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Rotator cuff fatty infiltration and muscle atrophy do not impact clinical outcomes after reverse total shoulder arthroplasty for glenohumeral osteoarthritis with intact rotator cuff

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Background: The clinical significance of rotator cuff muscle quality following reverse total shoulder arthroplasty (RTSA) remains uncertain. The purpose of this study was to evaluate the influence of rotator cuff fatty infiltration (FI) and muscle atrophy (MA) on clinical outcomes following RTSA for glenohumeral osteoarthritis (GHOA).

Methods: One hundred eight shoulders with primary GHOA that underwent RTSA with a lateralized glenosphere for GHOA with a minimum of 2-year follow-up were identified from a prospectively maintained registry. Each rotator cuff muscle was assessed on preoperative magnetic resonance imaging for FI and quantitative amount of MA. Pre- and postoperative outcomes included American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form score, Single Assessment Numerical Evaluation (SANE) score, visual analog scale pain score, and range of motion (ROM) measurements.

Results: Eighty-one patients with a mean age of 70.7 $\pm$ 5.4 years (range: 57-85) were included who underwent RTSA with a mean follow-up of 2.1 years (range: 2-3.9 years). There was a significant improvement in all outcome measures postoperatively ($P < .01$). Twenty-two patients (27.1%) had moderate to severe combined infraspinatus and teres minor FI. There was no significant difference in the postoperative external rotation or clinical outcomes compared with those patients with only mild FI ($P > .05$). Forty-three patients (53.1%) had moderate to severe global rotator cuff FI. There was no significant difference in postoperative outcomes compared with those patients with only mild FI ($P < .01$). Univariate analysis did not reveal any significant association between the degree of FI or MA of any individual rotator cuff muscle and postoperative clinical outcomes or ROM. The size ratio of the posterior rotator cuff to the subscapularis muscle was positively correlated with preoperative SANE scores but negatively correlated with absolute postoperative and change in preoperative to postoperative SANE scores. However, there were no significant correlations between this size ratio and the other outcome measures.

Conclusion: Rotator cuff muscle quality as assessed by MA and FI does not impact clinical outcomes following RTSA with a lateralized glenosphere in patients with GHOA and an intact rotator cuff.

This study was approved by the Institutional Review Board of the New England Baptist Hospital (project no. 1497641).

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Keywords: Reverse total shoulder arthroplasty; rotator cuff integrity; Goutallier classification; muscle volume; muscle atrophy; clinical outcome

Reverse total shoulder arthroplasty (RTSA) has historically been indicated for rotator cuff arthropathy (RCA). Evolving implant designs coupled with recent clinical literature and increased use have contributed toward expanding indications for this procedure.[16] RTSA has recently emerged as a reliable alternative to anatomic total shoulder arthroplasty for primary glenohumeral osteoarthritis (GHOA) with an intact rotator cuff.[7,17,18,24] Given the evolving indications for RTSA, further insight into the factors that may affect postoperative outcomes is necessary.

Alterations in the moment arm of the deltoid conferred by RTSA prosthesis design augment its torque-generating capacity during forward elevation and abduction, at the expense of axial rotation.[1,2] One way the loss in deltoid rotational efficiency may be compensated for is by the intact rotator cuff musculature.[2] A significant subset of patients with primary GHOA possess varying degrees of rotator cuff pathology, such as fatty infiltration (FI) and muscle atrophy (MA).[10,14] Such degenerative changes in the rotator cuff muscle have previously been associated with adverse clinical outcomes and range of motion (ROM) in patients following RTSA for RCA or rotator cuff deficiency with pseudoparesis.[20,25] Further investigation on this subject is warranted given the advancements in lateralized prosthesis designs, which may serve to optimize rotator cuff length-tension relationships[6,12] and the new indications for this procedure.

The purpose of this study was to assess the clinical outcomes of patients after RTSA with a lateralized glenosphere for GHOA with an intact rotator cuff, and to evaluate the prognostic effect that rotator cuff FI and MA have on these outcomes. Our hypothesis was that neither rotator cuff FI nor MA would correlate with outcomes after this procedure.

