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Does the etiology of a failed hemiarthroplasty affect outcomes when revised to a reverse shoulder arthroplasty?

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Background: The purposes of this study were to evaluate patient outcomes after revision of hemiarthroplasty to reverse shoulder arthroplasty (RSA) based on initial pathology, to determine the re-revision rate, and to identify characteristics that may predict subsequent re-revision.
Methods: A total of 207 shoulder hemiarthroplasty, bipolar prosthesis, and humeral resurfacing cases revised to RSA between January 2004 and January 2017 were reviewed. Outcome measures included shoulder motion and American Shoulder and Elbow Surgeons and Simple Shoulder Test (SST) scores. Sixteen RSAs underwent re-revision. A case-control study with each revised RSA matched to 4 controls based on age, sex, and minimum 2-year follow-up was performed to evaluate for factors predicting re-revision.
Results: The mean time from initial hemiarthroplasty to RSA was 3.6 years (range, 0.1-20 years). There were 114 patients with a minimum of 2 years' follow-up (mean, 57 months; range, 24-144 months). The most common initial diagnoses for hemiarthroplasty were fracture (n = 72), cuff tear arthropathy (CTA) (n = 22), and osteoarthritis (OA) (n = 20). Overall mean scores and range-of-motion values were as follows: American Shoulder and Elbow Surgeons score, 59 (95% confidence interval [CI], 54-64); SST score, 4 (95% CI, 4-5); forward flexion, 106° (95% CI, 96°-116°); and abduction, 95° (95% CI, 85°-105°). Compared with fracture cases, CTA cases had better forward flexion ($P = .01$) and abduction ($P = .006$) and OA cases had better SST scores ($P = .02$) and abduction ($P = .04$). The re-revision rate was 7.7% at a mean of 31 months (range, 0-116 months), with the most common diagnosis being fracture (10 of 16 cases). Humeral loosening (8 of 16 cases) was the most common failure mechanism, and larger glenosphere sizes were more likely to be revised.
Conclusion: Functional outcome scores of hemiarthroplasty cases revised to RSA were better for patients with OA than for patients with CTA or fracture. Cases of hemiarthroplasty for fracture had decreased motion after revision to RSA compared with CTA and OA. Humeral loosening was the most common failure mechanism.
Level of evidence: Level III; Retrospective Cohort Design; Treatment Study

Keywords: Hemiarthroplasty; reverse shoulder arthroplasty; revision; fracture; osteoarthritis; cuff tear arthropathy

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

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Shoulder hemiarthroplasty was first performed in the United States by Dr. Charles Neer in the 1950s to treat proximal humeral fractures.[14] Since its introduction, hemiarthroplasty has been used to treat a number of shoulder conditions, including osteoarthritis (OA), rotator cuff arthropathy, and avascular necrosis, in addition to proximal humeral fractures. Although the use of hemiarthroplasty has been decreasing over the past several years owing to the expanding indications for reverse shoulder arthroplasty (RSA), there is still a need for revision of failed hemiarthroplasties especially as these prostheses age.[15,19]

There are multiple causes of hemiarthroplasty failure, including humeral loosening, instability, rotator cuff deficiency, glenoid erosion, and infection.[1,4,11] Several studies have looked at patient outcomes after revision of hemiarthroplasty to RSA.[5,8,9,12,13] Most of these studies involved small patient populations with isolated pathologic conditions. Levy et al[9] evaluated the outcomes of RSA for the treatment of failed hemiarthroplasty for cuff tear arthropathy (CTA) in 19 shoulders. In addition, several studies have reported the outcomes of RSA for failed hemiarthroplasty for fracture. Levy et al[8] reported outcomes for 29 patients, Merolla et al[12] reported outcomes for 36 patients, and Holschen et al[5] reported 5-year outcomes of 35 patients.

