JSES International 9 (2025) 431–435

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Predictive factors of intraoperative conversion to reverse total shoulder arthroplasty in patients with primary glenohumeral arthritis

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ARTICLE INFO

Keywords:
Glenohumeral arthritis
Rotator cuff
Shoulder arthroplasty
Preoperative factors
Intraoperative decision
Reverse

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

Background: Many factors play a role in decision making for arthroplasty type in patients with glenohumeral osteoarthritis (GHOA). The purpose of this study was to evaluate preoperative and intraoperative factors that might predict the need for reverse total shoulder arthroplasty (rTSA) vs. anatomic total shoulder arthroplasty (aTSA) for patients with primary GHOA. Secondarily, American Shoulder and Elbow Surgeons (ASES) were compared.

Methods: Patients with primary GHOA indicated for aTSA vs. rTSA were identified. Preoperative records were reviewed for demographics, range of motion, rotator cuff strength, and glenoid morphology. Operative reports were assessed to identify intraoperatively rotator cuff pathology and glenoid deficiency. ASES scores at 2 years postoperative were collected.

Results: One hundred eleven patients were included from 2018 to 2021. Ninety-four patients underwent aTSA, while 17 were intraoperatively converted to rTSA. There were no significant differences in age, body mass index, or preoperative Walch classification between cohorts. rTSA patients had significantly decreased preoperative external rotation ($P = .006$). External rotation $\leq 30°$ was the only preoperative predictive factor for performing rTSA vs. aTSA ($P = .0004$). The most common reason for intraoperative transition to rTSA was rotator cuff deficiency. At 2-year follow-up, median ASES scores were 94.2 (interquartile range 85-96.7) and 88.3 (interquartile range 73.3-94.5) for aTSA and rTSA, respectively ($P = .097$).

Conclusion: Many patients with primary GHOA are well-served with aTSA. However, there are patients with primary GHOA in which rTSA may be ideal given rotator cuff deficiency or glenoid defects felt to limit aTSA glenoid component placement. This study highlights the need for preoperative external rotation and intraoperative evaluation of rotator cuff integrity and glenoid bone stock.

Reverse total shoulder arthroplasty (rTSA) was initially indicated for patients with rotator cuff tear arthropathy; however, indications for rTSA have expanded to include pathologies such as proximal humerus fractures and primary glenohumeral osteoarthritis (GHOA), among others[3,15,23] (Fig. 1). This has been driven by the satisfactory outcomes that rTSA has shown,[8] and by the need for an intact functional rotator cuff, and adequate glenoid bone stock for anatomic total shoulder arthroplasty (aTSA) to succeed. Implanting an aTSA in a patient with a deficient rotator cuff or insufficient glenoid bone stock can lead to early failure with glenoid loosening and poor functional outcomes.[22]

Prior studies have shown that only 5%-10% of patients with primary GHOA have significant rotator cuff pathology and in general, these patients still are able to achieve good short-term outcomes with anatomic shoulder arthroplasty and rotator cuff repair, especially for patients with small rotator cuff tears.[10,22] However, in some cases, patients with primary GHOA are found intraoperatively to have unexpected rotator cuff deficiency to an extent that may contradict the use of an aTSA. Furthermore, imaging studies can sometimes underestimate glenoid morphology, and the surgeon may encounter intraoperative glenoid bony defects felt to limit glenoid component placement with adequate backside seating. In these cases, surgeons may make the intraoperative decision to transition from aTSA to rTSA.

In addition to time-zero rotator cuff integrity and glenoid viability, surgeons also must consider potential future pitfalls. aTSA

The University of Iowa Institutional Review Board approved this study. IRB #: 202306419, 202305410.

