J Shoulder Elbow Surg (2022) 31, 923–931

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Primary reverse total shoulder arthroplasty performed for glenohumeral arthritis: does glenoid morphology matter?

Robert J. Pettit, MD[a], Sundeep B. Saini, DO[a], Richard N. Puzzitiello, MD[a,b], Paul-Anthony J. Hart, BA[c], Glen Ross, MD[a,d], Jacob M. Kirsch, MD[a,c], Andrew Jawa, MD[a,c,*]

[a]*Department of Orthopedic Surgery, New England Baptist Hospital, Boston, MA, USA*
[b]*Department of Orthopedic Surgery, Tufts Medical Center, Boston, MA, USA*
[c]*Boston Sports and Shoulder Center, Boston, MA, USA*
[d]*Boston Orthopedics and Spine, Boston, MA, USA*

Background: Indications for reverse total shoulder arthroplasty (RTSA) have expanded to include primary glenohumeral osteoarthritis (GHOA) with an intact rotator cuff. Limited evidence exists on RTSA in patients with primary GHOA and no posterior glenoid wear (Walch A1, A2, and B1 morphologies). The purpose of this retrospective cohort study was to determine if glenoid morphology is associated with clinical outcomes in patients undergoing RTSA for primary GHOA.

Methods: A retrospective review of prospectively collected data was performed in patients undergoing primary RTSA for GHOA with a minimum of 2-year clinical follow-up. Preoperative computed tomography and magnetic resonance imaging were used to categorize glenoid morphology as described by the modified Walch classification. Pre- and postoperative American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), Single Assessment Numeric Evaluation (SANE), visual analog scale (VAS) pain scores, and range of motion (ROM) measurements were compared across Walch glenoid subtypes. The percentage of patients that reached previously established clinically significant thresholds for minimal clinically important difference (MCID) and substantial clinical benefit (SCB) was also comparatively assessed. Multivariable analysis was used to evaluate the association between glenoid morphology and postoperative ASES score while controlling for potentially confounding variables.

Results: Of the 247 consecutive patients, 197 were available at a minimum 2-year follow-up (80%). Significant improvements were seen in ASES, VAS pain, SANE, and ROM from baseline to final postoperative follow-up in the combined patient cohort (all $P <$ .001). Most (98.0%) patients reached MCID, and 90.9% of patients reached SCB for ASES threshold. No significant differences were found among Walch subtypes in terms of preoperative to postoperative improvement in ASES ($P = .39$), SANE ($P = .4$), VAS pain ($P = .49$), forward elevation ($P = .77$), external rotation ($P = .45$), or internal rotation ($P = 0.1$). The only significant difference in postoperative outcomes between Walch glenoid subtypes was higher postoperative ASES scores among type B3 glenoids compared with type A1 glenoids ($P = .03$) on univariate analysis. However, no individual Walch glenoid subtype was associated with lower postoperative ASES scores on multivariable analysis ($P > .05$).

Conclusion: Primary RTSA provides excellent short-term outcomes in patients with glenohumeral arthritis with intact rotator cuff, regardless of the degree of preoperative glenoid deformity. Surgeons can use these data to support the use of RTSA for glenohumeral arthritis in a more standardized way.

New England Baptist Hospital Institutional Review Board approved this study (project number 1656475-1).

*Reprint requests: Andrew Jawa, MD, Boston Sports and Shoulder Center, 840 Winter St, Waltham, MA 02451, USA.
E-mail address: andrewjawa@gmail.com (A. Jawa).

https://doi.org/10.1016/j.jse.2021.10.022

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Osteoarthritis; glenohumeral arthritis; reverse total shoulder arthroplasty; glenoid morphology

Reverse total shoulder arthroplasty (RTSA) is the preferred treatment for rotator cuff arthropathy.[33] Improvements in design and instrumentation have led to substantial increases in the implantation of these devices; which have now surpassed anatomic total shoulder arthroplasty (ATSA) utilization in the US general population.[20] This upward trajectory is expected to continue as indications for RTSA continue to expand from just rotator cuff arthropathy to various diagnoses, including proximal humerus fracture, malunion, nonunion, inflammatory arthropathy, massive cuff tear with osteoarthritis, failed ATSA, failed hemiarthroplasty, and primary glenohumeral osteoarthritis (GHOA).[5,7,14,16,18,19,27] Long-term studies have demonstrated the durability of RTSA with lasting clinical and functional outcomes in both young and elderly age groups,[3,6,8,14,30,34] furthering the enthusiasm for RTSA as a treatment option for primary GHOA with an intact rotator cuff.