Merolla et al[13] published a multicenter study evaluating patient outcomes and revision rates after conversion of failed hemiarthroplasty to RSA in 157 patients. They reported the indication for the initial hemiarthroplasty but did not examine differences in patient outcomes regarding initial pathology. To our knowledge, no studies have looked at patient-reported outcomes after hemiarthroplasty revised to RSA with respect to initial pathology or intraoperative characteristics of the surgical procedure, such as humeral bone loss or use of proximal humeral allograft. Each of the initial diagnoses (fracture, OA, and CTA) is associated with varying amounts of bone loss, soft-tissue contracture, and muscle-tendon loss. We hypothesized that different initial pathologic conditions for hemiarthroplasty would affect the failure mechanisms, time to revision, and patient outcomes after revision to RSA.

The purposes of this study were to evaluate patient outcomes after revision of hemiarthroplasty to RSA based on initial pathology, to determine the revision rate, and to identify characteristics that may predict subsequent re-revision.

Methods

Patient characteristics

All shoulder hemiarthroplasty, bipolar prosthesis, or humeral resurfacing cases revised to an RSA for pain or loss of function between January 2004 and January 2017 by a single surgeon (M.A.F.) were reviewed for this retrospective comparative study. Hemiarthroplasties performed as part of a staged procedure with prior anatomic shoulder arthroplasty or RSA were excluded. Primary hemi-spacers for infection or primary hemiarthroplasty with glenoid bone graft were included. A total of 207 revision hemiarthroplasties were identified. General demographic characteristics were collected to describe the population, including age, sex, laterality, index diagnosis for the hemiarthroplasty, time to revision RSA from initial hemiarthroplasty, whether prior surgical procedures were performed before the initial hemiarthroplasty, and subsequent operations after the hemiarthroplasty before revision to RSA.

Preoperative assessment

Three independent observers evaluated the preoperative radiographs of each hemiarthroplasty case for stem fixation (cemented or uncemented), stem stability (loose, stable, or at risk), glenohumeral registry (concentric or eccentric), and tuberosity abnormalities (anatomic, abnormal, or absent). Glenohumeral registry was determined similarly to the criteria defined by Hsu et al.[6] On Grashey and axillary lateral views, a circle was fitted to the humeral component and a line was drawn perpendicular to the center of the glenoid face. Loss of congruency was recorded when the displacement was greater than 5%. The tuberosity status was determined from all available views. Anatomic tuberosities were recorded as such. An absent tuberosity was defined as the absence of the greater tuberosity or both tuberosities on all views. The group of abnormal tuberosities included malunions, nonunions, and loss of anatomic tuberosity position due to malposition of the hemiarthroplasty prosthesis. Abnormal tuberosities had a minimum displacement of 1 cm from the anatomic position.[2] If the glenoid appeared normal on all views, it was defined as having no wear. When glenoid wear was evident, it was classified according to its concentricity or eccentricity. Stems were defined as loose using criteria based on the Gruen zones described by Matsen et al[10] for uncemented stems and by Sanchez-Sotelo et al[17] for cemented stems.

Surgical characteristics

Revision of the failed hemiarthroplasty to an RSA was considered for patients with rotator cuff deficiency resulting in significant pain or loss of function, glenoid erosion resulting in persistent pain, or mechanical complications including loosening. All patients were treated with a single-stage revision through a deltopectoral approach to a Reverse Shoulder Prosthesis (RSP; DJO Surgical, Austin, TX, USA), RSP Monoblock (DJO Surgical), or AltiVate Reverse (DJO Surgical). Typical glenosphere sizes were 32-4 for female patients and 32N for male patients; glenosphere sizes were increased by glenoid bone grafting with a hooded glenosphere or for instability. Intraoperative data were collected, including the size of the implant used, whether the humeral stem was cemented, whether glenoid bone allograft or proximal humeral allograft was used, and whether a lateral tendon transfer was performed. Postoperative rehabilitation included use of 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 started after 3 months.