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https://doi.org/10.1016/j.jseint.2024.09.026

Figure 1 Grashey view of a right shoulder in a 66-year-old female patient with primary glenohumeral osteoarthritis.

relies on the rotator cuff remaining healthy for the patient's lifespan and for healing of the subscapularis tenotomy, subscapularis peel, or lesser tuberosity osteotomy. In the event of rotator cuff compromise, failure of the implant is likely.[24] Therefore, a surgeon should consider not only rotator cuff integrity, but rotator cuff muscle quality and other risk factors for rotator cuff retear or failure.[14,16]

For these reasons, some surgeons are evolving their practices to perform increasing numbers of rTSA for patients with primary GHOA despite an intact rotator cuff.[1,13] Early studies, generally with short-term follow-up, show promising results of rTSA for cuff-intact GHOA with good patient-reported outcomes (PROs) and low complication and revision rates.[23]

Ardebol et al published a retrospective series of patients with cuff-intact primary GHOA who were 75 years or older and had either aTSA or rTSA. They found similar clinical improvements in both cohorts with low rates of revision (3% aTSA, 0% rTSA) and complications (7% aTSA, 5% rTSA) at an average follow-up of 3 years.[2] Freidman et al showed similar results in a large cohort of patients with cuff-intact GHOA demonstrating similar functional and radiographic outcomes with aTSA and rTSA. They found that those with aTSA had greater postoperative external rotation, but also had increased rate of revision.[7] Many other studies have shown good-to-excellent PROs in patients with primary GHOA who underwent rTSA primarily, even those with glenoid deformity or Walch B2 and B3 glenoids.[17-20]

As such, it is important to identify preoperatively, and intraoperatively, which patients may benefit from aTSA and rTSA. The purpose of this study was to evaluate the preoperative patient characteristics and intraoperative factors that might predict the need for rTSA vs. aTSA for patients with primary GHOA. Secondarily, PROs at 2 years postoperatively were evaluated for patients undergoing aTSA and rTSA for primary GHOA.

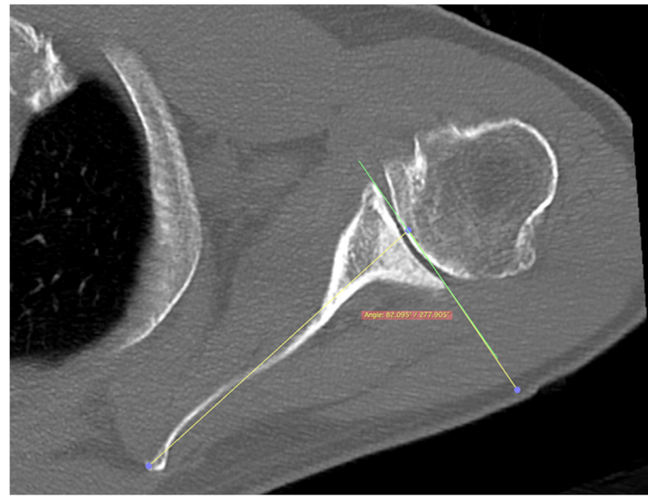

Figure 2 Axial slice of a fine-cut CT scan in a 68-year-old female patient demonstrating mild biconcavity of the glenoid and loss of joint space consistent with primary glenohumeral osteoarthritis. Friedman's line is drawn to calculate glenoid version, which, in this patient is 8° of glenoid retroversion. *CT*, computed tomography.

Materials and methods

This was a retrospective single-surgeon study performed at a tertiary-care medical center. Patients with the diagnosis of primary GHOA indicated and consented for "total shoulder arthroplasty (TSA) vs. rTSA" were identified over a 3-year period, 2018-2021. Patients who were indicated and consented for rTSA alone were excluded. Patients with preoperative magnetic resonance imaging (MRI) of the shoulder were excluded to minimize bias. Our institution's Institutional Review Board approval was obtained for all study procedures (#202305410 & 202306419). Preoperative records were reviewed for demographics, preoperative range of motion, and preoperative rotator cuff strength, which were assessed at standard-of-care patient clinic visits.

