be included in the statistical analysis.

The diagnoses, gender, age, and length of follow-up for the sixty-eight patients (seventy-one shoulders) are provided in Table I. Each patient underwent a shoulder hemiarthroplasty performed by the same surgeon with use of a consistent technique, including a deltopectoral approach and insertion of a prosthetic humeral head that duplicated the curvature of the biological head and a prosthetic stem that was press-fit in the medullary canal (Global; DePuy, Warsaw, Indiana) without cement and with soft-tissue balancing to allow external rotation to 40°, translation of 50% of the width of the glenoid on posterior drawer testing, and 60° of internal rotation with the arm in 90° of abduction[45]. The prosthetic heads ranged in diameter from 48 to 56 mm, with a median of 52 mm. The glenoid was not surgically altered.

The postoperative protocol included immediate postoperative continuous passive motion with use of a device that was custom-made at our university. Continuous passive motion was implemented for the first thirty-six hours after surgery and was discontinued for meals and walking. Patient-conducted active-assisted range-of-motion exercises were started on the first postoperative day. The same shoulder function questionnaire and general health-status questionnaire that had been administered preoperatively were administered at six-month intervals during the follow-up period.

Data Analysis

The total number of shoulder functions that could be performed, the SF-36 scores before and after surgery, and patient age were considered to be parametric variables. The diagnosis, gender, presence of a cuff tear, prior surgery, and the radio-

TABLE II Functional Improvement for the Seventy-one Shoulders as Reflected on the Simple Shoulder Test*

Function	No. of Shoulders Able to Perform Function		P Value*
	Preop.	Postop.	
Place arm comfortably at side	40	61	**<0.00004**
Sleep comfortably	13	45	**<0.000000009**
Tuck in back of shirt	23	41	**<0.0008**
Place hand behind head	23	37	**<0.003**
Place coin on a shelf	32	37	<0.07
Place 1 lb (0.5 kg) on a shelf	21	39	**<0.0003**
Place 8 lb (3.6 kg) on a shelf	5	18	**<0.0006**
Carry 20 lb (9.1 kg)	33	43	**<0.03**
Toss underhand	18	33	**<0.006**
Throw overhand	5	15	**<0.02**
Wash back of contralateral shoulder	9	31	**<0.000005**
Do usual work	21	30	<0.14

*The values in boldface type indicate a significant difference.

graphic condition of the glenoid were considered to be nonparametric variables. Preoperative and postoperative results for shoulder function and health status were compared for different groups with use of the paired t test. Comparison among groups was performed with use of analysis of variance. Chi-square analysis was used to compare the distribution of shoulders among categories.

Results

Overall, the patients undergoing hemiarthroplasty had significant improvements in shoulder function with an increase in the average number of shoulder functions that could be performed from 3.4 to 6.0 ($p < 0.00000003$), for an average improvement (and standard deviation) of 2.6 ± 3.6 functions. The improvement in the total number of functions was not significantly correlated with age ($R^2 = 0.04$).

Ten of the twelve individual shoulder functions also were significantly improved for the entire study population (Table II). The SF-36 comfort score (also known as the pain scale) for the entire study population improved from 31 to 52 ($p < 0.000000005$). The remaining scores did not improve significantly.

The average preoperative and postoperative shoulder function and SF-36 comfort scores were compared for each of the seven diagnoses (see Appendix). For shoulders with osteonecrosis, hemiarthroplasty led to the greatest improvement in function (from 3.9 to 9.1 functions; $p = 0.00004$) and comfort (from a score of 27.8 to 61.1; $p = 0.0004$). Hemiarthroplasty significantly improved the function of shoulders with secondary degenerative joint disease (from 3.9 to 6.2 functions; $p = 0.03$) and primary degenerative joint disease (from 3.3 to 5.4 functions; $p = 0.02$). The average comfort scores also improved for shoulders in these two disease categories (from 30.5 to 63.2 [$p = 0.007$] and from 26.3 to 37.4 [$p = 0.005$], respectively).

Table III demonstrates that hemiarthroplasty led to a significant improvement in shoulder function for patients of either gender, with an average increase in the number of functions that could be performed from 2.6 to 5.1 for females ($p = 0.0002$) and 4.1 to 6.7 for males ($p = 0.0001$), but the difference between the gender groups with respect to the increase in function was not significant. Function significantly improved for patients who had not had previous surgery (from an average of 3.1 to 6.8 functions; $p = 0.000000008$), but it improved only marginally for those who had previous shoulder surgery (from an average of 3.3 to 4.5 functions; $p = 0.05$); the increase in function was significantly greater for those who had not had previous surgery ($p = 0.012$). Hemiarthroplasty led to a significant improvement in the average shoulder function for patients without a rotator cuff tear (from 3.4 to 7.0 functions; $p = 0.0000007$) or with a rotator cuff tear (from 2.9 to 5.1 functions; $p = 0.0007$); the difference between these groups was not significant ($p = 0.11$). However, patients with an intact rotator cuff had a significantly greater improvement after hemiarthroplasty than did those who had a rotator cuff tear with respect to the ability to place a coin on a shelf at shoulder level ($p = 0.009$), to lift 1 lb (0.5 kg) to the level of the shoulder ($p = 0.02$), and to lift 8 lb (3.6 kg) to the level of the shoulder ($p = 0.01$).