Clinical outcomes

Outcome data were recorded preoperatively and postoperatively at subsequent follow-up visits beginning 3 months after revision to RSA. 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[7,16] and Simple Shoulder Test (SST) score.[3] Patients without preoperative ASES scores were excluded from the outcome analysis. Patient satisfaction with the surgical outcome was measured using a patient-reported score of 1 to 10, where 10 indicates extremely satisfied. The outcome data of patients who underwent a successive revision of their RSA were excluded after the date of their subsequent revision surgery. Patients for whom the initial diagnosis was unclear, as well as those missing preoperative or at least 1 subsequent postoperative reported range-of-motion value, ASES score, and SST score, were excluded from the outcome analysis.

Subsequent revisions

The total population was evaluated for subsequent surgical procedures after revision to RSA. A re-revision was classified as any subsequent surgical procedure in which any components were changed. Subsequent revisions were performed for radiographic loosening with associated pain and loss of function, mechanical failure, dislocation, or evidence of infection. Each revision RSA was matched with 4 case controls that did not undergo revision based on age and sex with a minimum follow-up period of 2 years. Descriptive statistics were used to evaluate differences between the 2 groups regarding initial pathology, characteristics on preoperative radiographs, and intraoperative findings.

Statistical analyses

Descriptive statistics are reported as frequencies and percentages for categorical variables and as medians and interquartile ranges or means and standard deviations for continuous variables, where appropriate. Bivariate analyses examining the association between initial pathology or intraoperative findings and time to revision were performed with Kaplan-Meier and/or unadjusted Cox regression models. $P < .05$ was considered statistically significant. All analyses were performed with Stata software (version 15.1; StataCorp, College Station, TX, USA).

Results

Patient characteristics

The mean age at the time of revision to RSA was 65 years (range, 29-86 years). Table I shows the demographic characteristics of the study population. The mean time from initial hemiarthroplasty to revision was 3.6 years (range, 0.1-20 years). No significant difference in time to revision was found based on the initial indication for hemiarthroplasty. Among the total of 207 revision hemiarthroplasties identified, there were 114 patients with a minimum of 2 years' clinical follow-up (mean, 57 months; range, 24-144 months). Among the patients with minimum 2-year follow-up, the most common initial pathologic condition was fracture (63%), followed by CTA (19.3%) and OA (17.5%). An additional 10 patients were excluded for having insufficient numbers to analyze for the initial pathologic condition (avascular necrosis [3], infection [1], instability [1], rheumatoid arthritis [4], and tumor [1]).

Table I Overall patient demographic characteristics (N = 207)

	Data
Age, mean (range), yr	65 (29-86)
Sex, n (%)	
Male	81 (39.1)
Female	126 (60.9)
Operative side, n (%)	
Right	125 (60.4)
Left	82 (39.6)
Diagnosis, n (%)	
Fracture	110 (53.1)
Cuff tear arthropathy	39 (18.8)
Osteoarthritis	31 (15.0)
Avascular necrosis	6 (2.9)
Inflammatory arthritis	6 (2.9)
Infection	4 (1.9)
Instability	2 (1.0)
Tumor	1 (0.5)
Initial implant, n (%)	
Hemiarthroplasty	169 (81.6)
Resurfacing	23 (11.1)
Bipolar	10 (4.8)
Hemi-spacer	5 (2.4)
Hemiarthroplasty cemented	116 (56.0)

Preoperative assessment

Preoperatively, significant differences in range of motion were found between the groups based on diagnosis. Specifically, compared with fracture patients, CTA patients had significantly higher forward flexion ($P = .001$), abduction ($P = .02$), and external rotation ($P = .03$). Shoulders with OA also had significantly higher forward flexion ($P < .001$) and abduction ($P < .001$) than shoulders with an initial diagnosis of fracture (Table II). The results of the preoperative radiographic assessment are shown in Table III. One patient had no available preoperative radiographs.