Anatomic total shoulder arthroplasty has traditionally been viewed as a superior treatment for glenohumeral arthritis with an intact rotator cuff, but this convention is shifting. Substantial evidence supports RTSA as a viable alternative to anatomic total shoulder arthroplasty for glenoid wear patterns with significant bone loss at a high risk for glenoid loosening.[2,12,23,26,27] Some authors advocate for RTSA in patients aged >70 years with GHOA where concern for fatty infiltration and rotator cuff insufficiency may increase risk of ATSA failure.[23,34] Parada et al[21] recently published data comparing ATSA to RTSA showed significantly higher complication and revision rates in ATSA, with the top 3 complications of ATSA being rotator cuff tear/subscapularis failure, aseptic glenoid loosening, and infection. Further, data from the Australian Orthopaedic Association National Joint Replacement Registry demonstrated significantly higher revision rate for ATSA (12.1%) vs RTSA (7.7%).[2]

The aforementioned reasons have broadened indications for primary RTSA in patients with GHOA with intact rotator cuff and all glenoid types.[2,12,21,23,26,27] To our knowledge, no large study has examined the effect of glenoid morphology on RTSA outcomes. Our study aims to report 2-year outcomes of patients undergoing RTSA for all glenoid morphologies in GHOA with an intact rotator cuff. We hypothesized that patients undergoing RTSA for GHOA with intact rotator cuff will have similar outcomes across glenoid morphologies. Through evaluation of such outcomes, we hope to validate RTSA as a viable treatment option in the setting of primary GHOA with intact rotator cuff, regardless of glenoid morphology.

Materials and methods

Following approval from the institutional review board, a retrospective review of a prospectively maintained database using the OBERD platform (Columbia, MO, USA) was conducted for all patients having undergone primary RTSA with an intact rotator cuff performed by the senior author (A.J.) between the years of 2015 and 2018. Patients were included in the retrospective cohort study if they had a diagnosis of primary GHOA with an intact rotator cuff and minimum 2-year clinical follow-up. A diagnosis of primary GHOA was defined as full rotator cuff strength on physical examination, presence of end-stage arthritis on radiographic and cross-sectional imaging, and no signs of humeral head superior migration on radiographic imaging. Patients were excluded for diagnoses other than primary GHOA including, but not limited to, rotator cuff arthropathy, signs of rotator cuff tear/atrophy assessed on preoperative imaging and intraoperatively, post-traumatic arthritis, postcapsulorrhaphy arthropathy, inflammatory arthritis, proximal humerus fracture, and avascular necrosis.

Demographic data including age, body mass index, American Society of Anesthesiologists score, and comorbidities (depression, diabetes, smoking) were recorded from the chart. Preoperative radiographs, cross-sectional advanced imaging (magnetic resonance imaging [MRI] or computed tomography [CT]), clinic notes, and operative reports were reviewed to confirm diagnosis. CT and/or MRI were used to classify glenoid morphology as described by the modified Walch classification.[1] Previous studies demonstrated fair interobserver agreement for both CT scans and radiographs (via κ coefficient) when classifying by modified Walch.[29] Glenoid classification was performed by consensus grading of 2 surgeons (R.P., S.S.) with unresolved classifications reconciled by a third surgeon (J.K. and/or A.J.). Eighty patients did not have CT scans, and therefore MRI was used as an equivalent method for classifying glenoids when necessary.[13,15]

Preoperative and most recent postoperative (at minimum 2-year follow-up) American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score, Single Assessment Numeric Evaluation score, and visual analog scale for pain (VAS pain) were collected electronically via iPad survey administered by clinical and/or research staff to evaluate subjective outcomes. Shoulder active range of motion (ROM), including forward elevation, external rotation, and internal rotation, was measured at the initial preoperative visit and the last documented postoperative visit by the senior surgeon with the routine use of a goniometer. Internal rotation was reported as a 10-point scale based on the most cephalad midline segment of the back that could be reached as described by Levy et al[30]: buttock/greater trochanter (2 points), sacrum-L4 (4 points), L3-L1 (6 points), T12-T8 (8 points), and T7-T1 (10 points). Complications encountered within the follow-up period were recorded. Patient-reported outcome measures (PROMs) and active ROM measurements were collected at the 2-week, 6-week, 3-month, 1 year, 2-year, and

5-year follow-up time intervals, with interval collection every 5 years beyond the 5-year follow-up appointment.

Surgical technique

Patients received a preoperative interscalene nerve block when possible and underwent general anesthesia for the surgery. The surgeon performed a standard deltopectoral approach with biceps tenodesis to the pectoralis major tendon (unless biceps was already tenodesed or tenotomized). The subscapularis was peeled from the lesser tuberosity and repaired at the end of the procedure when possible. The DJO Altivate system was used in 196 of 197 patients, whereas Tornier Aequalis Reverse was used in the remaining 1. Whenever possible, DJO glenospheres were lateralized to +6 mm utilizing 36 N and 32-4 for males and females, respectively. Glenoid bone loss was addressed with eccentric reaming of the anterior high side to maximize back-end coverage (>75%) and suitable fixation of the glenoid baseplate. In extreme cases of posterior retroversion where glenoid surface area coverage by the baseplate could not be corrected beyond 75% (n = 5), humeral head autograft was used to restore bony anatomy. For DJO implants, the humeral side was addressed with a noncemented inlay design and a standard-length humeral stem and a standard or +4-mm polyethylene insert. In the case of Tornier, the humeral side was addressed with a noncemented onlay design, a standard-length humeral stem, and +6-mm polyethylene insert. All patients participated in a standardized rehabilitation protocol, including restricted shoulder ROM for the first 2 postoperative weeks followed by gradual progression of passive and active-assisted exercises, adjusted at the 6-week and 3-month postoperative period.

