

INFLUENCE OF PREOPERATIVE FACTORS ON OUTCOME OF SHOULDER ARTHROPLASTY FOR GLENOHUMERAL OSTEOARTHRITIS

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Background: The results of shoulder arthroplasty for osteoarthritis have been reported to be excellent or good for the majority of patients, but the value of using a glenoid component and the anatomic factors that affect outcome are still debated. The purpose of this study was to evaluate the influence of an operatively confirmed full-thickness tear of the rotator cuff, the severity of preoperative erosion of glenoid bone, preoperative radiographic evidence of subluxation of the humeral head, and the severity of preoperative loss of the passive range of motion on the outcome of total shoulder arthroplasty and hemiarthroplasty.

Methods: In a multicenter clinical outcome study, we evaluated 128 shoulders in 118 patients with primary osteoarthritis who had been followed for a mean of forty-six months (range, twenty-four to eighty-seven months).

Results: Patients with $<10^\circ$ of passive external rotation preoperatively had significantly less improvement in external rotation after hemiarthroplasty ($p = 0.006$). Thirteen (10%) of the 128 shoulders had a repairable full-thickness tear of the supraspinatus tendon, but these tears did not affect the overall American Shoulder and Elbow Surgeons score, the decrease in pain, or patient satisfaction. Severe or moderate eccentric glenoid erosion was seen in twenty-nine (23%) of the 128 shoulders, and total shoulder arthroplasty resulted in significantly better passive total elevation and active external rotation as well as a trend toward significantly better active forward flexion than did hemiarthroplasty in these shoulders. The humeral head was subluxated posteriorly in twenty-three shoulders (18%), and when they were compared with the other shoulders in the study, these shoulders were found to have lower final American Shoulder and Elbow Surgeons scores, more pain, and decreased active external rotation following either total shoulder arthroplasty or hemiarthroplasty.

Conclusions: On the basis of our data, we recommend the use of a glenoid component in shoulders with glenoid erosion. Humeral head subluxation was associated with a less favorable result regardless of the type of shoulder arthroplasty and must be considered in preoperative planning and counseling. Severe loss of the passive range of motion preoperatively was associated with a decreased passive range of motion postoperatively. A repairable tear of the supraspinatus tendon is not a contraindication to the use of a glenoid component.

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

The effect of disease severity on the outcome of shoulder arthroplasty has rarely been studied in a cohort of patients with primary osteoarthritis¹. Although the effect of a large rotator cuff tear on the outcome of prosthetic arthroplasty has been studied^{2,11}, the effect of a small rotator cuff tear in a patient with primary osteoarthritis has not been clearly defined. Asymmetric glenoid bone loss associated with

osteoarthritis has been reported to have an adverse effect on the outcome of hemiarthroplasty, and total shoulder arthroplasty has been recommended for such patients¹. To our knowledge, no one has compared the outcomes of total shoulder arthroplasty and hemiarthroplasty in patients with eccentric glenoid bone loss. We hypothesized that glenoid bone erosion, humeral head subluxation, preoperative loss of motion, and a rotator cuff tear would have an adverse effect on the outcome of prosthetic arthroplasty. We also hypothesized that the effect of these factors on the outcome would vary depending on whether a glenoid component had been used.



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Materials and Methods

Between August 1990 and September 1993, fifteen North American investigators prospectively enrolled 154 consecutive patients with 170 shoulders affected by primary osteoarthritis of the glenohumeral joint in the study. Twenty-nine shoulders in twenty-seven patients were excluded because of inadequate follow-up, three shoulders (two patients) were excluded because the patients refused to return for a follow-up evaluation, and ten shoulders (seven patients) were lost because of death. The results of 128 shoulder arthroplasties were evaluated at a minimum of twenty-four months and a mean of

forty-six months (range, twenty-four to eighty-seven months) postoperatively. The present study represents a further analysis of the data presented in the previous report¹².

Seventy-nine shoulders (62%) were in men, and forty-nine were in women. The ages ranged between forty and eighty-five years, with a mean of sixty-four years, and 91% of the patients were between the ages of fifty and seventy-nine years. The majority of the shoulders (ninety-five; 74%) underwent total shoulder arthroplasty, and the remainder (thirty-three; 26%) underwent hemiarthroplasty.

