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The effect of glenoid bone loss and rotator cuff status in failed anatomic shoulder arthroplasty after revision to reverse shoulder arthroplasty

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Hypothesis: We evaluated outcomes and the risk of re-revision in patients with a failed anatomic total shoulder arthroplasty (TSA) revised to a reverse shoulder arthroplasty (RSA) based on rotator cuff deficiency and glenoid bone loss.
Methods: From 2004 to 2017, 123 patients with failed TSAs underwent revision to RSAs with minimum 2-year follow-up. Preoperative radiographs were evaluated to determine whether the glenoid component was fixed or loose. The rotator cuff was assessed intraoperatively and as intact or deficient. Patient outcomes including shoulder motion and American Shoulder and Elbow Surgeons (ASES) scores were obtained preoperatively and postoperatively. Patient outcomes were compared based on glenoid fixation and rotator cuff status. There were 18 TSAs revised to RSAs that underwent subsequent revision.
Results: The mean preoperative ASES score was 31 (95% confidence interval [CI], 29-33) with no difference in preoperative ASES scores based on glenoid status ($P = .412$) or rotator cuff status ($P = .89$). No difference in postoperative ASES score was found based on glenoid component status or rotator cuff status. However, improvement in the ASES score was greater with an intact rotator cuff (mean postoperative score, 67 [95% CI, 57-76] vs. 55 [95% CI, 50-60]; $P = .025$). The overall re-revision rate was 11.4%, with a mean time to re-revision of 22 months (range, 0-89 months). The odds ratio was 1.786 for subsequent revision in patients with glenoid loosening compared with those without loose glenoids on preoperative radiographs.
Conclusion: There was an overall improvement in patient outcomes for failed TSAs revised to RSAs; however, patients with an intact cuff had a greater improvement in ASES scores.
Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Total shoulder arthroplasty; reverse shoulder arthroplasty; revision; re-revision; glenoid loosening; intact rotator cuff

Failed total shoulder arthroplasty (TSA) has often been simplified into 3 main categories: (1) soft tissue deficiency, (2) osseous deficiency, and (3) component wear.[1-4,9,19] Although this provides a convenient way to rationalize clinical decision making for revision shoulder arthroplasty, there is often overlap between these categories. For example, rotator cuff deficiency can lead to glenoid component loosening and thus an osseous deficiency.[6] Revision shoulder arthroplasty is often complex and multifactorial. In addition, intraoperative factors add further variability such as the degree of glenoid or humeral bone loss that occurs on implant removal. All of these factors combined ultimately contribute to patient outcomes and implant survivorship.

This study was determined to be exempt from review by the Western Institutional Review Board.

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Multiple studies looking at revision shoulder arthroplasty have been performed. Often, these studies contained mixed cohorts of implants being revised including humeral resurfacing, hemiarthroplasties, and anatomic and reverse total shoulder arthroplasties.[7,10,14,15] Although the revision procedure was similar, the initial implants were used to treat different pathologies. Both the initial pathology and implant used are associated with differing degrees of humeral and glenoid bone loss during revision arthroplasty, which adds further variability and may affect reported outcomes.

The aim of this study was to evaluate outcomes and the risk of re-revision in patients with a failed anatomic TSA revised to a reverse shoulder arthroplasty (RSA). Analysis of complications reported to the US Food and Drug Administration found that the most common failure modes for anatomic TSA are glenoid component failure (20%), rotator cuff tear (15%), pain and/or stiffness (13%), dislocation and/or instability (12%), infection (9%), and humeral component failure (5%).[16] Our study focused on patient outcomes after revision to RSA and the effect of the 2 most common failure mechanisms of anatomic TSA, glenoid component failure and rotator cuff deficiency. We hypothesized that functional outcomes would be dependent on the degree of rotator cuff deficiency and that the risk of re-revision would be dependent on the severity of glenoid bone loss encountered at the time of revision.

Methods

Patient demographic characteristics

This was a retrospective review of all shoulder anatomic TSAs revised to RSAs between 2004 and 2017 by a single surgeon (M.A.F.). A total of 158 anatomic TSAs revised to RSAs were identified. General demographic data collected to describe the population included age, sex, laterality, diabetes, tobacco use, body mass index, and time from initial TSA to revision RSA.