Statistical analysis

The primary postoperative clinical outcome measure was ASES score recorded at a minimum of 2 years postoperatively. Secondary outcome measures included Single Assessment Numeric Evaluation, VAS pain score, forward flexion, external rotation, internal rotation, and complications (notching, baseplate failure, infection, instability, stress fracture, and revision). All demographic variables were reported as means and standard deviations (SDs) for continuous variables and as frequencies and percentages for categorical variables. Unpaired 2-tailed, Student *t* tests were used to compare mean differences in preoperative and postoperative clinical outcomes for the entire cohort. Improvements in postoperative scores were compared to threshold minimal clinically important difference (MCID) (10.3) and substantial clinical benefit (SCB) (25.9) ASES scores as described by Simovitch et al[24,25] and reported as percentages of patients reaching MCID and SCB. One-way analysis of variance testing with Tukey post hoc adjustment was performed to compare mean outcome scores and ROM measurements between Walch glenoid subtypes. Results were also compared across Walch glenoid subtypes after further analysis by gender, to elucidate the impact of sex on these outcomes. Multivariable linear regression analysis adjusted for age, sex, history of prior ipsilateral shoulder surgery, and preoperative ASES score was performed to assess for independent associations between Walch glenoid subtypes and absolute postoperative ASES scores. $P < .05$ was considered significant. Statistical analysis performed using SPSS statistical software (version 25; IBM, Armonk, NY, USA). Walch C and D subtypes were not included in the multivariable linear regression analysis owing to low sample sizes (n = 3 and n = 5, respectively).

Results

Demographics

A total of 197 patients with average age 71.8 years (range: 55-88 years, SD 6.0) with an average of 28.0-month (SD 7.6) follow-up were included in the study. Baseline demographic data including age, sex, follow-up, body mass index, comorbidities (depression, diabetes, smoking), American Society of Anesthesiologists score, previous ipsilateral shoulder surgery, and glenoid morphology distribution are presented in Table I. There were 53 A1 glenoids (26.9%), 20 A2 glenoids (10.2%), 10 B1 glenoids (5.1%), 57 B2 glenoids (28.9%), 49 B3 glenoids (24.9%), 3 C glenoids (1.5%), and 5 D glenoids (2.5%). There was a significantly higher preponderance of males with type-B3 glenoids compared with type A1 glenoids ($P = .01$); otherwise, there were no significant differences in sex distribution among Walch glenoid subtypes (% male: 30% A1, 30% A2, 20% B1, 44% B2, 53% B3, 33% C, 60% D).

Functional outcomes

In the combined cohort, significant improvements were seen from baseline to final follow-up in all outcome measures (Table II). Most patients (98.0%) reached MCID, and 90.9% of patients reached SCB for ASES threshold. MCID was achieved in most patients regardless of Walch classification (Table III).

The analysis of variance analysis comparing mean outcomes among Walch subgroups revealed no significant differences between glenoid morphologies in all postoperative outcomes ($P > .05$), except mean postoperative ASES scores (Table II). Tukey post hoc adjustments revealed that B3 glenoids had significantly higher postoperative ASES scores compared with A1 glenoids (91.0, SD 9.2, vs 82.6, SD 1.2; $P = .03$) (Table II). Further categorization of Walch glenoid subtypes by sex revealed that females with type A1 glenoids had significantly lower postoperative ASES scores compared to females with type B3 glenoids ($P = .02$) (Fig. 1).

Multivariable linear regression analysis did not identify any significant associations between individual Walch subtypes and postoperative ASES score, after controlling for age, sex, preoperative ASES score, and prior ipsilateral shoulder surgery (Table IV).

Table I Demographics and preoperative clinical characteristics (N = 197)

Parameter	Mean (SD) or n (%)
Age, yr, mean (SD)	71.8 (6.0)
Female sex	118 (59.9)
Follow-up, mo, mean (SD)	28.0 (7.6)
BMI, mean (SD)	31.1 (6.2)
Comorbid conditions	
Depression	49 (24.9)
Diabetes	36 (19.0)
Smoker	10 (5.1)
ASA score	
1	4 (2.0)
2	146 (74.1)
3	47 (23.9)
4	0
Preoperative glenoid	
Walch classification	
A1	53 (26.9)
A2	20 (10.2)
B1	10 (5.1)
B2	57 (28.9)
B3	49 (24.9)
C	3 (1.5)
D	5 (2.5)
Previous ipsilateral shoulder surgery	36 (18.2)

BMI, body mass index; *ASA*, American Society of Anesthesiologists; *SD*, standard deviation.

Revisions/complications

Of the 197 patients, only 1 patient (B3 glenoid) underwent revision for baseplate failure, resulting in a revision rate of 0.50%. Eight patients sustained an orthopedic related complication (4.06%). Transient radial nerve injury occurred in 1 C glenoid patient (0.51%). Brachial plexopathy persisted in 1 A1 patient (0.51%). Additional complications included 2 (1.02%) acromial stress fractures (A1, B2), 2 (1.02%) baseplate failures (B2, B3), and 1 (0.51%) intraoperative greater tuberosity fracture (A1).

Discussion

The principal finding of this study is that similar clinical and functional outcomes can be achieved after RTSA in patients with an intact rotator cuff and primary glenohumeral arthritis irrespective of glenoid morphology. Patients demonstrated excellent short-term functional outcome scores with low complication rates, with 98.0% of patients reaching MCID and 90.9% of patients reaching SCB for the postoperative ASES threshold. Furthermore, Walch glenoid subtype was not significantly associated with postoperative outcomes. As clinical indications for RTSA continue to expand, the findings of this study support the potential use in patients with less severe glenoid morphology.

