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Background: The number of total shoulder arthroplasties has increased exponentially over the last ten years, creating a more prominent role for revision shoulder arthroplasty in the future. The main reasons for failure of shoulder arthroplasty can be classified as soft-tissue deficiencies, osseous deficiencies, component wear, or infection. We hypothesized that, despite appropriate surgical techniques, the outcome of revision total shoulder replacement can be predicted on the basis of the indication for the revision procedure.

Methods: We conducted a retrospective review of seventy-eight shoulders that had undergone revision shoulder arthroplasty. The shoulders were divided into two categories: (1) those with osseous or component-related problems and (2) those with soft-tissue deficiency. Category 1 consisted of four cohorts of shoulders: twenty-two treated with revision of the glenoid component, sixteen treated with conversion of a hemiarthroplasty to a total shoulder arthroplasty because of glenoid arthrosis, eight treated with revision of the humeral stem, and four treated for a periprosthetic fracture. Category 2 consisted of five cohorts of shoulders: ten treated with rotator cuff repair following total shoulder replacement, four with a failed tuberosity reconstruction, four with cuff tear arthropathy, five with instability, and five with infection. Patients were evaluated with the UCLA subjective outcome instrument, the L'Insalata shoulder questionnaire, and a subjective satisfaction scale (maximum score of 5 points).

Results: The average UCLA score was 21.4 points and the average L'Insalata score was 68.73 points for the seventy-eight shoulders that were analyzed. The average score on the subjective satisfaction questionnaire was 2.91 points. According to the UCLA scores, twenty-four revisions were considered to have had an excellent result; fifteen, a good result; twenty-four, a fair result; and fifteen, a poor result. The average scores for the category-1 shoulders were significantly better than those for the category-2 shoulders ($p < 0.05$). Of the different types of operations, revision or implantation of a glenoid component and open reduction and internal fixation of a periprosthetic fracture provided the best outcomes. Tuberosity reconstruction, hemiarthroplasty for treatment of cuff tear arthropathy, and revision due to infection had uniformly poor outcomes.

Conclusions: In general, these results indicate that the outcome of revision shoulder arthroplasty can be predicted on the basis of the indication for the procedure. Component revisions, excluding humeral head revision for salvage, provide the best results, whereas soft-tissue reconstructions can be expected to yield poorer results overall.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

The number of total shoulder arthroplasties has increased considerably over the last decade. As the number of primary and secondary shoulder arthroplasties increases, a larger number of revision procedures can be expected. Cofield's survivorship analysis of unconstrained total shoulder replacements projected survival rates of 96% at two years, 92% at five years, and 88% at ten years[1]. Patients undergoing total shoulder arthroplasty are younger, on the average, than their counterparts receiving a knee or hip replacement[1,2]. Cofield noted 123 complications following 1183 shoulder arthroplasties, and this rate is consistent with those presented in other reports[2-5]. On the basis of the published literature on revision shoulder arthroplasty, the main reasons for failure can be classified as soft-tissue deficiencies, osseous deficiencies, component wear, and infection[1,2,5,6]. Often the cause for revision is multifactorial[2,5,6]. Successful treatment of complications depends on recognizing and addressing the problem(s) unique to each cause of failure. We hypothesized that, despite the use of appropriate surgical methods, the outcome of revision total shoulder replacement can be predicted on the basis of the surgical indication for the revision procedure.

Materials and Methods

The results of seventy-eight total shoulder revisions in seventy-five patients (forty women and thirty-five men) with a mean age of 62.6 years (range, twenty-six to eighty-two years) at the time of the revision surgery were evaluated. All revisions were performed by one of the three senior authors (D.M.D., R.F.W., or E.V.C.). The average duration of follow-up was seventy-six months with a range of twenty-four to 168 months. This was a retrospective study.

The initial arthroplasty was performed for the treatment of osteoarthritis in twenty-nine shoulders, arthritis associated with instability in ten, posttraumatic arthritis in eight, rheumatoid arthritis in seven, osteonecrosis of the humeral head in five, fracture or malunion in eleven, rotator cuff tear arthropathy in six, and osteogenic sarcoma of the proximal part of the humerus in two. Eight shoulders underwent multiple revision procedures (one, two, or three subsequent operations), but only the results of the first revision were analyzed. The indications for the repeat revisions were multifactorial in seven of these eight shoulders; the primary indication for these seven shoulders was a pathological disorder to the rotator cuff (two shoulders), periprosthetic fracture (one), soft-tissue deficiency causing instability (two), or loosening of the glenoid component (two). Infection was the sole indication in the eighth shoulder.