Operative reports were assessed for intraoperatively identified rotator cuff pathology or glenoid bone deficiency not fully appreciated preoperatively. Records were reviewed for complications or need for revision surgery, as well as for postoperative PROs. At our institution, patients complete PROs as standard-of-care practice during all clinic visits, which include the American Shoulder and Elbow Surgeons (ASES) score. Those patients who did not attend a 2-year postoperative visit (2-year +/− 2 months), were contacted by phone, consented, and assigned the ASES questionnaire. The survey was sent either via email using REDCap or was completed during the phone call.

Statistical analyses

We compared age and body mass index between groups using generalized linear models for repeated measures. The remaining continuous variables were not normally distributed and were compared between groups using Wilcoxon Rank Sum Tests for clustered data. Categorical variables were compared between groups using chi-square or Fisher's exact tests, as appropriate. A multivariable model for the relationship between odds of rTSA and participant characteristics was created using logistic regression with backwards selection. Analyses were completed using SAS statistical software version 9.4 (SAS Institute, Cary, NC, USA) and RStudio software version 4.0.2 (Posit, Boston, MA, USA) (clusrank procedure). *P* values at or below 0.05 were deemed statistically significant.

Table I
Demographics and preoperative clinical characteristics.

	rTSA	TSA	*P* value
Age	68.9	65.4	.132
Body Mass Index	33.1	31.5	.168
Preoperative Forward Flexion	121.2°	127.9°	.140
Preoperative External Rotation	32.5°	42.4°	**.006**
Preoperative Walch Classification			.269
A1	1 (5.9%)	15 (16.0%)	
A2	7 (41.2%)	23 (24.5%)	
B1	0	6 (6.4%)	
B2	5 (29.4%)	40 (42.6%)	
B3	4 (23.5%)	9 (9.6%)	
C	0	1 (1.1%)	
Preoperative glenoid retroversion	8.5°	8.0°	.760
Preoperative Rotator Cuff Strength			.257
≤4/5	3 (18.8%)	8 (9.0%)	
5/5	13 (81.2%)	81 (91.0%)	

TSA, total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.
The use of bold is to highlight the results that were statistically significant.

Radiographic analysis

Preoperative computed tomography (CT) scans were manually reviewed for Walch classification and glenoid version. CT scans were uploaded into a third party Digital Imaging and Communications in Medicine viewer (Horos, Purview, Annapolis, MD, USA). Scans were oriented into the plane of the scapula. Walch classification and version measurements were taken from axial slices of the CT scan in standard fashion (Fig. 2).[7] Walch classification was separately judged by 2 authors (BMP, GVC). When there was discordance, the authors met and came to a consensus decision.

Results

One hundred thirty-eight patients met initial inclusion criteria. Twenty-seven had a preoperative MRI which was felt to potentially create bias in the treatment decision making, these patients were thus excluded. The final cohort included 111 patients. Each patient's preoperative indication was for "TSA vs. rTSA" with the mutual understanding that an intraoperative decision would be made. The preoperative diagnosis was primary GHOA with a presumably intact rotator cuff. Seventeen patients (15%) had an intraoperative transition from aTSA to rTSA, while the remaining 94 patients (85%) proceeded with aTSA.

The only preoperative clinical exam feature that predicted intraoperative conversion from aTSA to rTSA was decreased external rotation (median 32.5° vs. 42.4°, $P = .006$). Patients who received rTSA trended towards decreased forward flexion (121.2° vs. 127.9°, $P = .140$), and trended toward increased body mass index (33.1° vs. 31.5°, $P = .168$) (Table I).

The most common intraoperative factor that influenced transition from aTSA to rTSA was rotator cuff pathology, which was encountered in 14 patients (12.6% of total cohort). Full thickness rotator cuff tears were identified in 7 patients (6.3% of total cohort). Of these patients that were found to have full-thickness rotator cuff tears intraoperatively, only 1 had preoperative weakness with cuff testing <5/5 strength in any rotator cuff muscle group. In review of the operative notes, partial or full-thickness supraspinatus tears were most common, occurring in 12 patients, followed by infraspinatus tears in 8 patients, and subscapularis tearing in 3 patients. Glenoid bone defects determined intraoperatively to limit adequate aTSA polyethylene implantation were encountered in 4 patients (3.6% of total cohort). For these patients rTSA was performed, despite an intact rotator cuff.