Methods

Patient population

Using a patient registry prospectively maintained on the Outcomes Based Electronic Research Database (OBERD) platform (OBERD, Columbia, MO, USA), we identified all patients who received an RTSA for a primary diagnosis of GHOA during the period of October 2015–August 2018. An RTSA was indicated in these patients based on the senior surgeon's discretion, considering patient age, activity level, and glenoid morphology. Patients with both concentric glenoid wear and those with posterior glenoid erosion were indicated for RTSA, because of the philosophy that this procedure provides excellent reliable long-term outcomes.[16-18] To be included in this study, patients must have undergone primary RTSA with a minimum of 2 years' clinical follow-up and had a preoperative magnetic resonance imaging (MRI) with an intact rotator cuff. All surgeries were performed by the senior author, a fellowship-trained shoulder surgeon. Patients were excluded from this study if they received an RTSA for an indication other than GHOA, if preoperative MRI revealed a full-thickness tear to any rotator cuff tendon, revision arthroplasty procedures, and if the correct MRI sequence used for radiologic evaluation and classification was not available.

Surgical technique

All surgeries were performed with general anesthesia and an interscalene nerve block when possible. A standard deltopectoral approach was used in all cases. If intact, the biceps tendon was tenodesed to the pectoralis major tendon. A subscapularis peel was performed and subsequently repaired to the lesser tuberosity at the conclusion of each procedure with a combination of simple and Mason Allen sutures. A 36- or 32-mm lateralized glenosphere was used in all patients, based on the treatment philosophy of the treating surgeon (DJO Global, Carlsbad, CA, USA). In the setting of posterior glenoid bone loss, anterior high-sided reaming was performed to restore acceptable glenoid retroversion. No patients in this study required glenoid bone grafting or an augmented baseplate. A noncemented inlay design with a standard-length humeral stem with a standard or ≥4-mm polyethylene insert was used in all patients. Postoperatively, all patients underwent a standardized rehabilitation protocol, including restricted shoulder ROM for the first 2 postoperative weeks followed by gradual progression of passive and active assisted exercises.

Radiographic evaluation

FI of the supraspinatus, infraspinatus, teres minor, and subscapularis were assessed on T1-weighted sagittal MRI sequences without fat suppression, using the grading system described by Goutallier et al[11] with adaptations for MRI as described by Fuchs et al.[9] An image just medial to the spinglenoid notch was used for evaluation of FI in each muscle, as previously described and validated.[9] FI grades for each muscle were determined through a consensus reading performed by 3 orthopedic surgeons.

For purposes of statistical analysis, patients were stratified into groups based on severity of individual rotator cuff muscle FI, as previously described[8,13,20]: absent to mild FI (Goutallier grade 0 or 1) and moderate to severe FI (grade ≥2). Because of the low number of patients with mild FI of the supraspinatus, and to allow for a valid statistical analysis, a Goutallier score 0-2 was considered mild and a score ≥3 was considered moderate to

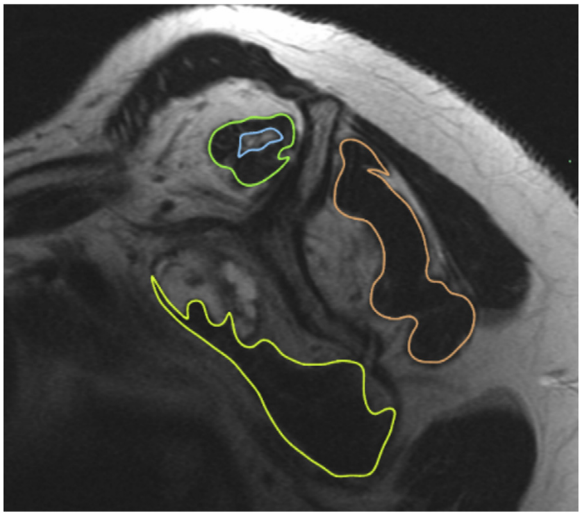

Figure 1 Select sagittal magnetic resonance imaging scan of a rotator cuff showing partial fatty infiltration and muscular atrophy. Surface area with individual muscle measurements were calculated automatically via OsiriX software. Areas of acute fatty infiltration were subtracted from total volume measurements. The location of the image was chosen as the most lateral point in which the scapular spine is connected to the scapular body. Cuff muscle outlines were then traced while excluding infiltration areas. Infraspinatus and teres minor areas were merged together for quantification.

severe FI of the supraspinatus. The posterior rotator cuff muscle FI was determined from a combined score of the infraspinatus and teres minor muscles and divided into groups of minimal FI (grade <4) and moderate to severe FI (grade ≥4).[8] For a global assessment of the combined level of FI of all rotator cuff muscles, patients were classified as minimal (grade <8) or moderate to severe FI (grade ≥8).