Previous studies have reported successful outcomes in GHOA patients treated with RTSA but with notably smaller cohorts of A1, A2, and B1 glenoids compared with our study.[8,34,35] Waterman et al[34] compared RTSA for primary cuff tear arthropathy to severe GHOA with an intact rotator cuff and reported superior outcomes for the rotator cuff intact group. When the GHOA group was categorized by glenoid morphology, no significant difference in functional outcome scores or ROM were noted. Additionally, numbers of A1 (n = 1), A2 (n = 13), and B1 (n = 7) glenoid types were relatively small compared to our cohorts. Wright et al[35] noted no differences in patient-reported outcome measures between patients aged >70 years with GHOA and an intact rotator cuff undergoing ATSA vs. RTSA. They noted a larger proportion of B3 glenoids in RTSA vs. ATSA groups but did not group outcomes based on glenoid morphology. Our study builds on the notion that patients have successful clinical and functional outcomes following RTSA for GHOA while expanding our understanding of the potential role in patients with less severe glenoid morphology.

An important point of emphasis is that our study showed A1 glenoids have significantly lower postoperative ASES scores compared to B3 glenoids on univariate analysis but not multivariate analysis. The significant gender imbalance between these groups may have influenced these results (Fig. 1). Our subanalysis did not reveal A1 glenoids or gender as predictive for worse postoperative ASES score.

The excellent improvements in functional outcomes seen in B2/B3 glenoids is supported by several published studies using RTSA for GHOA with posterior bone loss.[4,16,18,31,34,35] Mizuno et al[18] reported good outcomes for RTSA in the treatment of primary glenohumeral arthritis in patients with a biconcave glenoid without rotator cuff insufficiency. They suggested that an intact and functional rotator cuff may contribute to an improvement in outcome after RTSA. Similarly, McFarland et al[16] described RTSA without bone-grafting for severe glenoid bone loss in patients with osteoarthritis and intact rotator cuff, noting significant short-term improvement in pain and function. They concluded that off-label use of RTSA for GHOA with severe bone loss was a viable option for patients, obviating the need for bone graft or augmented glenoid components. Collin et al[4] reported significantly increased Constant scores overall, but when grouped by glenoid type, no significant difference in midterm results of RTSA for GHOA with B or C glenoids. Virk et al[31] showed good outcomes using an 8° posterior augmented baseplate for Walch B2, B3, or C glenoids with osteoarthritis and posterior glenoid wear. Overall, our study demonstrated equivalent or better functional outcomes for GHOA with posterior wear with few complications and no need for bone grafting or augmentation.

Table II Outcome scores by Walch classification

Outcome	Glenoid Walch classification, mean (SD)								*P* value
	All	A1 (n = 53)	A2 (n = 20)	B1 (n = 10)	B2 (n = 57)	B3 (n = 43)	C (n = 3)	D (n = 5)	
ASES score									
Preoperative	35 (15.6)	31.4 (15.9)	33.4 (11.2)	36.6 (13.3)	36.1 (17.0)	35 (15.3)	41.0 (15.6)	42.1 (18.7)	.42
Postoperative	86.8 (14)	82.6 (16.2)†	88.6 (8.6)	86.6 (7.2)	88.8 (13.2)	91 (9.2)†	73.5 (19.1)	81.0 (16.4)	.03*
Change	51.9 (19.3)	51.2 (22.4)	49.1 (13.1)	50.0 (13.4)	52.7 (20.5)	56 (17.2)	32.5 (34.7)	38.9 (2.9)	.39
SANE score									
Preoperative	31.1 (20.1)	30.1 (21.6)	32.5 (23.0)	29.0 (19.0)	30.1 (19.0)	30.2 (19.3)	42.6 (10.6)	31.0 (20.1)	.69
Postoperative	89.4 (16.6)	87.1 (19.8)	94.1 (5.5)	86.1 (22.9)	91.9 (13.9)	90.8 (13.5)	75.0 (35.4)	79.0 (23.6)	.26
Change	58.5 (26.4)	56.2 (30.2)	61.6 (26.0)	57.1 (38.7)	61.1 (23.7)	60.6 (21.5)	32.5 (46.0)	48.0 (27.1)	.4
VAS pain score									
Preoperative	6.0 (2.3)	6.6 (2.3)	5.5 (1.9)	5.1 (2.1)	6.0 (2.5)	5.9 (2.0)	6.0 (1.4)	6.2 (2.2)	.34
Postoperative	0.56 (1.2)	0.7 (1.4)	0.25 (0.44)	0.7 (1.6)	0.49 (1.1)	0.44 (1.1)	2.5 (3.5)	1.0 (1.4)	.27
Change	5.5 (2.4)	5.9 (2.6)	5.3 (2.1)	4.4 (1.8)	5.5 (2.5)	5.5 (2.2)	3.5 (5.0)	5.2 (2.5)	.49
Forward elevation (degrees)									
Preoperative	91.9 (24.1)	89.2 (28.5)	92.3 (22.6)	103.5 (17.3)	90.4 (21.0)	94.3 (21.0)	85.0 (7.1)	99.0 (15.2)	.6
Postoperative	138.1 (17.7)	138 (15.3)	137.3 (15.1)	139.0 (13.5)	140.1 (15.4)	138.4 (16.1)	135.0 (21.2)	138.0 (21.7)	.99
Change	46.9 (27.4)	48.8 (32.5)	45.0 (24.5)	35.5 (22.2)	49.9 (23.5)	46.2 (29.0)	50.0 (14.1)	39.0 (27.0)	.77
External rotation (degrees)									
Preoperative	26.4 (13)	29.2 (15.5)	28.8 (12.1)	28.5 (10.0)	24.9 (10.7)	24.5 (13.8)	20.0 (0.0)	20.0 (12.3)	.39
Postoperative	54.1 (17.3)	58.9 (15.1)	48.5 (20.2)	53.5 (18.6)	56.2 (17.9)	50.1 (16.5)	50.0 (14.14)	53.0 (15.7)	.14
Change	28.1 (19.2)	29.4 (17)	21.8 (23.2)	25.0 (19.2)	31.3 (19.9)	26.2 (19.5)	20.0 (0.0)	33.0 (18.6)	.45
Internal rotation‡									
Preoperative	2.6 (1)	2.7 (1.2)	3.0 (1.2)	2.2 (0.63)	2.5 (0.89)	2.5 (0.95)	3.0 (1.4)	3.3 (1.2)	.17
Postoperative	4.7 (1.6)	4.5 (1.5)	4.3 (1.6)	4.0 (0.94)	4.8 (1.4)	5.0 (1.7)	5.0 (4.2)	6.0 (2.0)	.26
Change	2.1 (1.7)	1.8 (1.7)	1.3 (1.9)	1.8 (1.1)	2.2 (1.8)	2.6 (1.6)	2.0 (2.8)	2.7 (1.2)	.1