Each patient was evaluated with two validated subjective outcome questionnaires: the UCLA shoulder scoring scale[7] and the L'Insalata shoulder rating questionnaire[8]. The UCLA scale has been used frequently, and the L'Insalata questionnaire is used to evaluate pain and the ability to carry out activities of daily living, work, and recreation. It is a valid, reliable, and responsive self-administered assessment tool[8]. In addition, the patients completed a questionnaire that asked them to assess their satisfaction after the revision surgery, compared with their satisfaction prior to the revision surgery, on a visual analog scale, with 1 indicating "much worse," 2 indicating "worse," 3 indicating "the same," 4 indicating "better," and 5 indicating "much better."

On completion of each patient's evaluation, a grade of excellent, good, fair, or poor was assigned on the basis of the results of the UCLA shoulder scoring scale. As described in the original paper on this system by Amstutz et al.[7], we considered a score of >8 points on each scale (pain, function, and range of motion) to be an excellent result, a score of >6 points to be a good result, a score of >4 points to be a fair result, and a score of <3 points to be a poor result.

The shoulders were divided into nine separate cohorts based on what the operating surgeon thought to be the most important aspect of the revision procedure. When an operation had multiple and equally important aspects, component revision was designated as the primary procedure. The nine cohorts were (I) revision or resection of the glenoid component (twenty-two shoulders), (II) conversion of a hemiarthroplasty to a total shoulder arthroplasty for treatment of progressively symptomatic glenoid arthrosis (sixteen), (III) open reduction and internal fixation of a periprosthetic fracture after shoulder arthroplasty (four), (IV) revision of the humeral stem because of malposition or loosening (eight), (V) revision of the humeral head component because of rotator cuff tear arthropathy (four), (VI) repair of a rotator cuff tear following total shoulder arthroplasty (ten), (VII) treatment of instability due to soft-tissue insufficiency (five), (VIII) revision of a failed tuberosity reconstruction (four), and (IX) revision due to infection after a shoulder arthroplasty (five).

The shoulders in each cohort were then grouped into one of two larger categories: (1) revision due to osseous or component-related problems (Cohorts I through IV) or (2) revision due to a soft-tissue disorder (Cohorts V through IX) (Table I). Fifty shoulders were included in the osseous/component-problem category, and twenty-eight were included in the soft-tissue-disorder category. The results for the two categories were analyzed and compared. Each of the nine cohorts was evaluated separately as well.

Although the shoulders in Cohort V (cuff tear arthropathy) were treated with a component revision, they were placed in the soft-tissue-disorder category because the component was changed to treat an irreparable rotator cuff deficiency. The shoulders in Cohort VIII (failure of a tuberosity reconstruction) were also placed in the soft-tissue-disorder category because the primary disorder and clinical symptoms stemmed from inadequate function of the rotator cuff secondary to malunion or malposition of the tuberosity. The shoulders in which a glenoid component was added to a preexisting humeral stem were not included in the glenoid-revision cohort. Instead, they were considered to be a separate cohort, treated with conversion from a hemiarthroplasty to a total shoulder replacement (Cohort II).

Results

The average UCLA score was 21.4 points, the average L'Insalata score was 68.73 points, and the average value for the self-assessment of patient satisfaction was 2.91 points in the overall series of seventy-eight revision shoulder arthroplasties (Table I). According to the UCLA scores, twenty-four results were graded as excellent; fifteen, good; twenty-four, fair; and fifteen, poor (Table I). Cohorts I through IV (osseous or component-related problems) had an average UCLA score of 26.1 points, an average L'Insalata score of 77.9 points, and an average satisfaction score of 3.45 points. Cohorts V through IX (soft-tissue disorder) had an average UCLA score of 12.3 points, an average L'Insalata score of 45.3 points, and an average satisfaction score of 1.99 points. The results for all three outcomes measures were significantly better for the shoulders in the osseous/component-problem category ($p < 0.05$) than they were for the shoulders with a soft-tissue disorder. Evaluation of the outcomes in the nine individual cohorts showed parallel results, in terms of the UCLA score and the L'Insalata score, in each category (Figs. 1 and 2).