Table II
Minimum 2-year postoperative patient-reported outcome scores including ASES scores.

	rTSA	TSA	*P* value
Patients (n)	12	66	
Time to follow-up (median, y)	2.2	2.7	.324
Postoperative ASES score (median)	88.3	94.2	.097

ASES, American Shoulder and Elbow Surgeons; *TSA*, total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Radiographic analysis

When comparing patients undergoing aTSA vs. rTSA there were no significant differences between the groups' preoperative glenoid version. Median glenoid retroversion measured manually was 8.5° and 8.0° for rTSA and aTSA, respectively ($P = .760$). Walch classification was compared between cohorts with the most common glenoid types being the Walch A2, B2, and B3 (Table I). There was no statistically significant difference between the aTSA and rTSA cohorts in proportion of glenoid types of Walch A2 ($P = .172$), Walch B2 ($P = .314$) or Walch B3 ($P = .115$). Of the patients undergoing aTSA, 21 patients had A1 or B1 glenoid morphology, with the remainder having some aspect of advanced glenoid wear classified as either A2, B2, B3, or C.

Patient-reported outcomes

Seventy-eight of the 111 patients (70% follow-up) were able to be contacted for minimum 2-year follow-up PROs. At the time of final follow-up, 4 patients had deceased, 3 patients declined to participate, and 26 patients were unable to be contacted despite multiple attempts by phone and email. At minimum 2-year follow-up, median ASES scores were 94.2 (interquartile range 85-96.7) and 88.3 (interquartile range 73.3-94.5) for aTSA and rTSA, respectively ($P = .097$) (Table II). There was 1 revision in the rTSA cohort and 1 in the aTSA cohort.

Discussion

Many patients with primary GHOA are well-served with aTSA. This study and others demonstrate excellent postoperative PROs in this cohort.[2,11,19] However, there are patients in which rTSA may be the best treatment choice given poor rotator cuff integrity or bony glenoid defects felt to limit adequate aTSA glenoid component fixation. The purpose of this study was to evaluate for preoperative and intraoperative factors that predict the need for rTSA in patients with presumed rotator cuff-intact primary GHOA who are consented for aTSA vs. rTSA.

This study highlights the difficulties in identifying rotator cuff pathology and glenoid bony defects preoperatively as physical exam and preoperative CT scan imaging often do not give a complete representation of the patient's intraoperative anatomy and/or pathology. Our data suggest that the strongest preoperative clinical predictor of transition from aTSA to rTSA in the setting of primary GHOA is decreased preoperative external rotation. This study highlights the need for preoperative and intraoperative evaluation of both the rotator cuff and glenoid bone stock as we have found these to be the two most common reasons for intraoperative conversion from aTSA to rTSA in the setting of primary GHOA.

In this cohort we did not identify a significant correlation between degree of glenoid retroversion and subjective ability to implant a glenoid polyethylene component. It should be stated, though, that this study excluded patients with glenoid bony defects or dysplasia which were preoperatively deemed to be best suited with rTSA. Contrary to these findings, Ardebol et al, found in their study of patients aged 75 years and older treated with aTSA vs. rTSA for primary GHOA that they were significantly more likely to choose rTSA for patients with eccentric glenoid wear (i.e. Walch B2/B3 glenoid).[2] However, it is worth noting a difference in inclusion criteria, since our cohort included only patients indicated for "TSA vs. rTSA", and we did not include patients with advanced glenoid deformities who were indicated for rTSA only. Other studies have suggested that increased glenoid retroversion can lead to worse outcomes and higher failure rates in aTSA.[6,9,21]