Three experienced shoulder surgeons blinded to the case information independently reviewed the preoperative radiographs of the failed anatomic TSAs. The glenoid component was assessed radiographically for loosening[12] on at least 3 radiographic views including anteroposterior, Grashey, scapular Y, and axillary lateral. Glenoid components were categorized as loose or fixed based on majority assessment of the reviewers.

Surgical characteristics

All revisions were performed through a standard deltopectoral approach using the Reverse Shoulder Prosthesis (RSP; DJO Surgical, Austin, TX, USA), RSP Monoblock (DJO Surgical), or AltiVate Reverse (DJO Surgical). Fourteen patients were treated with retention of the humeral stem and conversion to RSA using a convertible platform. Six of the revisions were performed as a staged procedure: 2 were due to infection; 3, the severity of glenoid bone loss; and 1, intraoperative myocardial infarction. The 5 staged revisions for infection or glenoid bone loss had loose glenoids on preoperative radiographs.

The rotator cuff was assessed intraoperatively by the surgeon at the time of revision and categorized as follows: normal; irreparable subscapularis; irreparable supraspinatus; irreparable subscapularis and supraspinatus; irreparable supraspinatus and infraspinatus; or irreparable supraspinatus, infraspinatus, and subscapularis. The teres minor was not routinely assessed. Irreparable rotator cuff tears were grouped into the cuff-deficient group, and normal tendons were categorized into the cuff-intact group. The severity and location of glenoid bone loss were also assessed intraoperatively and categorized as mild, moderate, or severe and as central, anterior, posterior, or superior, respectively. The decision to use glenoid bone allograft was based on the severity and location of glenoid bone loss. Mild or moderate contained defects or mild uncontained defects with >50% contact of the glenoid baseplate were not bone grafted. Moderate or severe uncontained defects were grafted using frozen femoral head allograft. Additional intraoperative characteristics were recorded including implant used, whether the humeral stem was cemented, and use of glenoid bone allograft or proximal humeral allograft.

Postoperative rehabilitation included immobilization of the operative extremity in a sling for 6 weeks with passive shoulder exercises only. From 6 weeks to 3 months, patients were instructed to begin active-assisted shoulder-stretching exercises, and strengthening was begun 3 months after the revision operation.

Clinical outcomes

Outcome data were recorded preoperatively and postoperatively at subsequent follow-up visits beginning 3 months after the revision procedure. Patient-reported active shoulder range of motion including forward elevation, abduction, external rotation, and internal rotation was recorded. In addition, patient-reported shoulder pain and function were assessed using the American Shoulder and Elbow Surgeons (ASES) score[11,17] and Simple Shoulder Test (SST) score.[8] Patients without preoperative ASES scores were excluded from the outcome analysis. Outcome data of patients who underwent a subsequent re-revision of their RSA were excluded after the date of their second revision operation.

Statistical analyses

Descriptive statistics are reported as frequencies and percentages for categorical variables and as medians or means and confidence intervals (CIs) for continuous variables where appropriate. Comparisons between patient outcomes were performed with 2-sample t tests for equal variances between the groups. $P < .05$ was considered statistically significant. Analyses were performed with SPSS software (IBM, Armonk, NY, USA).

Results

Patient demographic characteristics

Patient demographic characteristics of the overall patient population are reported in Table I. The mean age of the overall population was 67 years (range, 39-90 years). The

Table I Overall patient characteristics (N = 158)

	N (%) Data
Age, mean (range), yr	67 (39-90)
Sex, n (%)	
Male	81 (51)
Female	77 (49)
Operative side, n (%)	
Right	86 (54)
Left	72 (46)
Diabetes mellitus, n (%)	27 (17)
Body mass index, mean (range) kg/m^2	29.3 (17.6-52.2)
Tobacco use, n (%)	
None	78 (49)
History	59 (37)
Current	21 (13)
Workers' compensation, n (%)	4 (3)

mean time from initial TSA to revision was 5.7 years (range, 0.2-23 years).