The degree of MA was quantitatively determined for each rotator cuff muscle by measuring muscle area on T1-weighted sagittal images as previously described.[3,5,14] This methodology has been demonstrated to be reliable and accurate, as 2D muscle is directly correlated to 3D muscle volumes after cadaveric dissection.[15,23] The muscle areas were measured on the most lateral sagittal slice where the scapular spine contacts the scapular body. These 3 areas were outlined, and an area was automatically generated in OsiriX image analysis software (OsiriX, Bernex, Switzerland) (Fig. 1.) The areas were then added to generate a total volume. The infraspinatus and teres minor were measured as a single muscle area because these 2 cannot be reliably differentiated on imaging.[9] A size ratio of the posterior cuff to the subscapularis was also calculated to assess the effect of muscular imbalance on outcomes.

Clinical evaluation

A standardized clinical assessment was performed prior to their surgery and at a minimum of 2 years' follow-up for all patients. These evaluations included a thorough physical examination,

Table I Patient demographic, radiographic, and clinical data

Parameter	Mean ± SD (range) or n (%) (N = 81)
Age (yr), mean ± SD (range)	70.7 ± 5.4 (57-85)
Sex, n (%)	
Female	57 (70.4)
Male	24 (29.6)
Follow-up, yr, mean ± SD (range)	2.1 ± 0.4 (2-3.9)
BMI, mean ± SD	31.4 ± 6.5
Comorbid conditions, n (%)	
Depression	19 (23.4)
Diabetes	14 (17.2)
Obesity	15 (18.5)
Smoker	4 (4.9)
Previous surgery, n (%)	14 (17.3)
Preoperative glenoid Walch classificaiton, n (%)	
A1	26 (32.1)
A2	6 (7.4)
B1	7 (8.6)
B2	18 (22.2)
B3	20 (24.7)
D	2 (2.5)
VAS pain score, mean ± SD	
Preoperative	5.9 ± 2.2
Postoperative	0.72 ± 1.6
Change	5.1 ± 2.4*
SANE score, mean ± SD	
Preoperative	32.6 ± 18.3
Postoperative	90.1 ± 13.5
Change	57.5 ± 25.7*
ASES score, mean ± SD	
Preoperative	35.6 ± 15.4
Postoperative	85.6 ± 14.2
Change	50 ± 19.8*
Forward flexion (degrees), mean ± SD	
Preoperative	93 ± 21.8
Postoperative	140 ± 18.5
Change	48.2 ± 29.7*
External rotation (degrees), mean ± SD	
Preoperative	26.6 ± 13.8
Postoperative	57.7 ± 16
Change	30.7 ± 19.4*
Internal rotation†, mean ± SD	
Preoperative	1.1 ± 0.9
Postoperative	3.1 ± 2.2
Change	2.0 ± 2.1*

SD, standard deviation; *BMI*, body mass index; *VAS*, visual analog scale; *SANE*, Single Assessment Numerical Evaluation; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

* Statistical significance.

† Sequential point system, with 0 = rotation to the hip, and 9 = rotation to T10.

Table II Descriptive measurements of fatty infiltration and muscle atrophy for each rotator cuff muscle

Muscle	Fatty infiltration, n (%)*					Muscle atrophy† cm^2, mean (SD)
	0	1	2	3	4	
Supraspinatus	0	4 (5.0)	39 (48.1)	25 (30.9)	13 (16.0)	3.33 (1.28)
Infraspinatus	1 (1.2)	11 (13.6)	65 (80.2)	4 (4.9)	0	8.42 (2.31)‡
Teres minor	3 (3.7)	57 (70.4)	17 (21)	1 (1.2)	3 (3.7)	
Subscapularis	3 (3.7)	20 (24.7)	53 (65.4)	5 (6.1)	0	9.73 (3.37)

SD, standard deviation.
* Classification according to Goutallier.
† Cross-sectional measurement of muscle area.
‡ Cross-sectional measurement of the combined infraspinatus and teres minor muscles.