Each cohort was also analyzed individually. Of the twenty-two shoulders in Cohort I (glenoid revision), ten had undergone immediate reimplantation of the glenoid component and twelve had undergone resection of the glenoid component. Table II outlines the results in these two subgroups. The decision to reimplant or resect was made by the operating surgeon on the basis of the quality of the glenoid bone stock at the time of

TABLE I Mean Results Grouped by Category and Cohort

	Indication for Op.	No. of Shoulders	Average Score *(points)*			Result *(no. of shoulders)*			
			UCLA	L'Insalata	Satisfaction	Excellent	Good	Fair	Poor
Category 1	Osseous or component-related problems	50	26.1	77.9	3.45	22	14	12	2
Cohort I	Glenoid revision	22	25.95	76.9	3.50	13	3	5	1
Cohort II	Conversion of hemiarthroplasty to total shoulder replacement because of glenoid arthrosis	16	26.0	80.3	3.38	6	5	5	
Cohort III	Periprosthetic fracture	4	28.0	76.1	3.60	2	2		
Cohort IV	Humeral component malposition or loosening	8	25.8	76.8	3.50	1	4	2	1
Category 2	Soft-tissue disorder	28	12.3	45.3	1.99	2	1	12	13
Cohort V	Rotator cuff tear arthropathy	4	9.7	44.9	1.00			1	3
Cohort VI	Rotator cuff disorder after total shoulder replacement	10	15.7	59.3	2.28	2	1	4	3
Cohort VII	Instability due to soft-tissue compromise	5	13.6	45.4	3.30			2	3
Cohort VIII	Failed tuberosity reconstruction	4	9.8	34.1	1.50			2	2
Cohort IX	Infection	5	8.0	26.3	1.33			3	2
Total		78	21.4	68.73	2.91	24	15	24	15

the revision. Preoperative computerized tomographic scans were not available so we cannot comment on glenoid angles or erosion or how those variables corresponded with the decision to resect or reimplant the glenoid component. In the subgroup treated with immediate reimplantation, eight glenoid components were revised secondary to symptomatic loosening and two were revised secondary to component malposition with subsequent posterior instability. One shoulder had a poor result, and glenoid resection was subsequently performed because of progressive symptomatic loosening. Five shoulders in the glenoid-resection subgroup underwent concurrent bone-grafting at the time of the resection because of the possibility that reimplantation would be performed in the future. With the small numbers available, no significant differences were found between the resection and reimplantation subgroups.

There were sixteen shoulders in Cohort II (conversion of a hemiarthroplasty to a total shoulder arthroplasty). The initial indication for the hemiarthroplasty was osteoarthritis in eleven shoulders and trauma in five, and the indication for revision in all of these shoulders was progressively symptomatic glenoid arthrosis.

Cohort III (postoperative periprosthetic fracture) included four shoulders. All fractures were classified as Type B (a fracture about the stem) according to the system developed by Worland et al.[9]. All of the stems were well fixed and were preserved, and the patients were treated with open reduction and internal fixation. All patients regained their prefracture status with regard to pain and function. All were highly satisfied with the result.

The eight shoulders in Cohort IV underwent revision to treat symptomatic aseptic loosening of the humeral component (four) or malposition of the humeral component resulting in instability (four). In all cases, the original stem was removed and a new stem was implanted.

The results in Cohort V (revision of the humeral head component secondary to rotator cuff arthropathy) were not encouraging. The four shoulders in this group all had an irreparable rotator cuff disorder and underwent upsizing of the humeral head component and removal of the glenoid component. Of note, all four shoulders underwent subsequent revision procedures.

There were two subgroups in Cohort VI (rotator cuff repair following total shoulder arthroplasty). One subgroup (seven shoulders) underwent rotator cuff repair and/or soft-tissue repair without component revision, and there were one excellent, three fair, and three poor results in this group. The second subgroup (three shoulders) was treated with surgery on the rotator cuff and/or long head of the biceps combined with a revision of the humeral component (to a smaller component), and those shoulders had one excellent, one good, and one fair result. No consistent tear pattern was identified in these shoulders.

Cohort VII (instability secondary to soft-tissue deficiency) included five shoulders. Three had anterosuperior instability and were treated with Achilles tendon allograft reconstruction of the coracoacromial arch and a humeral head revision with increased retroversion. One of these shoulders underwent a concomitant pectoralis major transfer. The two other shoulders had subscapularis deficiency and were treated with Achilles tendon allograft reconstruction. Although the results were clearly worse than those achieved in the osseous/component-problem category, the sample size was too small to attribute significance to the results.