No patient had had open surgery or a fracture before the



Fig. 1-A

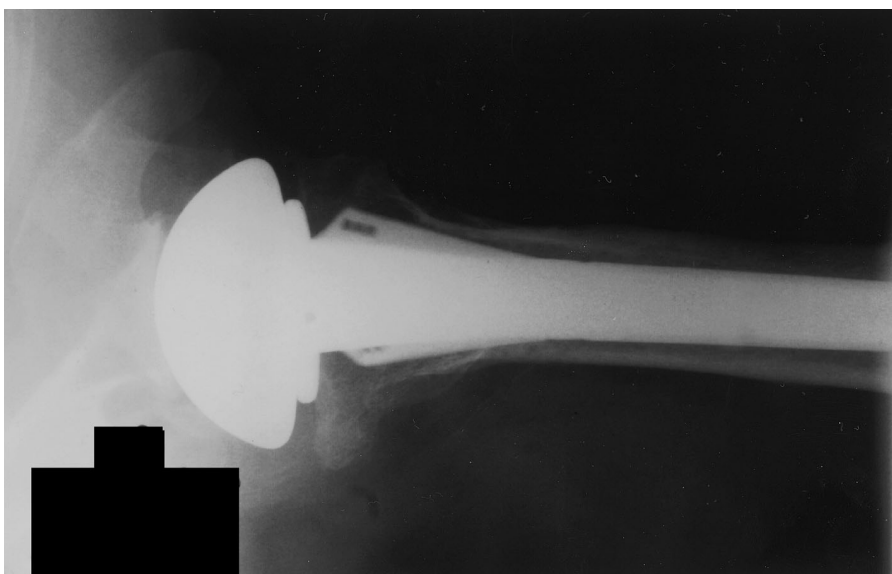


Fig. 1-B

Preoperative (Fig. 1-A) and postoperative (Fig. 1-B) axillary radiographs showing a typical case of primary osteoarthritis with moderate-to-severe posterior glenoid erosion.

shoulder arthroplasty. Patients were screened radiographically for glenohumeral osteoarthritis with use of criteria typical of the advancing stages. These included narrowing of the glenohumeral joint space, marginal osteophytes around the humeral head, progressive changes with sclerosis and subcortical cystic formation on both sides of the joint, and flattening of the humeral head. Some patients had progressive erosion of the posterior part of the glenoid, and some had fixed posterior subluxation of the humeral head. We had excluded shoulders with radiographic hallmarks of inflammatory arthritis, such as marked osteopenia, absence of marginal osteophytes, and periarticular cyst formation.

Surgical Technique

All of the shoulder arthroplasties were performed with use of a DePuy Global Shoulder modular prosthesis (DePuy [Johnson and Johnson], Warsaw, Indiana) (Figs. 1-A through 2-B). The humeral component was made of cobalt-chromium and had a reverse Morse-taper link with the humeral head, which was also made of cobalt-chromium. The proximal half of the humeral component was textured and was designed for use with or without cement. The glenoid component was manufactured from ultra-high molecular weight polyethylene and was available in two designs, keeled and pegged, both of which required implantation with bone cement. During this period, the polyethylene implants were sterilized with gamma irradiation in air.

The participating surgeons used a deltopectoral approach with a subscapularis tenotomy, leaving the deltoid origin and insertion intact. An extensive release of the anterior and inferior aspects of the capsule was performed. The capsule

was detached from the humeral and glenoid attachment sites in order to free the subscapularis tendon from any capsular contracture that was present. The subscapularis tendon was detached from the lesser tuberosity and was reattached to the osteotomy surface, thereby functionally lengthening it by approximately 1 cm. In all patients with posterior glenoid erosion, the anterior glenoid rim was reamed to help decrease glenoid retroversion. The decision to perform a total shoulder replacement or a hemiarthroplasty was left to the discretion of each participating surgeon. By design, the two types of all-polyethylene glenoid components were always cemented. An attempt was made to fill the humeral canal with a press-fit uncemented prosthetic stem, but if rotational stability could not be achieved, the humeral component was cemented in place. The presence of a rotator cuff tear was determined with direct observation at the time of surgery, and its maximum dimension was measured. Full-thickness rotator cuff tears were repaired with nonabsorbable sutures to the greater tuberosity.