Surgical characteristics

The stem used was related to subsequent implant design changes during the study period. There were 139 RSP stems (29 with an all-polyethylene shell and 110 with

Table II Preoperative clinical assessment, overall and by initial pathology

	Overall (n = 114)	CTA (n = 22)	Fracture (n = 72) (ref)	OA (n = 20)
ASES total score	33 (30-37)	27 (18-37)	34 (30-39)	35 (28-42)
ASES pain score	19 (17-21)	16 (10-22)	20 (17-23)	19 (14-24)
ASES function score	14 (12-16)	13 (8-17)	14 (12-16)	16 (12-20)
SST score	2 (1-2)	1 (1-2)	1 (1-2)	2 (1-3)*
Forward flexion, °	55 (48-62)	71 (53-89)*	43 (36-49)	83 (61-105)*
Abduction, °	51 (45-58)	60 (43-77)*	43 (36-49)	74 (56-93)*
External rotation, °	19 (13-25)	31 (19-42)*	15 (9-22)	19 (2-36)
Internal rotation†	2 (2-3)	2 (1-3)	2 (2-3)	2 (1-3)

CTA, cuff tear arthropathy; *ref*, reference category; *OA*, osteoarthritis; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test. Data are presented as mean (95% confidence interval).

* Statistically significant differences in CTA cases were found for forward flexion ($P = .001$), abduction ($P = .02$), and external rotation ($P = .03$). Statistically significant differences in OA cases were found for forward flexion ($P < .001$), abduction ($P < .001$), and SST score ($P = .02$).

† Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 to L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7), and C8 to T1 (8).

Table III Preoperative radiographic assessment

	n (%)
Glenohumeral registry	
Incongruent	159 (76.8)
Congruent	47 (22.7)
Tuberosity status	
Anatomic	113 (54.6)
Absent	67 (32.4)
Malunion	17 (8.2)
Nonunion	9 (4.3)
Glenoid wear	
No obvious wear	76 (36.7)
Eccentric	90 (43.5)
Concentric	34 (16.4)
Indeterminate	6 (2.9)
Stem assessment	
Stable	179 (86.5)
At risk	14 (6.8)
Loose	13 (6.3)

a metal shell), 54 RSP Monoblock stems, and 9 AltiVate Reverse stems. Three patients were treated with retained humeral stems and conversion to RSA. The RSA stem was cemented in 182 patients. Proximal humeral allograft was used in 61 revisions to RSA.

Clinical outcomes

At final follow-up, CTA shoulders had significantly higher forward flexion ($P = .01$) and abduction ($P = .006$) than shoulders with an initial diagnosis of fracture. Shoulders with an initial diagnosis of OA had significantly better abduction ($P = .04$) than shoulders with fractures (Table IV). Overall, the average point gain in ASES scores from preoperatively to postoperatively was 26 (95% confidence interval, 20-31). Some variation was found between the initial diagnosis groups, but all groups showed improvement in the ASES score, forward flexion, abduction, and external rotation. No statistically significant differences in the amount of improvement in any of the outcomes were found for any of the initial diagnosis groups. On the basis of the previously reported minimal clinically important difference, by use of a minimum improvement in the ASES score of 20 points,[18] 58% of the failed hemiarthroplasties revised to RSA achieved a 20-point improvement in the ASES score at final follow-up. On the basis of the initial diagnosis, 68% of patients with CTA, 61% of patients with OA, and 54% of patients with fracture had at least a 20-point improvement in the ASES score at final follow-up (Table V). These differences based on initial diagnosis were not statistically significant.

Subsequent revisions

A total of 16 revision RSAs (7.7%) underwent subsequent revision, and the mean time to revision of the RSA was 31 months (range, 0-116 months). The initial diagnoses in the revised RSA cases were fracture (n = 10), CTA (n = 3), OA (n = 2), and infection (n = 1). Humeral loosening (8 of 16 cases) was the most common failure mechanism for subsequent revision, followed by dislocation (n = 3) or infection (n = 3) and glenosphere dissociation (n = 2).