including active ROM measurements in forward flexion, abduction, external rotation at 0° of abduction, and internal rotation measured to the uppermost vertebral level of the spine reached by the thumb of the examined extremity. Internal rotation levels were then converted to a sequential numerical scale where zero was assigned to internal rotation to the hip, 1 for internal rotation to the sacrum, 2 for internal rotation to the L5 vertebral level, 3 for internal rotation to the L4 vertebral body, 4 for internal rotation to the L3 vertebral body, and so forth where each sequential vertebral body is an additional point. All measurements were made by the senior surgeon. Patient-reported outcome measures including the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score, Single Assessment Numerical Evaluation (SANE) score, and visual analog scale (VAS) pain score were collected for each patient preoperatively and at final follow-up. Any complications or revision surgeries performed were recorded at final follow-up as well. The primary outcome measure of this study was the ASES score at final follow-up.

Statistical analysis

Univariate analyses were performed using the Wilcoxon rank-sum, Student *t*, χ^2, and Fisher exact tests. Pre- and postoperative clinical outcomes were compared using paired *t* tests. Univariate associations of outcome scores with individual muscle FI grades and MA were assessed using analysis of variance and Pearson correlations. All statistical analysis was performed using SPSS statistical software (version 11.5; IBM, Armonk, NY, USA).

Results

One hundred eight shoulders in as many patients met final inclusion criteria for this study. The final study group included 81 shoulders in 81 patients (75%), who were available for a minimum 2-year in-office follow-up (mean: 2.1 years, range: 2-3.9 years). These patients had a mean age of 70.7 ± 5.4 years (range: 57-85) at the time of their surgery. Fifty-seven (70.4%) of these patients were female (Table I). MA did not significantly correlate with age, but women had significantly greater MA of all rotator cuff muscles compared with men ($P < .05$), with the exception of the posterior cuff to subscapularis ratio. FI was not significantly associated with age or sex.

Twenty-two patients (27.1%) had a moderate to severe combined infraspinatus and teres minor FI, defined as a combined grade ≥4. Forty-three patients (53.1%) had moderate-severe global rotator cuff FI as defined by a combined grade ≥8. The relative distribution of grades of FI and MA for each rotator cuff muscle among the study population can be found in Table II. There was a significant improvement in all clinical outcome measures at final follow-up ($P < .01$) (Table I). There was 1 patient who had postoperative hand weakness and paresthesias from an ulnar and median nerve palsy sustained during their procedure, which had not improved at final follow-up. Otherwise, there were no instances of postoperative complications such as an acromial stress fracture or dislocation, and there were no patients who required revision surgery.

Rotator cuff fatty infiltration association with clinical outcomes

No significant differences were found between patients with minimal FI and those with moderate or severe FI when comparing the preoperative, postoperative, or change in any clinical outcome measures ($P > .05$) (Table III). There were no significant differences in the preoperative, postoperative, or change in any clinical outcomes, including external rotation, when comparing combined infraspinatus and teres minor FI (Table III). Similarly, advanced FI of the subscapularis and supraspinatus did not influence internal rotation, abduction, or subjective outcomes, compared with those without advanced FI of these muscles (Table III). There were no significant differences in the incidence of patients with a combined rotator cuff FI grade ≥8 between those in the top quartile of postoperative ASES scores and the rest of the patients. Multiple 1-way analyses of variance did not reveal any changes in mean postoperative ASES scores between Goutallier FI grades for each individual rotator cuff muscle ($P > .05$).