Surgical characteristics

Surgical characteristics are reported in Table II. On the basis of preoperative radiographs, 96 patients (61%) were determined to have loose glenoids whereas 62 (39%) had fixed glenoids. Glenoid allograft was used in 75 of the revision procedures. Glenoid allograft was used more frequently in revisions with loose glenoids on preoperative radiographs; 54 (56%) of the revisions with loose glenoids and 21 (34%) of the revisions with fixed glenoids used glenoid allograft.

Intraoperative assessment of the rotator cuff at the time of revision surgery revealed 125 patients (79%) with irreparable rotator cuff tears and 33 (21%) with normal rotator cuffs. Of those in the rotator cuff–deficient group, 7 had isolated subscapularis tears, 50 had supraspinatus tears, 31 had supraspinatus and subscapularis tears, 27 had supraspinatus and infraspinatus tears, and 10 had cuff tears involving the subscapularis, supraspinatus, and infraspinatus.

Five of the revisions required proximal humeral allograft because of humeral bone loss prior to or during the revision procedure. Subsequent implant design changes over the study period resulted in the use of different stems, as summarized in Table II. There were 14 revisions with retained humeral stems that were converted to RSAs.

Clinical outcomes

There were 123 patients with reported outcomes at minimum 2-year follow-up (mean, 54 months; range, 22-138 months). Patients who underwent a second revision were excluded from the outcome analysis, leaving an overall follow-up rate of 78%. The overall mean preoperative ASES score was 31 (95% CI, 29-33), with no significant difference in preoperative ASES scores based on whether the glenoid was fixed or loose ($P = .412$) or whether the rotator cuff was intact or deficient ($P = .89$). The mean postoperative ASES score was 55 (95% CI, 50-60) in the cuff-deficient group and 67 (95% CI, 57-76) in the cuff-intact group, and the difference was statistically significant ($P = .025$). There was no statistically significant difference between the groups based on glenoid status ($P = .459$). The mean postoperative ASES score was 56 (95% CI, 50-62) in the fixed-glenoid group and 59 (95% CI, 53-65) in the loose-glenoid group. These results are summarized in Figure 1. The overall change in ASES score from preoperatively to 2-year follow-up was 26 (95% CI, 21-30).

SST score was 1.8 (95% CI, 1.5-2.1), with no significant difference in preoperative SST scores baded on whether the glenoid was fixed or loose ($P = .893$) or whether the rotator cuff was intact or deficient ($P = .627$). The overall mean postoperative SST score was 5 (95% CI, 4.4-5.6), with no significant difference in postoperative SST scores based on whether the glenoid was fixed or loose ($P = .876$) or whether the rotator cuff was intact or deficient ($P = .234$). Comparisons of preoperative and postoperative range of motion are summarized in Table III. No statistically significant differences in preoperative or postoperative range

Table II Surgical characteristics (N = 158)

	n (%)
Glenoid component	
Loose	96 (61)
Fixed	62 (39)
Glenoid bone loss severity	
Mild	10 (6)
Moderate	71 (45)
Severe	77 (49)
Glenoid bone loss location	
Anterior	7 (4)
Posterior	14 (9)
Central	133 (84)
Superior	4 (3)
Rotator cuff	
Intact	33 (21)
Deficient	125 (79)
RSA stem type	
Modular all-polyethylene	5 (3)
Modular	61 (38.5)
Monoblock	52 (33)
AltiVate	25 (16)
Conversion	14 (9)
Cemented RSA stem	103 (65)
Proximal humeral allograft	5 (3)
Glenoid allograft	75 (47)

RSA, reverse shoulder arthroplasty.