For the fifty-six shoulders for which preoperative radiographs were available, the assessment of glenoid erosion demonstrated that hemiarthroplasty improved the function of the shoulders with or without glenoid erosion; those without glenoid erosion had an average increase in the number of functions that could be performed from 3.3 to 8.4 functions ($p = 0.0001$), and those with glenoid erosion had an average increase of 3.0 to 4.7 functions ($p = 0.0017$). The results were

TABLE III Differences in Shoulder Function Preoperatively and Postoperatively with Respect to Previous Surgery, Cuff Tear, and Glenoid Surface

Characteristic	Average Result on Simple Shoulder Test		P Value for Difference*	P Value for Parameter†
	Preop.	Postop.		
Female gender (n = 40)	2.6	5.1	**0.0002**	NS
Male gender (n = 33)	4.1	6.7	**0.0001**	
Cuff intact (n = 41)	3.4	7.0	0.0000007	0.11
Cuff tear (n = 30)	2.9	5.1	**0.0007**	
Uneroded glenoid bone‡ (n = 21)	3.3	8.4	**0.0001**	0.001
Eroded glenoid bone (n = 40)	3.0	4.7	**0.0017**	
Previous surgery (n = 19)	3.3	4.5	0.05	0.012
No previous surgery (n = 52)	3.1	6.8	**0.000000008**	

*The values in boldface type represent a significant difference. †NS = not significant. ‡Preoperative radiographs were not available for fifteen shoulders.

significantly better for shoulders without glenoid erosion ($p = 0.001$). Although data for fifteen shoulders were not available, we suggest that the absence of these preoperative radiographs would be unlikely to inject a bias that would detract from the significance of the findings. In fact, as a worst-case scenario, if it is assumed that each of the shoulders with missing preoperative radiographs showed uneroded bone yet had the poor improvement in function seen with the shoulders with eroded bone (an average increase of 1.7 functions), the average improvement for this hypothetical group of "uneroded" glenoids would be 3.45 functions, or twice the value for the group with erosion. The number of glenoids in the different groups was insufficient to determine whether the functional improvement associated with the different patterns of erosion was significant. A linear regression of the improvement in shoulder function compared with patient age showed a lack of significant correlation; there was only a small negative slope of –0.03 function per year ($R^2 = 0.0185$). The relationship between the improvement in shoulder function and the different parameters included in this analysis for each of the patients in this study is presented graphically in the Appendix.

Discussion

The present study is one of the first to show the association between certain preoperative characteristics and the improvement in self-assessed shoulder function and level of comfort following hemiarthroplasty. We found greater improvement with respect to self-assessed function and level of comfort in patients who had not had previous surgery, who had no radiographic evidence of glenoid erosion, and who did not have a full-thickness rotator cuff tear. The least improvement in function occurred in shoulders with rheumatoid arthritis, capsulorrhaphy arthropathy, and cuff tear arthropathy, while the greatest improvement was observed in shoulders with osteonecrosis and those with primary and secondary degenerative joint disease.

These results are consistent with those in studies that used a variety of outcome measures to evaluate the individual characteristics of shoulders treated with shoulder arthroplasty[5,11,46-49]. In a study of total arthroplasty and hemiarthroplasty that was limited to patients with primary osteoarthritis, Iannotti and Norris[46] found that patients with <10° of passive external rotation preoperatively had substantially less improvement in external rotation after hemiarthroplasty. Thirteen of the 128 shoulders had a repairable full-thickness tear of the supraspinatus tendon, but these tears did not affect the overall score according to the system of the American Shoulder and Elbow Surgeons, the decrease in pain, or patient satisfaction. Severe or moderate eccentric glenoid erosion was seen in twenty-nine of the 128 shoulders, and total shoulder arthroplasty resulted in substantially better passive total elevation and active external rotation as well as a trend toward substantially better active forward flexion than did hemiarthroplasty in these shoulders. The humeral head was subluxated posteriorly in twenty-three shoulders. When compared with the other shoulders in the study, these shoulders were found to have lower final scores according to the system of the American Shoulder and Elbow Surgeons, increased pain, and decreased active external rotation following either total shoulder arthroplasty or hemiarthroplasty.

Kay and Amstutz found better results in patients with osteonecrosis compared with those who had a fracture[11]. Levine et al. reported that thirteen of fifteen patients with a concentric glenoid achieved a satisfactory result following hemiarthroplasty compared with ten of sixteen patients with a nonconcentric glenoid[5]. Trail and Nuttall[47] found that an intact rotator cuff was associated with a better outcome in patients with rheumatoid arthritis. Sperling et al.[48] noted inferior results after shoulder arthroplasty for the treatment of arthritis following instability surgery. Levy and Copeland[49] found poorer outcomes in patients with cuff tear arthropathy and posttraumatic arthropathy than in those with other diagnoses.

The present study had certain limitations: (1) the patient sample was from the practice of one surgeon; thus, the results may not be generalized to other patient populations; (2) the choice of treatment was limited to hemiarthroplasty and was not compared with other treatment modalities; (3) many other factors, such as comorbidities, socioeconomic considerations, and mental attitude, may have affected the patients' self-assessment of their function and health status; (4) the assignment to the different diagnostic groups was performed by the surgeon and not by independent observers; and (5) data on glenoid erosion were not available for fifteen of the seventy-one shoulders. It is also recognized that the variables included in this study are not independent. We did not attempt to determine the relative influence of the different factors on the outcome of hemiarthroplasty.

In our patient population, the degree to which hemiarthroplasty improved patient self-assessed shoulder function was significantly associated with the characteristics of the shoulder that can be determined before surgery, including the integrity of the rotator cuff, the absence of glenoid erosion, the absence of previous surgery, and the specific diagnosis. These associations may be of use in preoperative decision-making by surgeons and patients considering shoulder hemiarthroplasty.

Appendix

eA A table showing changes in function and comfort according to diagnosis and a chart showing the changes in the Simple Shoulder Test scores for each patient are available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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