The case-control study evaluated for factors that may be associated with an increased risk of subsequent revision of the RSA. The re-revision cases were compared with controls based on patient and surgical characteristics including initial implant type, initial diagnosis, whether the hemiarthroplasty or RSA stems were cemented, and use of proximal humeral allograft. Data from the preoperative radiographic assessment were also compared for the 2 groups, including joint congruence, tuberosity status, and glenoid wear. No significant difference in subsequent revisions was found regarding the initial implant, diagnosis,

Table IV Postoperative clinical assessment, overall and by initial pathology

	Overall (n = 114)	CTA (n = 22)	Fracture (n = 72) (ref)	OA (n = 20)
ASES total score	59 (54-64)	56 (42-70)	58 (52-63)	68 (53-82)
ASES pain score	34 (31-37)	31 (23-38)	35 (31-38)	34 (26-43)
ASES function score	25 (22-27)	26 (19-32)	23 (20-26)	32 (25-40)*
SST score	4 (4-5)	5 (3-6)	4 (3-4)	6 (4-8)*
Forward flexion, °	106 (96-116)	129 (104-154)*	95 (83-107)	120 (93-148)
Abduction, °	95 (85-105)	119 (96-142)*	83 (72-95)	111 (81-140)*
External rotation, °	34 (27-41)	36 (18-53)	31 (22-41)	41 (20-62)
Internal rotation†	3 (3-4)	3 (2-4)	3 (3-4)	4 (2-5)
Satisfaction	7 (7-8)	7 (6-9)	7 (6-8)	8 (6-9)

CTA, cuff tear arthropathy; *ref*, reference category; *OA*, osteoarthritis; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test.
Data are presented as mean (95% confidence interval).
* Statistically significant differences were found for forward flexion ($P = .01$) and abduction ($P = .006$) in CTA cases and for ASES function scores ($P = .008$), SST scores ($P = .01$), and abduction ($P = .04$) in OA cases.
† Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 to L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7), and C8 to T1 (8).

Table V Difference in preoperative and postoperative outcomes, overall and by initial pathology

	Overall (n = 114)	CTA (n = 22)	Fracture (n = 72) (ref)	OA (n = 20)
ASES total score	26 (20-31)	29 (16-41)	23 (16-30)	32 (16-48)
ASES pain score	15 (11-18)	15 (7-23)	15 (10-19)	15 (6-24)
ASES function score	11 (8-14)	13 (7-19)	9 (5-12)	16 (9-24)
≥20-point gain in ASES score, %	58 (48-68)	68 (44-92)	54 (41-66)	61 (36-86)
SST score	3 (2-3)	3 (2-4)	2 (1-3)	3 (1-5)
Forward flexion, °	51 (40-61)	58 (31-85)	52 (40-65)	37 (8-67)
Abduction, °	43 (33-54)	59 (35-82)	41 (28-53)	36 (5-68)
External rotation, °	15 (6-24)	5 (−16 to 26)	16 (5-27)	22 (−2 to 47)
Internal rotation*	1 (0-2)	1 (0-2)	1 (0-2)	1 (0-3)

CTA, cuff tear arthropathy; *ref*, reference category; *OA*, osteoarthritis; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test.
Data are presented as mean (95% confidence interval).
* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 to L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7), and C8 to T1 (8).

or preoperative radiographic characteristics assessed (Table VI). Glenosphere size was predictive of revision, with glenosphere sizes of 40N and larger being more likely to be revised.

Discussion

This study showed overall mean scores, with minimum 2-year follow-up, of 59 for the ASES score, 4 for the SST score, and 7 for patient satisfaction. Merolla et al[13] reported similar results with a median ASES score of 60 and SST score of 6, as well as a mean patient satisfaction score of 7.2, at latest postoperative follow-up. They reported the indication for the initial hemiarthroplasty but did not examine differences in patient outcomes regarding initial pathology.