The results were not encouraging in Cohort VIII, which consisted of four shoulders in which a tuberosity reconstruction had failed after a hemiarthroplasty for the treatment of a fracture. These shoulders underwent another reconstruction of the tuberosity with or without replacement of the humeral head component.

The results in Cohort IX (infection at the site of a total shoulder arthroplasty) were worse than those in any other individual cohort. Three shoulders underwent staged reimplantation, with an antibiotic spacer placed at the time of the initial débridement and implant removal. These three shoulders had two fair results and one poor result. However, even

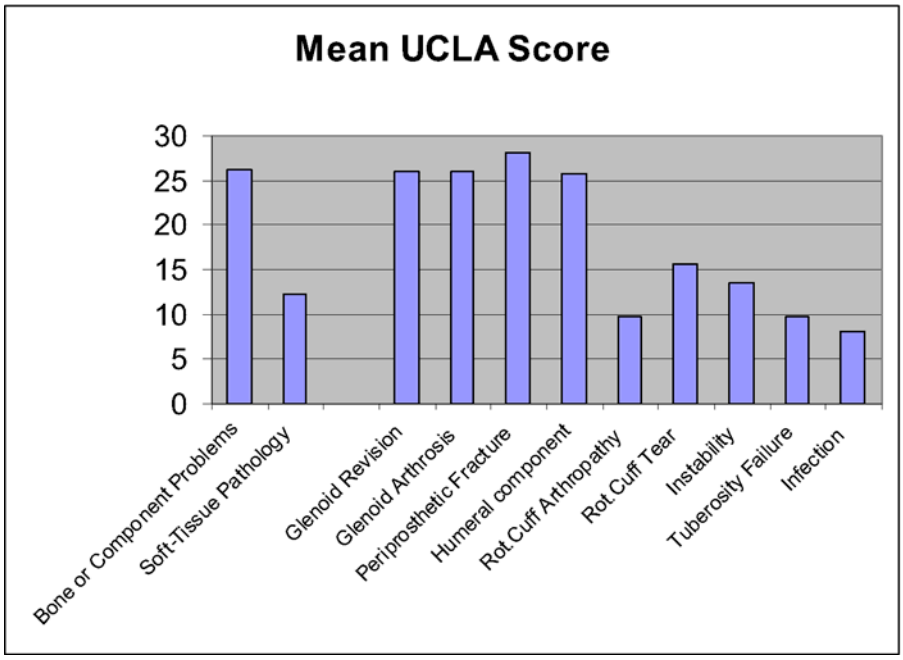

Fig. 1

Graph depicting the average UCLA scores according to category and cohort.

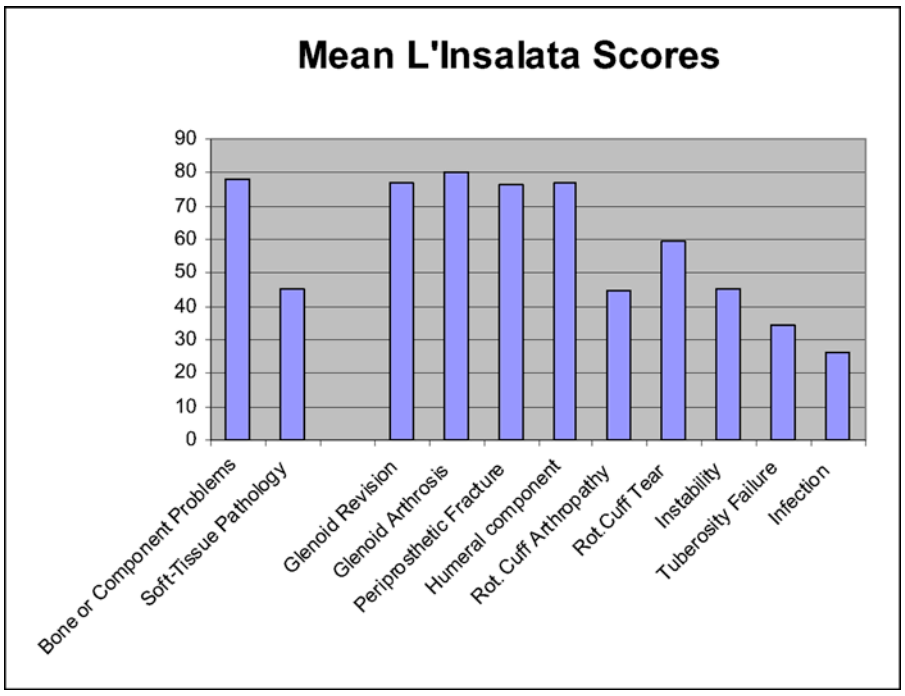

Fig. 2

Graph depicting the average L'Insalata scores according to category and cohort.