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *SANE*, Single Assessment Numeric Evaluation; *VAS*, visual analog scale.

* Denotes statistical significance in scores across Walch glenoid subtypes at $P < .05$.

† Significant differences between groups identified on post hoc Tukey test.

‡ Level of internal rotation converted to numeric scale as previously described: buttock/greater trochanter (2 points); sacrum-L4 (4 points); L3-L1 (6 points); T12-T8 (8 points); T7-T1 (10 points).

Table III Number of patients who reached clinically significant thresholds of improvement in ASES scores grouped by Walch classification

ASES threshold	All	Glenoid Walch classification (%)						
		A1 (n = 53)	A2 (n = 20)	B1 (n = 10)	B2 (n = 57)	B3 (n = 43)	C (n = 3)	D (n = 5)
% MCID	193 (98.0)	52 (98.1)	20 (100)	10 (100)	55 (96.5)	49 (100)	2 (66.7)	5 (100)
% SCB	179 (90.9)	47 (88.6)	19 (95)	10 (100)	53 (33)	45 (91.8)	2 (66.7)	5 (100)

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *MCID*, minimal clinically important difference; *SCB*, substantial clinical benefit.

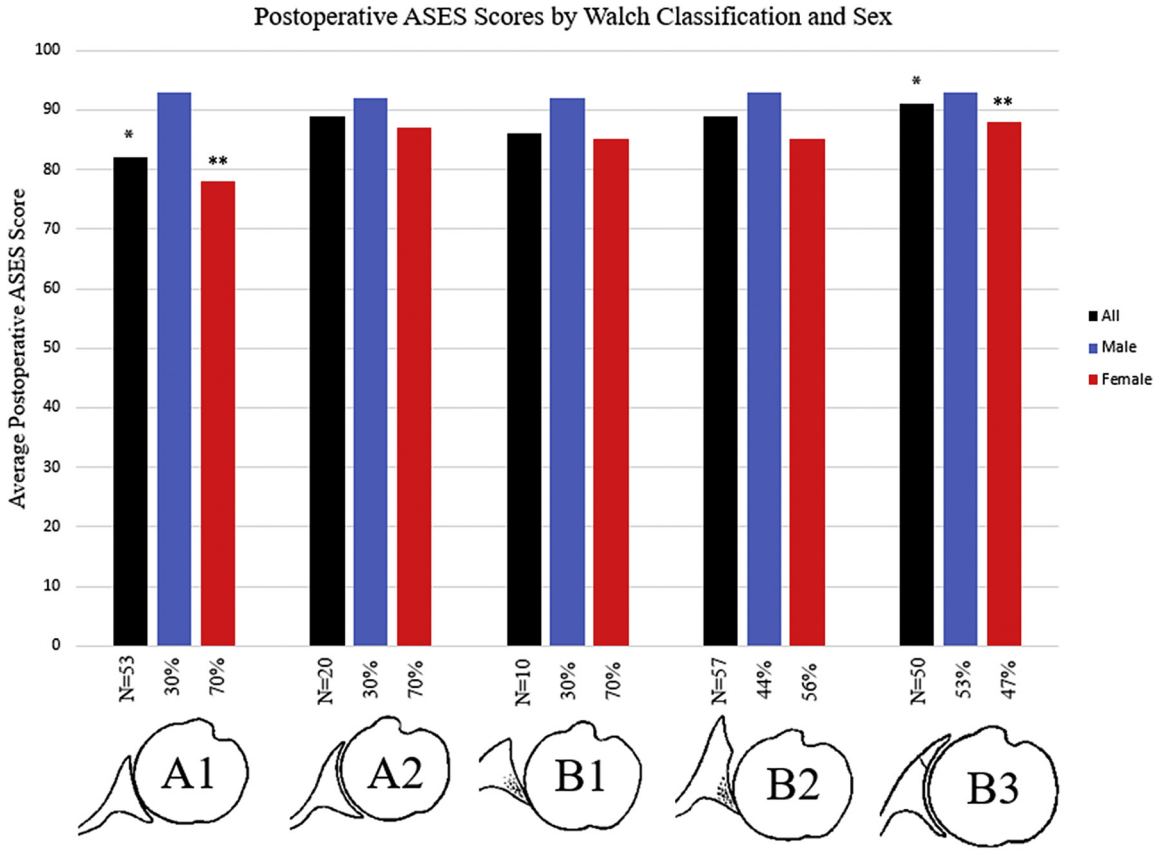

Figure 1 Bar graph displaying the average postoperative ASES score separated by Walch classification and sex. On the *x* axis: Walch classification (A1, A2, B1, B2, B3). On the *y* axis: average postoperative ASES score. *Black* indicates all; *blue*, male; *red*, female.

Table IV Linear regression model for variables associated with postoperative ASES scores

Parameter	Beta*	Standardized beta†	*P* value
Age	−0.28 (−0.6, 0.04)	−0.13	.08
Sex (male)	0.49 (−3.4, 4.4)	0.02	.8
Prior ipsilateral shoulder surgery	−2.2 (−7, 2.7)	−0.07	.38
Preoperative ASES score	0.06 (−0.06, 0.2)	0.07	.35
A1 glenoid	−5.7 (−12.3, 0.87)	−0.2	.09
B1 glenoid	−2.3 (−12.3, 7.4)	−0.04	.64
B2 glenoid	0.43 (−6.1, 6.9)	0.02	.9
B3 glenoid	2.5 (−4.3, 9.2)	0.08	.47

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.
A2 glenoid was set as the categorical reference variable.
* Beta coefficient values with 95% confidence intervals in parentheses, signifying the strength of association between the dependent variable and the variable of interest.
† Standardized beta coefficient, weighted to allow for comparison of the relative strength of association with the dependent variable between the variables of interest.

The choice between anatomic total shoulder arthroplasty and RTSA for patients with GHOA remains a controversial topic. Most of the literature focuses on RTSA for rotator cuff arthropathy rather than GHOA. Therefore, comparing rotator cuff arthropathy patients undergoing RTSA to patients undergoing ATSA for GHOA may not be valid. Our study provides a cohort of patients undergoing RTSA for GHOA, thus providing a more accurate comparison to cohorts undergoing ATSA. When comparing our RTSA series to the results of ATSA patients, our study demonstrates similar ASES improvement and postoperative ROM.[24,27]