Table III Influence of rotator cuff fatty infiltration on clinical outcomes

Outcome	Combined rotator cuff fatty infiltration ≥8*		P value
	Yes (n = 43)	No (n = 38)	
ASES score			
Preoperative	34.2 (14.9)	37.2 (16)	.38
Postoperative	86.6 (12.2)	84.5 (16.3)	.50
Change	52.4 (18.5)	47.3 (21)	.24
SANE score			
Preoperative	29.3 (18.1)	36.3 (18)	.09
Postoperative	90.6 (14.7)	89.5 (12.2)	.73
Change	61.3 (26.1)	53.2 (25)	.16
VAS pain score			
Preoperative	6 (2.3)	5.7 (2.2)	.50
Postoperative	0.7 (1.6)	0.8 (1.6)	.64
Change	5.4 (2.4)	4.9 (2.4)	.35
Forward elevation (degrees)			
Preoperative	90.2 (21)	96 (22.6)	.22
Postoperative	141.3 (15)	138.3 (21.9)	.47
Change	51.2 (23.5)	44.8 (35.4)	.34
External rotation (degrees)			
Preoperative	25.9 (14.1)	27.4 (13.7)	.63
Postoperative	56.7 (16.8)	58.8 (15.3)	.56
Change	30.1 (20.2)	31.4 (18.7)	.78
	Combined IS+TM ≥4*		
	Yes (n = 22)	No (n = 59)	
ASES score			
Preoperative	35.3 (15.3)	35.7 (15.6)	.91
Postoperative	87.4 (8.6)	85 (15.8)	.50
Change	52.1 (16.2)	39.2 (21)	.57
SANE score			
Preoperative	31.4 (16.6)	33.1 (19)	.71
Postoperative	90.3 (11.8)	90 (14.2)	.92
Change	59 (19.4)	57 (27.8)	.75
VAS pain score			
Preoperative	5.6 (2.4)	6 (2.1)	.57
Postoperative	0.6 (1.3)	0.8 (1.7)	.64
Change	5.1 (2.5)	5.2 (2.4)	.84
External rotation (degrees)			
Preoperative	27.5 (14.7)	26.3 (13.6)	.73
Postoperative	60.7 (18.8)	56.6 (14.9)	.31
Change	31.9 (22)	30.3 (18.6)	.74
	Subscapularis grade ≥2*		
	Yes (n = 58)	No (n = 23)	
ASES score			
Preoperative	35.2 (14.8)	36.6 (16.8)	.72
Postoperative	85.8 (14.3)	85.1 (13.9)	.85
Change	50.6 (19.2)	48.5 (21.2)	.68
Internal rotation			
Preoperative	1.1 (0.9)	1 (0.63)	.52
Postoperative	3 (2.2)	3.6 (1.9)	.31
Change	1.8 (2.1)	2.3 (2.0)	.34
	Supraspinatus grade ≥3*		
	Yes (n = 38)	No (n = 45)	
ASES score			
Preoperative	34.8 (13.6)	36.7 (17)	.52
Postoperative	85.8 (13.3)	85.5 (15.3)	.92
Change	51.1 (18.6)	48.8 (21.1)	.57
Forward flexion (degrees)			
Preoperative	90.9 (19.2)	95.7 (23.6)	.25
Postoperative	141.7 (14.5)	138.6 (21.7)	.52
Change	50.8 (22.6)	46.3 (35.4)	.39

(*continued on next page*)

ASES, American Shoulder Elbow Surgeon score; *SANE*, Single Assessment Numerical Evaluation; *VAS*, visual analog scale; *IS*, infraspinatus; *TM*, teres minor.

* Classification according to Goutallier.

Rotator cuff muscle atrophy association with clinical outcomes

The cross-sectional area of each rotator cuff muscle did not significantly correlate with preoperative, postoperative, or change in any patient-reported outcome measure or ROM measurement ($P > .05$) (Table IV). There was a significant positive correlation between increasing posterior rotator cuff size relative to the subscapularis muscle and preoperative SANE scores ($r = 0.23$, $P = .03$), and a significant negative correlation with the size ratio and postoperative ($r = -0.27$, $P = .02$) as well as preoperative to postoperative improvement in SANE scores ($r = -0.32$, $P < .01$). However, there were no significant correlations between the size ratio of the posterior rotator cuff to the subscapularis and ASES scores, VAS pain scores, or any ROM measurements ($P > .05$) (Table IV).