Clinical Assessment

The treating surgeon performed a clinical assessment preoperatively and at one-year intervals postoperatively for at least two years. Patient self-assessment questionnaires including the American Shoulder and Elbow Surgeons score¹³ (which is an overall shoulder score based on ten questions concerning functional activities of daily living, pain, and patient satisfaction) were administered preoperatively and at the last follow-up visit. The level of pain at rest and with activities of daily living, patient satisfaction, and an overall rating of quality of life were each rated on a visual analog scale. Active and passive total



Fig. 2-A



Fig. 2-B

Preoperative (Fig. 2-A) and postoperative (Fig. 2-B) axillary radiographs showing a case of primary osteoarthritis with humeral head subluxation.

TABLE I Preoperative and Postoperative Pain, Satisfaction, Quality-of-Life, and American Shoulder and Elbow Surgeons Scores After Hemiarthroplasty and Total Shoulder Arthroplasty for the Treatment of Osteoarthritis*

	Pain		Satisfaction		Quality of Life		American Shoulder and Elbow Surgeons Score ¹³	
	Preop.	Postop.	Preop.	Postop.	Preop.	Postop.	Preop.	Postop.
Hemiarthroplasty	73 ± 20	20 ± 24	78 ± 19	18 ± 24	61 ± 28	17 ± 27	35 ± 15	79 ± 21
Total shoulder arthroplasty	74 ± 23	14 ± 20	75 ± 18	15 ± 22	65 ± 26	12 ± 19	33 ± 18	86 ± 17

*The values are given, in points, as the mean and the standard error of the mean.

shoulder elevation as well as internal and external rotation with the arm by the side and in abduction were measured by the physician with a goniometer preoperatively and at one-year intervals. All data were submitted to a central database for analysis.

Radiographic Assessment

The radiographic evaluation included an anteroposterior view made perpendicular to the plane of the scapula and an axillary view. If an adequate axillary view could not be made, a limited axial computed tomographic scan was performed. All radiographs were submitted to a central database. Both of us evaluated the radiographs in a blinded fashion. We each measured the parameters of humeral head subluxation and glenoid erosion independently, and if there was a difference in our findings, a final measurement was determined by consensus.

Loss of glenoid bone was measured on the axillary radiograph or computed tomographic scan. A straight line was drawn parallel to the scapular body. A line perpendicular to this line was drawn from the anterior glenoid margin, and the amount of bone from the posterior edge of the glenoid to the perpendicular line was measured in millimeters. Mild glenoid bone loss was considered to be <5 mm; moderate loss, between 5 and 10 mm; and severe loss, >10 mm (Fig. 3).

Subluxation of the humeral head was measured on the axillary radiograph. The center of the humeral head was determined with use of concentric best-fit circles. The center point between the anterior and posterior aspects of the glenoid rim was marked on a line perpendicular to the scapular body. The distance from the center of the humeral head to the center of the glenoid was measured and was divided by the diameter of the humeral head. The humeral head was considered centered in the glenoid if the distance between the center of the humeral head and the center of the glenoid was within 25% of the humeral head diameter. If the distance was >25% of the humeral head diameter, the head was considered to be subluxated (Fig. 4).

Statistical Analysis

Continuous variables such as age, range of motion, American Shoulder and Elbow Surgeons scores, and scores on the visual analog scales were assessed with use of analysis of variance and the Student t test. Categorical variables such as gender, activities of daily living, rotator cuff status, and glenoid wear were examined with use of the Fisher exact test. The type of surgery (hemiarthroplasty or total shoulder arthroplasty); the presence or absence of glenoid bone loss, a rotator cuff tear, and