Several recent studies have shown increased revision rates of ATSA compared with RTSA.[2,21,22] Glenoid component loosening is the most cited mode of failure in anatomic total shoulder arthroplasty for GHOA,[11,17,26] especially in posteriorly worn glenoids. The best method for addressing glenoids with posterior bone loss remains unclear. ATSA with posterior bone graft showed inconsistent results with high complication rates, and variable graft healing/glenoid loosening[9,12,28,32] leading to the implementation of augmented glenoids. Compared to augmented glenoids in recent studies, our data show similar short-term results.[10] An advantage of using RTSA in these patients is the bony glenoid ingrowth and biomechanical advantage obviating the need for intact rotator cuff. By removing the risk of revision due to rotator cuff failure and decreasing the risk of glenoid loosening, an RTSA for posterior worn glenoids is an enticing option.

This study has several limitations most notably owing to its retrospective nature, placing it at risk for bias. Patients were not randomized but the consecutive series and prospective data collection help mitigate bias. The short-term follow-up of a minimum of 2 years is relatively short in the life of reverse total shoulder prosthesis, and longer follow-up is necessary. Although all patients had advanced imaging, 80 patients lacked CT scans, which may decrease the reliability of our classification system and prevents direct reporting of preoperative glenoid retroversion for patients within the cohort. This was countered by having 2 surgeons separately and independently review and classify the glenoid morphology. Our lack of postoperative measurement of glenoid retroversion introduces increased variability in the cohort with respect to degrees of lateralization, use of bone grafting, and restoration of version, which may have confounded our results. Additionally, grouping our cohort by Walch classification confounds comparability of patient groups at baseline. Thus, we must assume that all groups are not at different stages of the disease. Given that not all patients had preoperative MRIs, we were unable to assess fatty infiltration grading for all patients in the cohort, which also decreases the reliability of our assessment. Further, the number of C and D glenoids were consistent with reported percentages in the literature, but these are small numbers to have significant data. The fact that all statistical measures were not significant begs the question if the sample size was large enough.

This study has several strengths to highlight. This is the largest number of patients undergoing RTSA for GHOA with an intact rotator cuff among all glenoid morphologies. Recall bias was minimized by prospectively collecting data. Selection bias was minimized by the consecutive series of patients with high follow-up. The study reports excellent outcomes in a patient cohort (less severe glenoid types undergoing RTSA for GHOA with intact rotator cuff) that has infrequently been studied.

Conclusion

Primary RTSA provides excellent short-term outcomes in patients with glenohumeral arthritis with intact rotator cuff, regardless of the degree of preoperative glenoid deformity. Surgeons can use these data to support the use of RTSA for glenohumeral arthritis in a more standardized way.