Discussion

The findings of our study demonstrate that despite a high prevalence of advanced rotator cuff FI and MA, patients receiving an RTSA with a lateralized glenosphere for GHOA in the setting of intact rotator cuff(s) demonstrate excellent outcomes at a minimum of 2-year follow-up. We also found that the presence and severity of rotator cuff FI

Table IV Influence of rotator cuff muscle volume on clinical outcomes

Outcome	Supraspinatus muscle volume*, Pearson correlation coefficient	*P* value
ASES score		
Preoperative	0.14	.22
Postoperative	−0.14	.24
Change	−0.21	.07
SANE score		
Preoperative	0.06	.60
Postoperative	−0.13	.27
Change	−0.11	.34
VAS pain score		
Preoperative	−0.12	.28
Postoperative	0.09	.42
Change	0.18	.13
Forward elevation (degrees)		
Preoperative	0.06	.64
Postoperative	−0.07	.58
Change	−0.05	.65
	IS+TM muscle volume*	
ASES score		
Preoperative	0.17	.15
Postoperative	−0.06	.64
Change	−0.17	.14
SANE score		
Preoperative	0.06	.58
Postoperative	−0.12	.31
Change	−0.11	.36
VAS pain score		
Preoperative	−0.15	.19
Postoperative	0.04	.76
Change	0.16	.16
External rotation (degrees)		
Preoperative	0.04	.70
Postoperative	−0.15	.21
Change	−0.15	.21
	Subscapularis muscle volume*	
ASES score	−0.01	
Preoperative	0.07	.95
Postoperative	0.06	.53
Change		.61
SANE score	−0.15	.19
Preoperative	0.13	.26
Postoperative	0.17	.13
Change		
VAS pain score	0.02	.84
Preoperative	−0.07	.57
Postoperative	−0.07	.57
Change		
Internal rotation	−0.02	.87
Preoperative	−0.04	.75
Postoperative	−0.07	.56
Change		
	Ratio of posterior cuff to subscapularis muscle volume*	
ASES score	0.15	.19
Preoperative	−0.07	.52
Postoperative	−0.17	.13
Change		
SANE score		
Preoperative	0.24	.03†
Postoperative	−0.27	.02†
Change	−0.32	.005†
VAS pain score		
Preoperative	−0.18	.12
Postoperative	0.07	.55
Change	0.21	.07
External rotation (degrees)		
Preoperative	−0.08	.47
Postoperative	−0.15	.20
Change	−0.06	.61
Forward elevation (degrees)		
Preoperative	0.03	.78
Postoperative	−0.2	.08
Change	−0.21	.07
Internal rotation		
Preoperative	−0.08	.49
Postoperative	−0.1	.38
Change	−0.03	.77

(*continued on next page*)

ASES, American Shoulder Elbow Surgeon score; *SANE*, Single Assessment Numerical Evaluation; *VAS*, visual analog scale; *IS*, infraspinatus; *TM*, teres minor.

* Cross-sectional measurement of muscle area.

† Statistical significance.

and MA of any rotator cuff muscle do not affect these outcomes, which confirms our hypothesis. Increasing posterior rotator cuff size relative to the subscapularis muscle was positively correlated with preoperative SANE scores but negatively correlated with absolute postoperative and improvement in pre- to postoperative SANE scores. However, there were no significant correlations between this size ratio and the other outcome measures. Our findings are in contrast to previous investigations that conclude that deficiency in posterior cuff musculature fails to restore external rotation in patients with RCA receiving Grammont-style glenosphere.[20]

The only significant association that our study identified between rotator cuff muscle pathology and outcomes after RTSA was between increasing posterior cuff size relative to the subscapularis and SANE scores. However, similar results were not appreciated when assessing the correlation with ASES scores, VAS pain scores, or ROM measurements. Therefore, it is difficult to conclude whether an imbalance in axial forces from the anterior and posterior rotator cuff truly impacts preoperative function, or postoperative outcomes after RTSA for GHOA. If this correlation were to truly exist, it may be partially explained by the previously described association between an increased ratio of the posterior cuff area to the subscapularis area with type B glenoids according to the Walch classification, as well as with increasing glenoid retroversion and humeral head subluxation.[3]