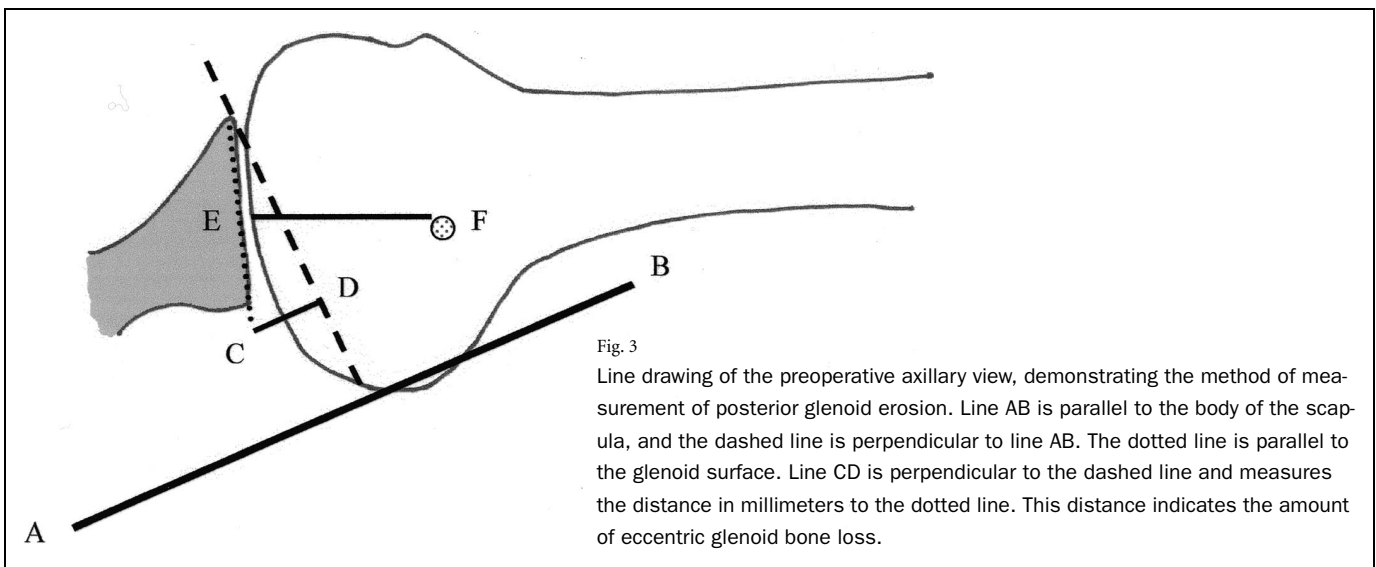


Fig. 3

Line drawing of the preoperative axillary view, demonstrating the method of measurement of posterior glenoid erosion. Line AB is parallel to the body of the scapula, and the dashed line is perpendicular to line AB. The dotted line is parallel to the glenoid surface. Line CD is perpendicular to the dashed line and measures the distance in millimeters to the dotted line. This distance indicates the amount of eccentric glenoid bone loss.

humeral head subluxation; and the preoperative passive range of motion were analyzed in relation to preoperative and postoperative function and clinical parameters of outcome.

The statistical method used for each comparison is indicated within the text. All results are reported as the mean and the standard error of the mean. A difference was considered significant when the p value was ≤ 0.05 , and a trend was reported when the p value was >0.05 but ≤ 0.1 . Analysis of variance was performed to assess the effect of the rotator cuff status, the type of operation (hemiarthroplasty or total shoulder arthroplasty), and the interaction between the rotator cuff status and the type of operation on the American Shoulder and Elbow Surgeons scores. This analysis was repeated separately for the other outcome variables (range of motion and visual analog scores). The purpose of these multiple tests was to exclude a "false-positive" statistical correlation due to statistical chance that occurred as a result of a large number of comparisons and an alpha (type-1 error) of 0.05. In addition to relying on the results of the analyses of variance, we also examined patterns of difference across outcome variables to determine whether hemiarthroplasty or total shoulder arthroplasty provided a small but relatively consistent advantage in terms of outcomes associated with a particular factor.

Results

No significant difference was noted in the mean age at the time of the surgery between the patients treated with total arthroplasty (sixty-four years) and those treated with hemiarthroplasty (sixty-six years) (two-sided t test). Thirty-six (73%) of the forty-nine shoulders in women were treated with a total shoulder arthroplasty compared with fifty-nine (75%) of the seventy-nine shoulders in men. That difference

was also not significant (two-tailed Fisher exact test).

Both the total shoulder arthroplasties and the hemiarthroplasties provided significant improvements ($p < 0.0001$; paired two-tailed t tests), compared with the preoperative baseline values, in the visual analog scores, American Shoulder and Elbow Surgeons scores, and range-of-motion measures (Table I). The visual analog scores for pain, patient satisfaction, and quality of life did not differ between the treatment groups. The improvement in the American Shoulder and Elbow Surgeons function score, which averaged 50 (of 100) points in the total patient population, was slightly less after the hemiarthroplasties than after the total shoulder arthroplasties; the difference was not significant but may be interpreted as a trend ($p = 0.10$). Overall, mean active total elevation improved from $102^\circ \pm 2.3^\circ$ preoperatively to $138^\circ \pm 2.5^\circ$. Mean active external rotation increased from $14^\circ \pm 1.7^\circ$ to $45^\circ \pm 1.7^\circ$.