We did find that decreased preoperative range of motion correlated with increased utilization of rTSA. Even though preoperative external rotation was the only significant predictor of the use of rTSA instead of aTSA, preoperative forward elevation was also decreased in the rTSA group, though not statistically significant. This could be due to worsening arthritic disease with increased glenoid bone wear, or occult rotator cuff disease. Additionally, worsened arthritic disease could lead to disuse and stiffness prior to shoulder arthroplasty.[5]

Our study showed that rotator cuff weakness, defined as <5/5 strength in any rotator cuff muscle group at the preoperative clinic visit, trended toward increased utilization of rTSA ($P = .257$). Interestingly, though, we had 14 patients (12.6% of total cohort) found to have full or partial-thickness rotator cuff tears, or significant thinning intraoperatively. Full-thickness rotator cuff tears were identified in 7 patients (6.3% of total cohort); however, only 1 (14.3%) of these patients had weakness with preoperative rotator cuff strength testing. The prevalence of patients with GHOA with concomitant rotator cuff pathology in our cohort is like that previously reported in the literature.[10] Thus, clinical exam alone can be misleading when making a best estimate on which patients might have adequate cuff integrity for aTSA implantation. In addition, isolating the rotator cuff can be difficult and one can be mistaken by pain-limited motion and strength deficits in diffuse GHOA with an intact cuff.

Some authors advocate for MRI preoperatively prior to shoulder arthroplasty.[4] MRI is generally the best study to evaluate soft tissues and can allow a surgeon to evaluate the rotator cuff preoperatively. MRI, however, is very costly, time consuming, and can be difficult to access for some patients. Levin et al performed a cost efficiency modeling study and found MRI-for-all to be very cost-ineffective.[12] They reported, rather, that having both aTSA and rTSA components available in the operating room and making an intraoperative decision was the most cost-effective model. This may not be possible for all surgeons based on implant availability or surgery center limitations, so MRI selectively was shown to be a reasonably cost-effective model, as well.[12]

Our preference is to obtain a preoperative CT scan on most patients undergoing shoulder arthroplasty as this can be used for preoperative planning. MRI is used in our practice on a selective basis for those patients with prior rotator cuff repair, or patients in which rotator cuff pathology is suspected preoperatively based on clinical exam.

We did elect to exclude all patients with primary GHOA indicated for aTSA vs. rTSA who had a preoperative MRI given that we sought to limit bias. Results of an MRI could bias a surgeon and potentially push them to be more or less likely to indicate a patient for aTSA vs. rTSA.

Our study is limited by its retrospective nature, and its single-surgeon nature, which is inherently biased by training and experience. In addition, our 2-year follow-up data were collected from online surveys and phone calls; therefore, range of motion measurements and radiographs are not available. This study was performed at a large academic medical center where aTSA and rTSA components are readily available each day, which may not be generalizable to all orthopedic surgeons in a smaller hospital, surgery center, or outpatient setting.

The current study does highlight the fact that patients indicated for aTSA vs. rTSA preoperatively who receive rTSA given inadequate glenoid bone stock or rotator cuff pathology still achieve excellent 2-year postoperative PROs, with a low rate of revision surgery. Future studies should continue to evaluate factors that might predict those patients with cuff-intact GHOA who would most benefit from rTSA.

Conclusion

Determining which patients with primary GHOA may benefit most from rTSA as opposed to aTSA continues to be difficult and debated. The current study suggests that the strongest preoperative predictor of intraoperative transition from aTSA to rTSA in the setting of primary GHOA is decreased preoperative external rotation. The most common intraoperative factor that influences transition from aTSA to rTSA in the setting of primary GHOA is rotator cuff pathology, which in our cohort occurred in 12.6% of patients. Results from this study indicate that intraoperative conversion from aTSA to rTSA in patients with primary GHOA yields excellent short-term outcomes with low revision rates.

Disclaimers:

Funding: This study did not receive financial support.
Conflicts of interest: Brendan M. Patterson receives research funding from Stryker Orthopedics and is a paid consultant for Stryker Orthopedics. Joseph W. Galvin is a board or committee member for the American Academy of Orthopedic Surgeons and American Shoulder and Elbow Surgeons. 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.

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