Previous literature has demonstrated a negative impact of rotator cuff FI on outcomes after RTSA. In the 30-patient series by Wiater et al,[25] FI of the infraspinatus was correlated with decreased postoperative external rotation after RTSA for RCA. Simovitch et al[20] reported stage 3 or 4 FI of the teres minor in 23.8% of patients who received an RTSA for RCA. These patients had significantly inferior absolute postoperative and pre- to postoperative improvements in Constant score and external rotation. Additional literature[4,21] suggests limited external rotation improvement after RTSA if the posterior rotator cuff is deficient. Several notable differences exist between these previous studies and our current study, including underlying pathology/surgical indication, prosthesis design, and methods of radiographic evaluation. The previous studies evaluated only patients with RCA, Grammont-style prostheses, and computed tomography scans were used for the assessment of rotator cuff FI. The latter deviation in these prior studies represents a significant limitation, as MRI has superior interobserver agreement over computed tomography for assessment of FI.[22] In regard to implant design, one option with modern implants is to lateralize the center of rotation (COR) on the glenoid side, which retensions the external rotators, thus providing an increased rotational capacity compared with medialized COR prostheses.[12] The discrepancy between our results and these previous findings could partially be explained by using an implant with a lateralized COR in the setting of an intact rotator cuff, which may provide the posterior cuff sufficient biomechanical advantage to generate axial rotation despite advanced muscular pathology. Finally, RCA represents a spectrum of disease pathology including massive full-thickness tears with variable involvement of the posterior cuff tendons, which may be a causative factor for the decrease in external rotation seen in the results of these prior studies.

The majority of literature on RTSA for primary GHOA in patients with an intact rotator cuff focuses on patients with advanced glenoid deformity, without evaluating rotator cuff FI or MA. The case series by Collin et al,[7] Mizuno et al,[18] and McFarland et al[17] all corroborate our findings that RTSA provides excellent clinical outcomes in the setting of GHOA. Both Mizuno et al[18] and McFarland et al[17] demonstrated significant global improvements in ROM and subjective outcome measures at the 2-year follow-up. The study by Collin et al[7] demonstrated similar findings, with high rates of scapular notching (43%) but no revision surgeries, at the 5-year follow-up. Most recently, Waterman et al[24] compared the results of RTSA for patients with RCA to those with GHOA with an intact rotator cuff. They found that patients with GHOA and an intact rotator cuff had superior absolute postoperative external rotation and subjective outcomes, but there was no difference in pre- to postoperative improvement in any subjective or objective outcomes.[24] These findings suggest that the presence of an intact rotator cuff may provide an overall benefit to patients receiving an RTSA; however, these results are likely influenced by their superior preoperative function compared to those with RCA.

After RTSA, the fibers of the anterior and posterior deltoid subregions pass more superior to the glenohumeral joint relative to their anatomic location, resulting in diminutive rotational torque production.[1,2] The anterior and posterior rotator cuff muscles, on the other hand, retain their rotational moment arms. However, rotational torque is also dependent on the force-generating capability of muscle, which is intimately related to the degree of FI and MA.[10,14] For these reasons, some authors suggest concurrent tendon transfer procedures with RTSA for RCA or massive cuff tear with pseudoparesis in patients with greater than stage 2 FI of teres minor and clinical signs of a deficient posterior cuff, in order to restore external rotation.[19,20] However, the results of our study suggest that RTSA with a lateralized COR for GHOA with an intact rotator cuff provides excellent functional outcomes even in patients with advanced rotator cuff muscle FI and MA. Careful delineation of prosthesis design and patient indication for surgery is therefore advised when considering treatment adjuncts to RTSA.

There were several strengths to this current study, including our large sample size relative to the published literature on this topic, our high rate of patient follow-up, the use of MRI to quantitatively and qualitatively evaluate the rotator cuff musculature, the evaluation of FI by 3 reviewers, and the use of a single implant. Despite these strengths, our study was not without limitation. These are the results from a single surgeon's experience, and therefore the reproducibility of these outcomes is unknown. Additionally, strength measurements were not obtained for this study; therefore, it remains unknown whether this is affected by rotator muscle FI and MA. A third limitation of this study was the lack of postoperative MRI or computed tomographic imaging, which precluded the assessment of whether muscle pathology had evolved at the time of final follow-up. We were also limited by the lack of a formal control group. Finally, our lack of significant findings may be the result of a type II statistical error owing to the small sample sizes after patient stratification.

Conclusion

Rotator cuff FI and MA do not impact clinical outcomes following RTSA for GHOA with an intact rotator cuff. Further study is necessary to determine if these findings are unique to prosthesis design or underlying diagnosis and rotator cuff integrity.

Disclaimers

Andrew Jawa is a paid speaker and consultant for DJO Global, a paid consultant for Ignite Orthopedics, receives royalties from DePuy Synthes, and has equity in Boston Outpatient Surgical Suites.

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