Disclaimer

Glen Ross is a board/committee member of the American Academy of Orthopaedic Surgeons and a paid consultant and paid speaker for Stryker. Andrew Jawa is a board/committee member of the American Academy of Orthopaedic Surgeons and the American Shoulder and Elbow Surgeons Society. He is a member of the editorial/governing board of the *Journal of Shoulder and Elbow Surgery*. This author reports IP royalties and stock/stock options from Ignite Orthopaedics and is a paid consultant and receives paid presenter/speaker fees, research support, and personal fees from DJO Global. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Bercik MJ, Kruse K 2nd, Yalizis M, Gauci MO, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elbow Surg 2016;25:1601-6. https://doi.org/10.1016/j.jse.2016.03.010
2. Brown JS, Gordon RJ, Peng Y, Hatton A, Page RS, Macgroarty KA. Lower operating volume in shoulder arthroplasty is associated with increased revision rates in the early postoperative period: long-term

analysis from the Australian Orthopaedic Association National Joint Replacement Registry. J Shoulder Elbow Surg 2020;29:1104-14. https://doi.org/10.1016/j.jse.2019.10.026
3. Clark NJ, Samuelsen BT, Alentorn-Geli E, Assenmacher AT, Cofield RH, Sperling JW, et al. Primary reverse shoulder arthroplasty in patients older than 80 years of age: survival and outcomes. Bone Joint J 2019;101-B:1520-5. https://doi.org/10.1302/0301-620x.101b12.bjj-2018-1571.r2
4. Collin P, Hervé A, Walch G, Boileau P, Muniandy M, Chelli M. Mid-term results of reverse shoulder arthroplasty for glenohumeral osteoarthritis with posterior glenoid deficiency and humeral subluxation. J Shoulder Elbow Surg 2019;28:2023-30. https://doi.org/10.1016/j.jse.2019.03.002
5. Ek ET, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: results after five to fifteen years. J Shoulder Elbow Surg 2013;22:1199-208. https://doi.org/10.1016/j.jse.2012.11.016
6. Ernstbrunner L, Suter A, Catanzaro S, Rahm S, Gerber C. Reverse total shoulder arthroplasty for massive, irreparable rotator cuff tears before the age of 60 years: long-term results. J Bone Joint Surg Am 2017;99:1721-9. https://doi.org/10.2106/JBJS.17.00095
7. Ernstbrunner L, Werthel JD, Wagner E, Hatta T, Sperling JW, Cofield RH. Glenoid bone grafting in primary reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:1441-7. https://doi.org/10.1016/j.jse.2017.01.011
8. Haritinian EG, Belgaid V, Lino T, Nové-Josserand L. Reverse versus anatomical shoulder arthroplasty in patients with intact rotator cuff. Int Orthop 2020;44:2395-405. https://doi.org/10.1007/s00264-020-04754-z
9. Hill JM, Norris TR. Long-term results of total shoulder arthroplasty following bone-grafting of the glenoid. J Bone Joint Surg Am 2001;83:877-83.
10. Ho JC, Amini MH, Entezari V, Jun BJ, Alolabi B, Ricchetti ET, et al. Clinical and radiographic outcomes of a posteriorly augmented glenoid component in anatomic total shoulder arthroplasty for primary osteoarthritis with posterior glenoid bone loss. J Bone Joint Surg Am 2018;100:1934-48. https://doi.org/10.2106/JBJS.17.01282
11. Hsu JE, Hackett DJ Jr, Vo KV, Matsen FA 3rd. What can be learned from an analysis of 215 glenoid component failures? J Shoulder Elbow Surg 2018;27:478-86. https://doi.org/10.1016/j.jse.2017.09.029
12. Klika BJ, Wooten CW, Sperling JW, Steinmann SP, Schleck CD, Harmsen WS, et al. Structural bone grafting for glenoid deficiency in primary total shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:1066-72. https://doi.org/10.1016/j.jse.2013.09.017
13. Kopka M, Fourman M, Soni A, Cordle AC, Lin A. Can glenoid wear be accurately assessed using x-ray imaging? Evaluating agreement of x-ray and magnetic resonance imaging (MRI) Walch classification. J Shoulder Elbow Surg 2017;26:1527-32. https://doi.org/10.1016/j.jse.2017.03.014
14. Lindbloom BJ, Christmas KN, Downes K, Simon P, McLendon PB, Hess AV 2nd, et al. Is there a relationship between preoperative diagnosis and clinical outcomes in reverse shoulder arthroplasty? An experience in 699 shoulders. J Shoulder Elbow Surg 2019;28:S110-7. https://doi.org/10.1016/j.jse.2019.04.007
15. Lowe JT, Testa EJ, Li X, Miller S, DeAngelis JP, Jawa A. Magnetic resonance imaging is comparable to computed tomography for determination of glenoid version but does not accurately distinguish between Walch B2 and C classifications. J Shoulder Elbow Surg 2017;26:669-73. https://doi.org/10.1016/j.jse.2016.09.024
16. McFarland EG, Huri G, Hyun YS, Petersen SA, Srikumaran U. Reverse total shoulder arthroplasty without bone-grafting for severe glenoid bone loss in patients with osteoarthritis and intact rotator cuff. J Bone Joint Surg Am 2016;98:1801-7. https://doi.org/10.2106/jbjs.15.01181