Each initial diagnosis (fracture, OA, and CTA) is associated with varying amounts of bone loss, soft-tissue contracture, and muscle-tendon loss, so we hypothesized that the initial pathology for hemiarthroplasty would affect patient outcomes after revision to RSA. Our study did find significant differences in range of motion between the diagnoses. Preoperative and postoperative range of motion was lower for patients with an initial diagnosis of fracture than for patients with a diagnosis of OA or CTA. Tuberosity malposition or nonunion and post-traumatic stiffness may contribute to these differences.

For fracture, our study population had a mean preoperative ASES score of 34 and mean postoperative score of 58, with an average 23-point improvement in the ASES score. Levy et al[8] reported on outcomes following revision to RSA for failed hemiarthroplasty after fracture in 29 patients. They found a mean preoperative ASES score of 22.3 and mean postoperative ASES score of 52.1, with an average 29-point improvement in the ASES score at final follow-up. For CTA, our study reported improvement in the ASES score from an average of 27 preoperatively to an average of 56 postoperatively. This closely matches the results of patients with CTA in another study by Levy et al,[9]

Table VI Factors predicting subsequent revision of RSA

	Control (n = 64) (%)	Case (n = 16) (%)	*P* value
Patient demographic characteristic			
Female sex, n (%)	36 (56.2)	9 (56.2)	.99
Age, mean (SD), yr	64 (8)	64 (8)	.98
Initial implant, n (%)			.71
Hemiarthroplasty	53 (82.8)	14 (87.5)	
Bipolar	4 (6.2)	1 (6.2)	
Hemi-spacer	2 (3.1)	1 (6.2)	
Resurfacing	5 (7.8)	0	
Initial diagnosis, n (%)			.64
Fracture	31 (48.4)	10 (62.1)	
CTA	13 (20.3)	3 (18.7)	
OA	14 (21.9)	2 (12.5)	
Infection	1 (1.6)	1 (6.2)	
RA	4 (6.2)	0	
AVN	1 (1.6)	0	
Preoperative assessment, n (%)			
Congruent glenohumeral registry	15 (23.4)	1 (6.2)	.17
Tuberosity status			.29
Anatomic	38 (59.4)	6 (37.5)	
Absent	20 (31.2)	7 (43.7)	
Malunion	4 (6.2)	2 (12.5)	
Nonunion	2 (3.1)	1 (6.2)	
Glenoid wear			.89
No obvious wear	25 (39.1)	5 (31.2)	
Eccentric	25 (39.1)	8 (50)	
Concentric	10 (15.6)	2 (12.5)	
Indeterminate	4 (6.2)	1 (6.2)	
Hemiarthroplasty stem cemented	38 (59.4)	11 (68.7)	.57
Stem assessment			.22
Stable	58 (90.6)	13 (81.2)	
At risk	4 (6.2)	1 (6.2)	
Loose	2 (3.1)	2 (12.5)	
Surgical characteristic, n (%)			
RSA stem type			.1
Modular all-polyethylene	8 (12.5)	5 (31.2)	
Modular	38 (59.4)	8 (50)	
Monoblock	17 (26.6)	2 (12.5)	
AltiVate	1 (1.6)	0	
Conversion or retained stem	0	1 (6.2)	
RSA stem cemented	5 (7.8)	1 (6.2)	.99
Proximal humeral allograft	19 (29.7)	7 (43.7)	.37
Glenosphere size			.001
32-4	22 (44.9)	1 (12.5)	
32N	7 (14.3)	2 (25)	
36-4	8 (16.3)	1 (12.5)	
36N	11 (22.4)	0	
40N	1 (2.0)	3 (37.5)	
44	0	1 (12.5)	

RSA, reverse shoulder arthroplasty; *SD*, standard deviation; *CTA*, cuff tear arthropathy; *OA*, osteoarthritis; *RA*, rheumatoid arthritis; *AVN*, avascular necrosis.

in which they reported an improvement in the ASES score from 29.1 to 61.2.