Intraoperative Complications

Intraoperative complications occurred in ten (8%) of the 128 shoulders. There were nine fractures, four of which were periprosthetic fractures of the humeral shaft. One of the four was a stable crack at the distal part of the prosthetic stem, secondary to oversizing of the distal part of the stem, and it was not detected until the first postoperative radiograph was made. It was treated with a decrease in the intensity of the rehabilitation program for six weeks, and it healed uneventfully. Another of the diaphyseal fractures was stabilized with two cortical bone screws, and a third was stabilized immediately with a long-stem prosthesis and two cerclage wires. These two fractures also healed. However, the fourth fracture of the humeral shaft required three operative procedures to achieve a successful union and a functional result. All four patients

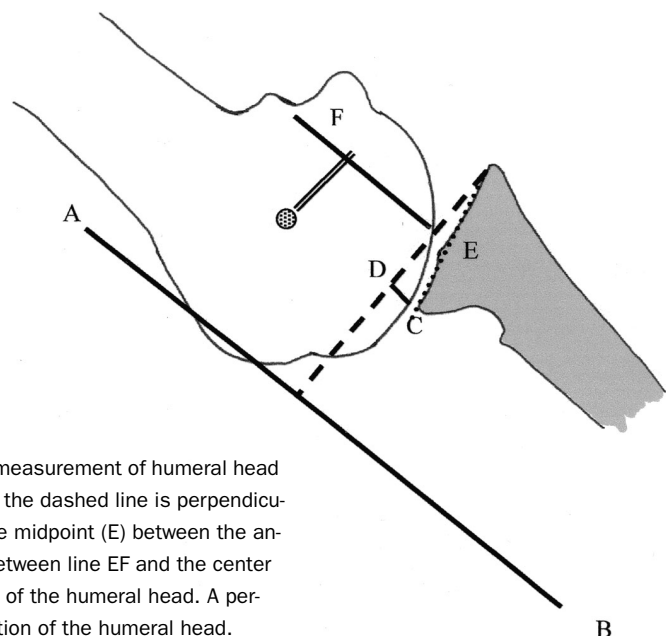


Fig. 4

Line drawing of the axillary view, demonstrating the method of measurement of humeral head subluxation. Line AB is parallel to the body of the scapula, and the dashed line is perpendicular to line AB. Line EF is perpendicular to the dashed line at the midpoint (E) between the anterior and posterior aspects of the glenoid rim. The distance between line EF and the center of the humeral head is measured as a percentage of the width of the humeral head. A percentage of >25 was considered to represent posterior subluxation of the humeral head.

eventually had satisfactory shoulder function and little pain. The mean score for this group of four patients at the time of final follow-up was not significantly different from that of the rest of the cohort.

There were also two glenoid fractures. One was treated with humeral head replacement as well as reduction and fixation with a screw. The other, a fracture of the anterior part of the rim in a patient with posterior glenoid wear, occurred while the surgeon was attempting to lower the anterior "high side" of the glenoid. The fracture became stable after the glenoid component was cemented. It was protected by placing the humeral component in neutral version and putting the arm in a gunslinger brace for three weeks postoperatively. Both fractures healed without complications, and both patients had a satisfactory clinical result.

Two fractures occurred at the level of a tuberosity. One, a minimally displaced fracture of the greater tuberosity, was treated satisfactorily with sutures. The other, a compression fracture of the lesser tuberosity caused by humeral retraction, did not require special treatment beyond repair of the subscapularis.

A nondisplaced fracture at the surgical neck occurred when the surgeon was seating an uncemented press-fit stem. It became stable with placement of the humeral component.

All but one of the intraoperative fractures were adequately treated at the time of the index procedure. All patients had a satisfactory clinical result.

A transient radial nerve palsy developed in one patient. It resolved spontaneously within four months after the surgery.