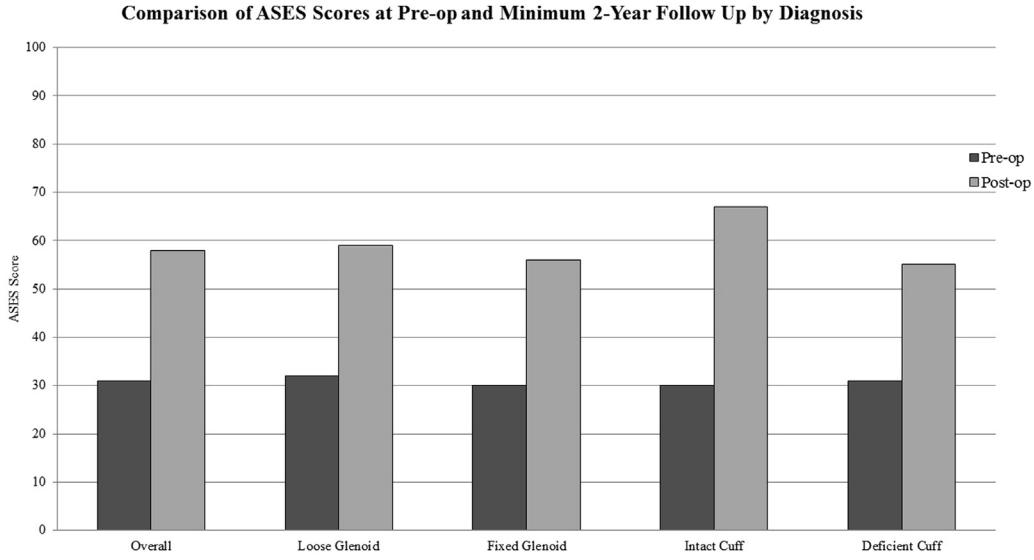

Figure 1 Comparison of American Shoulder and Elbow Surgeons *(ASES)* scores preoperatively *(Pre-op)* and postoperatively *(Post-op)* at minimum of 2 years' follow-up by diagnosis.

of motion were found between the 2 groups: fixed vs. loose glenoid or intact vs. deficient cuff.

Subsequent revisions

The overall re-revision rate was 11.4%, with a mean time to re-revision of 22 months (range, 0-89 months). The most common reason for subsequent revision was glenoid-sided failure (11 of 18 cases). There were 3 RSAs revised for humeral loosening, 3 with subsequent infections, and 1 revised for instability. Of the 11 RSAs with glenoid-sided failure, all (100%) had loose glenoids on preoperative radiographs at the time of the initial revision. This is in contrast to 53.8% of cases (n = 85) with loose glenoids on preoperative radiographs in the group that were not subsequently revised (n = 83) or that underwent revision for reasons other than glenoid-sided failure (n = 2 [humeral loosening in 1 and infection in 1]). Rates of rotator cuff deficiency were similar between the revision groups. The odds ratio was 1.786 for subsequent revision in patients with glenoid loosening compared with those without loose glenoids on preoperative radiographs.

Discussion

Although revision arthroplasty is often complex and multifactorial, there is an overall improvement in patient outcomes when revised to RSA. A recently published study comparing patient outcomes after TSA revision to RSA vs. primary RSA showed no significant differences in ASES and visual analog scale pain scores between groups.[15] However, the previous study did show a significant difference between the 2 groups regarding patient satisfaction and the number of complications, with the revision group having lower patient satisfaction scores and more complications.

Kelly et al[10] evaluated patient outcomes after revision to RSA in 30 patients, with a mixed cohort of revised hemiarthroplasties, TSAs, and RSAs. The initial mean preoperative ASES score was 54.8 and the mean postoperative ASES score was 71.8, with a change in the ASES score of 17.1. Although our study's mean preoperative and postoperative ASES scores differed, the change in the ASES score was greater in our cohort. In addition, Kelly et al examined a subset of revision RSAs based on reconstruction of the scapula with and without tricortical iliac crest bone graft. Their study showed no difference in ASES scores, Constant scores, or range of motion between the groups with and without bone graft. This finding is similar to the findings of our study as there was no difference in functional outcomes after revision when the fixed- and loose-glenoid groups were compared. Kelly et al reported 7 subsequent re-revision RSAs or resection arthroplasties: 2 for humeral loosening, 2 for instability, 2 for infection, and 1 for glenoid baseplate loosening in a patient with tricortical iliac crest bone graft.