Furthermore, our study showed that the OA group had significantly better postoperative SST scores, ASES function scores, and abduction than the fracture group. The total ASES score for OA patients was 68 at final follow-up compared with 58 for fracture patients. Holschen et al[5] evaluated patient outcomes of proximal humeral fracture

or OA cases. The study population primarily comprised failed hemiarthroplasties but also included failed total shoulder arthroplasties revised to RSA. Their study reported a significant difference in the ASES score at a mean follow-up of 2 years between OA cases (ASES score, 71.3) and proximal humeral fracture cases (ASES score, 58.9), with no significant difference in postoperative range of motion between the groups. The improvement in functional outcome scores for OA cases compared with fracture or CTA cases may be related to the greater likelihood of an intact or functioning rotator cuff.

With the ASES scores separated regarding pain and function, no difference in preoperative or postoperative pain was found between the different diagnoses. All diagnoses showed similar overall improvement in pain scores. Despite the differences in preoperative and postoperative range of motion, the difference in improvement after RSA between the different pathologic conditions was similar regarding both range of motion and functional outcomes. In our study, average overall improvement in the ASES score was 26, and only 58% of the failed hemiarthroplasties revised to RSA achieved a minimum 20-point improvement in the ASES score, which highlights the difficulty of achieving successful patient outcomes after revision arthroplasty.

In this study, the revision rate was 7.7% (16 of 208 cases), with a mean time to subsequent revision of 31 months. Humeral loosening was the most common mode of failure (8 of 16 cases). Our revision rate is similar to that in the study by Merolla et al,[13] who reported a rate of 7% (11 of 157 cases), with a mean time to revision of 14.5 months. However, their study showed that the reason for revision was more commonly glenoid loosening ($n = 4$) and instability ($n = 3$). The differences in failure mechanism may in part be due to the differences in implants used, including glenoid baseplate features such as a central post or a center screw.

Glenosphere size was predictive of re-revision of the RSA in our study, with larger glenosphere sizes being more likely to be revised. The failure mechanisms for subsequent revision of the larger glenospheres varied: dislocation in 1 case, fracture through the proximal humeral allograft and stem in 1, glenosphere dissociation in 1, and infection in 1. Other characteristics such as tuberosity abnormalities, stem stability, or glenohumeral registry on preoperative radiographs were not predictive of subsequent revision in the case-control study. The small numbers of revisions available for comparison limit the ability to identify further predictive factors. In addition, specific technical factors that were not measured, such as cementing technique or working length of the stem, may have an effect on humeral loosening and are a potential area for further study. Of the 8 revision RSAs with humeral loosening, 5 (62.5%) were cemented using a cement-within-cement technique; the other 3 stems were uncemented.

Another limitation of this study is the large loss to follow-up. Postoperative outcomes are affected by which patients choose to undergo follow-up and which patients do not. Often, patients who return do so because they are having a problem, which skews the outcome data for the population. The strengths of the study include a large number of revision hemiarthroplasties from a single institution with similar implant designs over an extended period and validation of previously reported outcomes and re-revision rates for failed hemiarthroplasties revised to RSA.

Conclusion

Regardless of the initial diagnosis, all groups showed improvement in ASES scores, SST scores, forward elevation, abduction, and external rotation compared with preoperative values. Hemiarthroplasty cases with the initial diagnosis of fracture were associated with lower range of motion after revision to RSA compared with CTA and OA cases. After revision to RSA, functional outcome scores were better in patients whose failed hemiarthroplasty was performed for OA than in those whose hemiarthroplasty was performed for CTA or fracture. Humeral loosening was the most common failure mechanism of revision RSA for hemiarthroplasty.

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