17. Melis B, Bonnevialle N, Neyton L, Lévigne C, Favard L, Walch G, et al. Glenoid loosening and failure in anatomical total shoulder arthroplasty: is revision with a reverse shoulder arthroplasty a reliable option? J Shoulder Elbow Surg 2012;21:342-9. https://doi.org/10.1016/j.jse.2011.05.021
18. Mizuno N, Denard PJ, Raiss P, Walch G. Reverse total shoulder arthroplasty for primary glenohumeral osteoarthritis in patients with a biconcave glenoid. J Bone Joint Surg Am 2013;95:1297-304. https://doi.org/10.2106/jbjs.l.00820
19. Monir JG, Abeyewardene D, King JJ, Wright TW, Schoch BS. Reverse shoulder arthroplasty in patients younger than 65 years, minimum 5-year follow-up. J Shoulder Elbow Surg 2020;29:e215-21. https://doi.org/10.1016/j.jse.2019.10.028
20. Palsis JA, Simpson KN, Matthews JH, Traven S, Eichinger JK, Friedman RJ. Current trends in the use of shoulder arthroplasty in the United States. Orthopedics 2018;41:e416-23. https://doi.org/10.3928/01477447-20180409-05
21. Parada SA, Flurin PH, Wright TW, Zukerman JD, Elwell JA, Roche CP, et al. Comparison of complication types and rates associated with anatomic and reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2021;30:811-8. https://doi.org/10.1016/j.jse.2020.07.028
22. Polisetty TS, Colley R, Levy JC. Value analysis of anatomic and reverse shoulder arthroplasty for glenohumeral osteoarthritis with an intact rotator cuff. J Bone Joint Surg Am 2021;103:913-20. https://doi.org/10.2106/JBJS.19.01398
23. Poondla RK, Sheth MM, Heldt BL, Laughlin MS, Morris BJ, Elkousy HA, et al. Anatomic and reverse shoulder arthroplasty in patients 70 years of age and older: a comparison cohort at early to midterm follow-up. J Shoulder Elbow Surg 2021;30:1336-43. https://doi.org/10.1016/j.jse.2020.08.030
24. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. https://doi.org/10.1016/j.jse.2017.09.013
25. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the substantial clinical benefit. J Shoulder Elbow Surg 2018;27:903-11. https://doi.org/10.1016/j.jse.2017.12.014
26. Somerson JS, Hsu JE, Neradilek MB, Matsen FA 3rd. Analysis of 4063 complications of shoulder arthroplasty reported to the US Food and Drug Administration from 2012 to 2016. J Shoulder Elbow Surg 2018;27:1978-86. https://doi.org/10.1016/j.jse.2018.03.025
27. Steen BM, Cabezas AF, Santoni BG, Hussey MM, Cusick MC, Kumar AG, et al. Outcome and value of reverse shoulder arthroplasty for treatment of glenohumeral osteoarthritis: a matched cohort. J Shoulder Elbow Surg 2015;24:1433-41. https://doi.org/10.1016/j.jse.2015.01.005
28. Steinmann SP, Cofield RH. Bone grafting for glenoid deficiency in total shoulder replacement. J Shoulder Elbow Surg 2000;9:361-7.
29. Shukla DR, Mclaughlin RJ, Lee J, Cofield RH, Sperling JW, Sánchez-Sotelo J. Intraobserver and interobserver reliability of the modified Walch classification using radiographs and computed tomography. J Shoulder Elbow Surg 2019;28:625-30. https://doi.org/10.1016/j.jse.2018.09.021
30. Triplet JJ, Everding NG, Levy JC, Moor MA. Functional internal rotation after shoulder arthroplasty: a comparison of anatomic and reverse shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:867-74. https://doi.org/10.1016/j.jse.2014.10.002
31. Virk M, Yip M, Liuzza L, Abdelshahed M, Paoli A, Grey S, et al. Clinical and radiographic outcomes with a posteriorly augmented glenoid for Walch B2, B3, and C glenoids in reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2020;29:e196-204. https://doi.org/10.1016/j.jse.2019.09.031
32. Walch G, Moraga C, Young A, Castellanos-Rosas J. Results of anatomic nonconstrained prosthesis in primary osteoarthritis with

biconcave glenoid. J Shoulder Elbow Surg 2012;21:1526-33. https://doi.org/10.1016/j.jse.2011.11.030
33. Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am 2007;89:1476-85. https://doi.org/10.2106/jbjs.f.00666
34. Waterman BR, Dean RS, Naylor AJ, Otte RS, Sumner-Parilla SA, Romeo AA, et al. Comparative clinical outcomes of reverse total shoulder arthroplasty for primary cuff tear arthropathy versus severe glenohumeral osteoarthritis with intact rotator cuff: a matched-cohort analysis. J Am Acad Orthop Surg 2020;28:e1042-8. https://doi.org/10.5435/jaaos-d-19-00493
35. Wright MA, Keener JD, Chamberlain AM. Comparison of clinical outcomes after anatomic total shoulder arthroplasty and reverse shoulder arthroplasty in patients 70 years and older with glenohumeral osteoarthritis and an intact rotator cuff. J Am Acad Orthop Surg 2020;28:e222-9. https://doi.org/10.5435/jaaos-d-19-00166