Sheth et al[14] recently published a study with a combined cohort of 70 hemiarthroplasties and 40 TSAs revised to RSAs. Glenoid bone graft was used in 25% of the revisions and was more common in patients with previous TSAs (50%) vs. hemiarthroplasties (10%). Reoperation was required in 10 patients (11%); 2 of these reoperations were for glenoid baseplate loosening. Functional outcome scores

Table III Mean range-of-motion comparison: preoperative and minimum 2-year follow-up

	Overall			Glenoid status				Cuff status			
				Fixed		Loose glenoid		Intact		Deficient	
	Preoperative	Follow-up (minimum, 2 yr)	Preoperative	Follow-up (minimum, 2 yr)	Preoperative	Follow-up (minimum, 2 yr)	Preoperative	Follow-up (minimum, 2 yr)	Preoperative	Follow-up (minimum, 2 yr)
Forward flexion, °	67	122	65	124	68	110	77	134	64	110
Abduction, °	59	114	56	116	61	113	67	123	57	111
External rotation, °	28	35	33	37	25	33	34	38	27	34
Internal rotation *	S1-L5	T11-L4	S1-L5	T11-L4	S1-L5	S1-L5	S1-L5	T11-L4	S1-L5	T11-L4

* Vertebral level patient is able to reach with hand behind back.

were obtained for 73 of the patients. The mean ASES score for all patients with minimum 2-year follow-up was 63. Preoperative ASES scores were not available for comparison.

There are limited studies available looking at revision of isolated anatomic TSA. A previous case series evaluating 22 patients from 2004 to 2008 who underwent revision to RSA reported a median total ASES score improvement from 38.5 preoperatively to 67.5 postoperatively with minimum 2-year follow-up.[18] Melis et al[13] reported on 40 anatomic TSAs revised to RSAs for aseptic glenoid loosening. The mean interval between primary TSA and revision was 75.3 months. At the time of revision, a diagnosis of associated rotator cuff tears, in addition to glenoid loosening, was made in 65% of patients. Patient outcomes at minimum 2-year follow-up showed significant improvement in the Constant score, and forward elevation improved from 68° to 121° ($P < .0001$). Melis et al reported no significant difference in internal or external rotation after revision to RSA, which was similar to the findings of our study. In addition, they reported subsequent revision in 8 of the anatomic TSAs revised to RSAs (22%). Of these, 3 were due to glenoid loosening; 3, anterior instability; and 2, humeral loosening or subsidence. Similar to our study, their study showed that glenoid loosening was a common reason for subsequent revision.

In a previous study performed at our institution looking at 207 hemiarthroplasties or humeral resurfacings revised to RSAs, humeral loosening (8 of 16) was found to be the most common failure mechanism regarding the need for re-revision, with an overall re-revision rate of 7.7%.[5] This result is in contrast to the findings in our study, which showed glenoid loosening to be a more common cause of re-revision after TSA. In the previous study cohort, ASES scores at a minimum of 2 years' follow-up were separated by the indications for which the original hemiarthroplasty was performed. These scores were reported as 68 for osteoarthritis, 56 for cuff tear arthropathy, and 58 for fracture. Although the previous study did not evaluate the condition of the rotator cuff at the time of revision to RSA, pathologies more likely to have an intact rotator cuff, such as osteoarthritis, had statistically significantly higher ASES scores than cuff-deficient pathologies such as cuff tear arthropathy or fracture. The results of both the aforementioned study and our study suggest that patients with an intact rotator cuff will have higher average ASES scores at a minimum of 2 years' follow-up than their counterparts with cuff deficiencies.

Limitations to our study include its retrospective design, although patient outcomes were collected prospectively. Intraoperative assessment of the rotator cuff was based on a single surgeon's subjective interpretation of the intraoperative findings. However, the strengths of this study include the homogeneous population with respect to implants used and the relatively large population of anatomic TSAs revised to RSAs compared with previous studies.

Conclusion

There was an overall improvement in patient outcomes for failed TSAs revised to RSA; however, patients with an intact cuff had a greater improvement in ASES scores than those with a deficient rotator cuff. Patients with loose glenoid components and more severe glenoid bone loss intraoperatively have an increased risk of subsequent revision of the RSA owing to glenosphere loosening or failure.

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