Postoperative Complications

Nine (7%) of the 128 shoulders had a postoperative complication related to the prosthesis, and six of them had additional surgery. Glenoid loosening and glenohumeral instability were the most common complications after total shoulder arthroplasty. Seven glenoid components were noted to be loose or to have shifted at a mean of forty-six months (range, twenty-four to sixty months) after the index operation. There were no failures of the implant materials. Five shoulders had postoperative humeral head subluxation or dislocation. Three of the five had posterior subluxation of the humeral head associated with a loose glenoid component, and one of the three also had a rotator cuff tear, which was repaired at the time of revision. In a fourth patient, anterosuperior subluxation of the humeral head was associated with a postoperative tear of the subscapularis tendon. Three months postoperatively, the rotator cuff was repaired and a prosthesis with a larger head was used to restore stability. Thus, four of the five shoulders with humeral head subluxation had glenoid loosening or a rotator cuff tear. In the fifth shoulder, anterior subluxation of the humeral head was noted at three months and was treated with rotational strengthening exercises. No operative procedure was undertaken; hence, we were unable to determine whether additional pathology was present.

Of the seven shoulders with glenoid loosening and the five with posterior subluxation of the humeral head, all but

two had had moderate to severe preoperative glenoid erosion or humeral head subluxation.

Preoperative Loss of Motion

The severity of the preoperative loss of passive external rotation was found to affect the postoperative range of external rotation, particularly in the patients treated with hemiarthroplasty. Postoperative external rotation averaged $25^\circ \pm 4.4^\circ$ in patients who had had $<10^\circ$ of external rotation before a hemiarthroplasty, whereas it averaged $47^\circ \pm 4.7^\circ$ in those who had had $\geq 10^\circ$ before a hemiarthroplasty ($p = 0.006$; two-tailed t test). In contrast, a preoperative internal rotation contracture did not have an adverse effect on the results of the total shoulder arthroplasties. Postoperative external rotation averaged $43^\circ \pm 2.5^\circ$ in patients who had had $<10^\circ$ of external rotation before a total shoulder arthroplasty, whereas it averaged $50^\circ \pm 2.6^\circ$ in those who had had $\geq 10^\circ$ before a total shoulder arthroplasty. Furthermore, the severity of the preoperative loss of forward flexion had no effect on postoperative forward flexion after either type of operation.

Rotator Cuff Tears

The status of the rotator cuff was recorded at the time of the surgery. Most (115; 90%) of the 128 shoulders had a structurally intact rotator cuff. Thirteen were found to have a full-thickness tear, but only seven (5% of 128) had a tear of >1 cm. All of the tears were isolated to the supraspinatus tendon, and all were repairable (maximum size, 3 cm). Eight of the thirteen shoulders underwent hemiarthroplasty, and five underwent total shoulder arthroplasty.

The presence of a full-thickness repairable tear of the rotator cuff isolated to the supraspinatus tendon did not affect the postoperative American Shoulder and Elbow Surgeons scores for pain or function, the decrease in pain, or patient satisfaction (two-tailed t tests). Better active external rotation was seen in patients with a rotator cuff tear who had been treated with total shoulder arthroplasty.

Glenoid Erosion

Twenty-nine shoulders had moderate-to-severe loss of posterior glenoid bone, and nineteen of the twenty-nine underwent total shoulder arthroplasty. Preoperative glenoid erosion was found to significantly affect the postoperative range of motion for patients with hemiarthroplasty. For shoulders with moderate-to-severe glenoid erosion preoperatively, total shoulder arthroplasty resulted in a greater increase ($p = 0.0013$) in active external rotation (mean improvement, $32^\circ \pm 3.7^\circ$) than did hemiarthroplasty (mean improvement, $16^\circ \pm 7.0^\circ$) (see Appendix). The difference between active forward flexion following total shoulder arthroplasty ($139^\circ \pm 4.0^\circ$) and that following hemiarthroplasty ($117^\circ \pm 10.4^\circ$) in patients with moderate-to-severe glenoid erosion approached significance ($p < 0.08$). The results of total shoulder arthroplasty were the same in all patients regardless of the degree of glenoid erosion. There was no difference between the American Shoulder and Elbow Surgeons scores or the pain scores after the hemiarthroplasties and those after

the total shoulder arthroplasties in patients with or without glenoid erosion (two-sided t tests).

Humeral Head Subluxation

Twenty-three shoulders had posterior subluxation of the humeral head seen on the preoperative axillary radiograph or axial computed tomographic scan. These shoulders, compared with those that had not had preoperative humeral head subluxation, had lower American Shoulder and Elbow Surgeons scores (75 ± 5.7 compared with 86 ± 1.6 points, $p = 0.07$; unequal variance two-sided t test), more pain (27 ± 6.9 compared with 13 ± 2.0 of 100 points, $p = 0.07$; two-sided t test), and less active external rotation (38° compared with 47° , $p = 0.07$; two-sided t test) at the time of follow-up after either total shoulder arthroplasty or hemiarthroplasty (see Appendix).