TABLE II Comparison of Results of Glenoid Reimplantation with Those of Resection

	Procedure	No. of Shoulders	Average Score *(points)*		Result *(no. of shoulders)*			
			UCLA	L'Insalata	Excellent	Good	Fair	Poor
Cohort I	Glenoid revision	22	25.95	76.9	13	3	5	1
Subgroup 1	Immediate glenoid reimplantation	10	25.25	78.0	6	1	2	1
Subgroup 2	Glenoid resection	12	26.53	75.91	7	2	3	

those with the fair results had worse function than they had had before the infection. A resection arthroplasty was performed in the other two shoulders in this cohort. The decision to proceed with the resection arthroplasty was based on both the poor general health of the patients and poor bone stock. One shoulder had a fair result and one had a poor result, both shoulders had worse function than they had had preoperatively, and a repeat infection developed in one of these shoulders.

Discussion

Revision shoulder arthroplasty is one of the most technically demanding operations performed. Petersen and Hawkins characterized failures into one of three categories: soft-tissue deficiencies, osseous deficiencies, and component wear[10]. Soft-tissue deficiencies include rotator cuff disorders, complications related to tuberosity reattachment that affect rotator cuff competence, and anterior capsule shortening. Often, the cause of failure is multifactorial[11]. Although some of the individual cohorts were small in our series, we found that, overall, the results of revisions done to treat osseous or component-related disorders were significantly better than the results of revision total shoulder replacements done to treat soft-tissue deficiencies ($p < 0.05$).

There are few reports on revisions of shoulder arthroplasties in the literature. Neer and Kirby reported on forty revision shoulder replacements in thirty-six patients, thirty of whom reported satisfactory pain relief and function for activities of daily living[12]. Ten patients regained nearly normal function. Neer and Kirby identified numerous causes for revision, which they grouped into preoperative, surgical, and postoperative categories. Caldwell et al. reported on thirteen patients (five with repeat revisions), eight of whom had a satisfactory result on postoperative evaluation[13]. Wirth and Rockwood found the results of twenty-eight of thirty-eight revisions to be satisfactory[2]. Causes of failure in their series, in order of decreasing frequency, were component loosening, instability, a rotator cuff tear, periprosthetic fracture, infection, implant failure, and deltoid dysfunction.

Component loosening remains the most common reason for revision, and the glenoid component is affected more often than the humeral component[14,15]. Indications for revision of the glenoid component include symptomatic loosening, material failure, and malposition or wear causing instability. The decision regarding whether to reimplant or resect the glenoid component is a difficult one and is often based on bone quality at the time of surgery. Antuna et al. retrospectively reviewed the results of glenoid revision in forty-eight patients, thirty of whom had a new glenoid component implanted and eighteen of whom underwent resection and bone-grafting[16]. Overall, the shoulders had significant improvements ($p < 0.05$) in pain relief, active elevation, and external rotation, but the patients who had undergone resection were less satisfied than those who had had a new glenoid component implanted ($p = 0.01$). Twelve of the patients (eight treated with reimplantation and four treated with glenoid resection) required a subsequent revision.

Rodosky and Bigliani assessed the results of twenty-five glenoid revisions and noted slightly better outcomes following those that involved reimplantation[4]. Cofield and Edgerton reviewed the results in thirteen patients with glenoid loosening[5]. Nine of them underwent glenoid resection, and all but one of the nine had satisfactory pain relief. The results of other studies have been similar in that patients treated with either reimplantation or resection did equally well[15,17,18].

The largest cohort in this study was treated with either revision or resection of the glenoid component, and the overall results in that group were good to excellent. Unlike Antuna et al.[16], we found no significant difference between the group treated with immediate reimplantation and the group treated with resection, with the numbers studied. Longer follow-up of larger numbers of patients will help to delineate whether one procedure is better than the other. In general, however, patients who undergo glenoid revision surgery can generally expect good to excellent outcomes.

Loosening of the humeral component is much less common than loosening of the glenoid component. Despite high rates of radiographic changes around the stem, loosening is rarely a cause for revision surgery[19-21]. Torchia et al. reported a high rate of subsidence of press-fit humeral prostheses; however, they noted no association between loosening and pain[22]. Four shoulders in our study were revised because of symptomatic, aseptic loosening of the humeral stem, and the overall results were good. Again, these results were consistent with the results of shoulder revisions due to osseous or component-related problems.