Only six patients had both humeral head subluxation and moderate-to-severe glenoid erosion. Three had a hemiarthroplasty, and three had a total shoulder arthroplasty. The small number of patients with these combined factors did not allow for sufficient power to perform proper statistical analysis.

For patients without glenoid erosion or humeral head subluxation, total shoulder arthroplasty resulted in better American Shoulder and Elbow Surgeons scores than did hemiarthroplasty (79 ± 5.5 compared with 89 ± 1.5 points, $p = 0.08$; unequal variance two-sided t test).

Discussion

Prosthetic arthroplasty for treatment of severe osteoarthritis of the shoulder has been demonstrated to provide reproducible and sustained relief of pain and improvement in function in the majority of patients^{1,3,10,11,14-17}. Our multicenter prospective study of a large population followed for two to seven years after shoulder arthroplasty with a single design of prosthesis confirms the overall decrease in pain and improvement in function reported in the literature.

Our data demonstrated that, when preoperative passive external rotation was $<10^\circ$, postoperative passive external rotation was less satisfactory after hemiarthroplasty. On the basis of this information, we recommend that, when nonoperative treatment fails and the patient has sufficient pain to warrant joint replacement, surgery be performed before there is a progressive loss of the passive range of motion. When a patient has severe loss of motion, a total shoulder arthroplasty and extensive soft-tissue release will yield the most predictable results.

In our group of patients with moderate-to-severe eccentric posterior erosion, active external rotation and forward flexion were better after total shoulder arthroplasty than after hemiarthroplasty. We believe that, for patients with substantial eccentric glenoid wear, reaming of the glenoid to improve version and addition of a glenoid component with a uniform concave surface will improve the fulcrum for rotation of the humeral head and thereby improve function.

Humeral head subluxation adversely affects the prognosis: in our series, it was associated with lower American Shoulder and Elbow Surgeons scores, worse pain scores, and

less active and passive motion of the shoulder. When humeral head subluxation is seen postoperatively, less favorable results can be anticipated regardless of whether a hemiarthroplasty or total shoulder arthroplasty has been performed. Humeral head subluxation is seen in shoulders with severe osteoarthritis and is often associated with extreme loss of external rotation and loss of posterior glenoid bone. Together, these findings represent the most severe situation in advanced osteoarthritis of the shoulder, and the likelihood of a favorable result is substantially decreased. In this series, their relationship with late prosthetic failure was demonstrated by seven cases of glenoid loosening and five cases of postoperative humeral head instability, with three shoulders having both glenoid loosening and instability. Of the nine shoulders with glenoid loosening and/or postoperative instability, seven had had moderate-to-severe glenoid bone loss or humeral head subluxation preoperatively.

In series of patients undergoing prosthetic arthroplasty for a variety of shoulder disorders, the presence of a rotator cuff tear has been shown to be associated with a less favorable outcome^{3,5,15-20}. Most often, the presence of a rotator cuff tear was associated with a diagnosis of rheumatoid or other inflammatory arthritis and the tears were large and generally irreparable^{2-4,6-9,21}. Some case series demonstrated a higher prevalence of loosening of the glenoid component in patients with a large rotator cuff tear associated with superior migration of the humeral head^{2,5}. In our study, the humeral head was seen to be centered within the glenoid fossa on both the preoperative and the postoperative anteroposterior radiographs. Our study design excluded patients with larger rotator cuff tears, and we did not find repairable full-thickness tears of the supraspinatus to have an adverse effect on the outcome.

In conclusion, glenoid erosion, humeral head subluxation, and a severe preoperative loss of passive motion of the shoulder were found to have significant effects on outcome, whereas a repairable full-thickness tear of the rotator cuff isolated to the supraspinatus tendon did not affect outcome. On the basis of these data, we recommend the use of a glenoid component in shoulders with glenoid erosion and in the presence of a small repairable tear of the supraspinatus tendon when there is coexistent glenoid arthritis. Humeral head subluxation consistently resulted in a less favorable outcome regardless of whether a hemiarthroplasty or a total shoulder arthroplasty had been performed. This anatomic factor must be considered in the preoperative surgical planning and counseling of the patient.

Appendix

eA A table showing the effects of glenoid erosion, humeral head subluxation, and a full-thickness rotator cuff tear on the results of surgery is 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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