Progressively symptomatic glenoid arthrosis has been commonly reported after hemiarthroplasty. In a short-term retrospective study, Sperling and Cofield reported on eighteen shoulders that had been treated with glenoid replacement because of painful glenoid arthrosis following prosthetic replacement of the humeral head[23]. Although the patients' satis-

faction with the pain relief after the revision was excellent, seven patients were not satisfied with the result of the surgery because of a decreased range of motion and/or the need for a subsequent operation.

Carroll et al. retrospectively reviewed the results in sixteen consecutive patients who had undergone conversion of a hemiarthroplasty to a total shoulder replacement because of pain[24]. Seven of the sixteen patients had an unsatisfactory result according to Neer's criteria. Carroll et al. concluded that conversion of a humeral head replacement to a total shoulder arthroplasty is a salvage procedure with results that are inferior to those of primary total shoulder replacement. Of note is the fact that, despite the poor scores according to Neer's criteria in their series, twelve of the patients stated that they would undergo the procedure again. Our findings differed in that the majority of our patients (eleven of sixteen) who had undergone conversion from a hemiarthroplasty to a total shoulder replacement had a good or excellent result. One potential explanation for the difference in our findings is that a postoperative infection requiring a revision developed in two patients in the study by Sperling and Cofield[23] and in one patient in the study by Carroll et al.[24]. In small series such as these, infections can have a substantial effect on the overall rate of patient satisfaction.

The reported rate of humeral fracture after shoulder arthroplasty is about 2%[9,25]. Treatment outcomes can often be attributed to the location and configuration of the fracture. Kumar et al. retrospectively reviewed the results of treatment of sixteen periprosthetic humeral fractures[26]. Ten of the fractures were managed operatively, and all healed. Similarly, in our series, all four fractures healed well, and the patients were all satisfied with the result.

Post-arthroplasty instability remains a very difficult problem. Along with loosening of the glenoid component, it is the reason for the majority of revision total shoulder replacements[10,27,28]. Instability has been noted to occur in any direction on the basis of the condition of the soft tissues and the positions of the components. Moeckel et al. reported ten cases of shoulder instability following a total of 236 arthroplasties[27]. Revision surgery successfully restored stability in nine of the patients. However, three of the patients required two surgical procedures. In a retrospective review of thirty-three shoulders, Sanchez-Sotelo et al. reported a modest rate of success of surgical revision for the treatment of instability after shoulder arthroplasty[29]. They concluded that instability after shoulder arthroplasty is difficult to treat and may require allograft reconstruction or pectoralis major transfer to address subscapularis deficiency.

Our results showed a similar trend in that revision surgery for treatment of instability had fair results overall. However, it is important to note that we divided our patients into two separate cohorts. Patients who had undergone component revision because of instability caused by component malposition did better than those in whom the shoulder had been revised to treat a soft-tissue disorder. Fixed anterosuperior instability through the coracoacromial arch in patients with a prior reconstruction of the coracoacromial ligament is one of the most devastating instability patterns following shoulder replacement[30]. It was no surprise that the patients who had this problem and underwent Achilles tendon allograft reconstruction with or without a pectoralis major transfer scored poorly on the UCLA and L'Insalata questionnaires. Interestingly, however, patient satisfaction was high as these patients had had limited functional goals prior to the surgery and had considerable pain relief after it.

Superior instability (or anterior-superior escape) can occur after a hemiarthroplasty as a result of cuff tear arthropathy[28]. The pain and limited range of motion that often develop in these cases are severely debilitating. Galatz et al. used a subcoracoid pectoralis major transfer to treat fourteen patients with this problem[31]. Patients reported decreased pain and an improved range of motion; however, function was still limited. In our series, the four patients with an irreparable rotator cuff tear were treated with removal of the glenoid component and upsizing of the humeral head. All patients had an unsatisfactory result.

Many authors have classified a tuberosity malunion or nonunion after an arthroplasty done to treat a proximal humeral fracture as a soft-tissue problem because it represents failure of reattachment of the rotator cuff[6]. Secure tuberosity fixation is essential to treat a proximal humeral fracture successfully with a shoulder arthroplasty. Boileau et al. reviewed the sequelae of proximal humeral fractures treated with shoulder replacement[32] and found that all patients who required a tuberosity osteotomy had either a fair or a poor result and none had regained active elevation of >90°. They concluded that the most likely cause of poor outcomes following treatment of complex sequelae of proximal humeral fractures is the need to perform an osteotomy of the greater tuberosity. In our series, the results of revisions due to tuberosity malunion or nonunion were unsatisfactory.

Infection is widely regarded as one of the most devastating complications leading to revision total shoulder replacement. Previous studies have demonstrated uniformly poor results of such revisions, with the outcomes of delayed reimplantation being moderately better than those of resection arthroplasty[33,34]. To our knowledge, the largest review of infections following shoulder arthroplasty was performed at the Mayo Clinic by Sperling et al.[33], who reported on thirty-two infections diagnosed at an average of 3.5 years after the initial shoulder replacement. Those authors concluded that prosthetic revision yielded better results than did resection arthroplasty and delayed reimplantation provided the best outcomes in terms of pain relief, eradication of infection, and function. In our study, all patients had a lower functional level after the surgery to treat the infection. However, there were no cases of reinfection in the group treated with delayed reimplantation. Our present preferred method of treatment is delayed reimplantation following a six-week course of antibiotics.

The purpose of this study was to review the overall results of revision shoulder arthroplasty with the intention of identifying the expected outcome on the basis of the surgical indication for the revision procedure. Previous studies[2,5,10,16,33]

have demonstrated better results following revision total shoulder replacement for the treatment of aseptic glenoid loosening or symptomatic glenoid arthrosis after primary hemiarthroplasty, whereas patients requiring revision because of soft-tissue deficiencies or infection had poor outcomes. Our study validates those findings. The poor results in cohorts V through IX suggest that better treatment options are needed for those situations.

Our results indicate that the outcome of revision surgery can be predicted on the basis of the indication for the procedure. In our series, component revisions had better results than did soft-tissue reconstructions. All types of glenoid revisions had consistently good results, whereas soft-tissue reconstructions for the treatment of instability or rotator cuff disorders had only fair outcomes. Salvage procedures such as tendon transfers and the use of cadaver allografts relieved pain somewhat but did not improve function as much. This information can be used by surgeons when they counsel patients regarding the expected outcome of revision shoulder arthroplasty. ■

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References

1. Cofield RH. Revision procedures in shoulder arthroplasty. In: Morrey BF, editor. Reconstructive surgery of the joints. 2nd ed. New York: Churchill Livingstone; 1996. p 789.

2. Wirth MA, Rockwood CA Jr. Complications of total shoulder-replacement arthroplasty. J Bone Joint Surg Am. 1996;78:603-16.

3. Barrett WP, Franklin JL, Jackins SE, Wyss CR, Matsen FA 3rd. Total shoulder arthroplasty. J Bone Joint Surg Am. 1987;69:865-72.

4. Rodosky MW, Bigliani LU. Surgical treatment of non-constrained glenoid component failure. Oper Tech Orthop. 1994;4:226-36.

5. Cofield RH, Edgerton BC. Total shoulder arthroplasty: complications and revision surgery. Instr Course Lect. 1990;39:449-62.

6. Kalandiak SP, Wirth MA, Rockwood CA. Complications of shoulder arthroplasty. In: Williams GR Jr, Yamaguchi K, Ramsey ML, Galatz M, editors. Shoulder and elbow arthroplasty. Philadelphia: Lippincott Williams and Wilkins; 2005. p 229-50.

7. Amstutz HC, Sew Hoy AL, Clarke IC. UCLA anatomic total shoulder arthroplasty. Clin Orthop Relat Res. 1981;155:7-20.

8. L'Insalata JC, Warren RF, Cohen SB, Altchek DW, Peterson MG. A self-administered questionnaire for assessment of symptoms and function of the shoulder. J Bone Joint Surg Am. 1997;79:738-48.

9. Worland RL, Kim DY, Arredondo J. Periprosthetic humeral fractures: management and classification. J Shoulder Elbow Surg. 1999;8:590-4.

10. Petersen SA, Hawkins RJ. Revision of failed total shoulder arthroplasty. Orthop Clin North Am. 1998;29:519-33.

11. Hasan SS, Leith JM, Campbell B, Kapil R, Smith KL, Matsen FA 3rd. Characteristics of unsatisfactory shoulder arthroplasties. J Shoulder Elbow Surg. 2002;11:431-41.

12. Neer CS 2nd, Kirby RM. Revision of humeral head and total shoulder arthroplasties. Clin Orthop Relat Res. 1982;170:189-95.

13. Caldwell GL, Dines DM, Warren RF, Altchek DW, Wickiewicz TL. Revision shoulder arthroplasty. Orthop Trans. 1993;17:140.

14. Matsen FA, Rockwood CA, Wirth MA, Lippitt SB. Glenohumeral arthritis and its management. In: Rockwood CA, Matsen FA, editors. The shoulder. 2nd ed. Philadelphia: WB Saunders; 1998. p 840-964.

15. Rodosky MW, Weinstein DM, Pollock RG, Flatow EL, Bigliani LU, Neer CS 2nd. On the rarity of glenoid component failure. J Shoulder Elbow Surg. 1995;4:S13-4.

16. Antuna SA, Sperling JW, Cofield RH, Rowland CM. Glenoid revision surgery after total shoulder arthroplasty. J Shoulder Elbow Surg. 2001;10:217-24.

17. Hawkins RJ, Greis PE, Bonutti PM. Treatment of symptomatic glenoid loosening following unconstrained shoulder arthroplasty. Orthopedics. 1999;22:229-34.

18. Brems JJ. Complications of shoulder arthroplasty: infections, instability, and loosening. Instr Course Lect. 2002;51:29-39.

19. Klimkiewicz JJ, Ianotti JP, Rubash HE, Shanbhag AS. Aseptic loosening of the humeral component in total shoulder arthroplasty. J Shoulder Elbow Surg. 1998;7:422-6.

20. Sanchez-Sotelo J, Wright TW, O'Driscoll SW, Cofield RH, Rowland CM. Radiographic assessment of uncemented humeral components in total shoulder arthroplasty. J Arthroplasty. 2001;16:180-7.

21. Sanchez-Sotelo J, O'Driscoll SW, Torchia ME, Cofield RH, Rowland CM. Radiographic assessment of cemented humeral components in shoulder arthroplasty. J Shoulder Elbow Surg. 2001;10:526-31.

22. Torchia ME, Cofield RH, Settergen CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg. 1997;6:495-505.

23. Sperling JW, Cofield RH. Revision total shoulder arthroplasty for the treatment of glenoid arthrosis. J Bone Joint Surg Am. 1998;80:860-7.

24. Carroll RM, Izquierdo R, Vazquez M, Blaine TA, Levine WN, Bigliani LU. Conversion of painful hemiarthroplasty to total shoulder arthroplasty: long-term results. J Shoulder Elbow Surg. 2004;13:599-603.

25. Boyd AD, Thornhill TS, Barnes CL. Fractures adjacent to humeral prostheses. J Bone Joint Surg Am. 1992;74:1498-504.

26. Kumar S, Sperling JW, Haidukewych GH, Cofield RH. Periprosthetic humeral fractures after shoulder arthroplasty. J Bone Joint Surg Am. 2004;86:680-9.

27. Moeckel BH, Altchek DW, Warren RF, Wickiewicz TL, Dines DM. Instability of the shoulder after arthroplasty. J Bone Joint Surg Am. 1993;75:492-7.

28. Moeckel BH, Warren RF, Dines DM, Altchek DW. The unstable shoulder arthroplasty. In: Friedman RJ, editor. Arthroplasty of the shoulder. New York: Thieme; 1994. p 254-63.

29. Sanchez-Sotelo J, Sperling JW, Rowland C, Cofield RH. Instability after shoulder arthroplasty: results of surgical treatment. J Bone Joint Surg Am. 2003;85:622-31.

30. Dines DM, Warren RF, Rodriguez DF. Revision shoulder arthroplasty. Tech Shoulder Elbow Surg. 2001;2:26-37.

31. Galatz L, Connor PM, Calfee RP, Hsu JC, Yamaguchi K. Pectoralis major transfer for anterior-superior subluxation in massive rotator cuff insufficiency. J Shoulder Elbow Surg. 2003;12:1-5.

32. Boileau P, Trojani C, Walch G, Krishnan SG, Romeo A, Sinnerton R. Shoulder arthroplasty for the treatment of the sequelae of fractures of the proximal humerus. J Shoulder Elbow Surg. 2001;10:299-308.

33. Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. Clin Orthop Relat Res. 2001;382:206-16.

34. Codd TP, Yamaguchi K, Pollock RG, Flatow EL, Bigliani LU. Infected shoulder arthroplasties: treatment with staged reimplantations vs resection arthroplasty. Orthop Trans. 1996;20:59.