



Retrospective Cohort Study

Outcomes after arthroscopic repair of rotator cuff tears in the setting of mild to moderate glenohumeral osteoarthritis

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Abstract

BACKGROUND

Rotator cuff pathology is a very common source of shoulder pain. Similarly, osteoarthritis of the glenohumeral joint can cause shoulder pain and produce similar symptoms. Surgical management can be indicated for both pathologies, however, outcomes data is limited when examining rotator cuff repair (RCR) in the setting of glenohumeral arthritis (GHOA). Thus, this study sought to determine outcomes for patients who undergo RCR in the setting of GHOA.

AIM

To evaluate if a relationship exists between outcomes of RCR in the setting of GHOA.

METHODS

This was a retrospective analysis of patients who underwent arthroscopic rotator cuff repair with concurrent glenohumeral osteoarthritis between 2010-2017.

Patients were stratified based on rotator cuff tear size and glenohumeral osteoarthritis severity. Cohorts were paired 1:1 with patients without glenohumeral osteoarthritis. Patients included had a minimum two year follow-up. Rate of conversion to total shoulder arthroplasty, complication rates following initial surgery, and patient-reported outcome measures were collected.

RESULTS

A total of 142 patients were included. The number of patients that required total shoulder arthroplasty within two years after index surgery was low. 2/71 (2.8%) patients with GHOA, and 1/71 (1.4%) without GHOA. Following rotator cuff repair, both groups showed favorable patient-reported outcomes.

CONCLUSION

Patients with glenohumeral osteoarthritis who underwent arthroscopic rotator cuff repair showed comparable outcomes to patients without glenohumeral osteoarthritis.

Key Words: Rotator cuff repair; Rotator cuff tear; Glenohumeral osteoarthritis; Shoulder; Arthroscopic; Outcomes

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Core Tip: We evaluated a cohort of patients with mild to moderate glenohumeral arthritis who underwent rotator cuff repair. We retrospectively reviewed 71 patients with glenohumeral osteoarthritis (GHOA) (Glenohumeral Arthritis) who underwent concomitant rotator cuff repair, and matched these patients to 71 patients who underwent rotator cuff repair without GHOA. We evaluated patient reported outcomes and demographic information for both cohorts.

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INTRODUCTION

Rotator cuff pathology is a common source of shoulder pain. A significant proportion of individuals have rotator cuff tears with increasing age and can become disabled[1-3]. In older patients, onset of new symptoms correlate to the progression of rotator cuff tear size and increasing morbidity[3].

Like rotator cuff pathology, glenohumeral osteoarthritis (GHOA) is related to advancing age and is estimated to affect 16%-20% of adults over age 65[4,5]. It can be debilitating and a source of shoulder dysfunction, pain, and loss of motion[6,7].

Although rotator cuff pathology and GHOA are two prevalent shoulder pathologies, there are limited studies evaluating the relationship of GHOA to outcomes after rotator cuff repair (RCR)[8-11]. Cases of severe GHOA accompanied by rotator cuff pathology are most appropriately managed with either reverse total shoulder arthroplasty (RTSA) or total SA (TSA) with RCR. However, a recent study by Jeong *et al*[8] suggests that patients with mild GHOA and repair of large rotator cuff tears fare similarly to their counterparts without GHOA in terms of clinical outcomes and progression to GHOA. In contrast, another study found that GHOA was associated with lower outcome scores after RCR at 1-year follow-up[10].

Studies have shown that patients with concomitant GHOA and rotator cuff tears can range from 13%-27% of patients treated for rotator cuff tears; to our knowledge, the outcomes of these patients after RCR are lacking within literature[12,13]. This study evaluated the effect of the presence or absence of GHOA on short and mid-term clinical outcomes after arthroscopic repair of small to large rotator cuff tears, comparing the rates of conversion to shoulder arthroplasty (TSA or RTSA) as well as PROM's at follow-up > 2 years from their RCR surgery. We hypothesized there would be no significant differences in clinical outcomes or rates of subsequent conversion to shoulder arthroplasty in patients with small to large rotator cuff tears undergoing arthroscopic repair with or without concurrent GHOA.

MATERIALS AND METHODS

Following International Review Board approval, patients who underwent arthroscopic RCR of small (< 1 cm), medium (1-3 cm), or large (3-5 cm) rotator cuff tears with GHOA were identified at a large single-center academic orthopedic group. All patients treated between January 2010 and June 2017 were identified using Current Procedural Terminology code 29827 for “arthroscopy, shoulder, surgical, with rotator cuff repair.” Patients with GHOA were initially identified and paired with patients without GHOA. The three criteria for matching the patients involved: Age \pm 3 years, clinical follow-up \pm 1 year, and same sex (Figure 1A).

Inclusion criteria consisted of patients who: (1) Were 18 years old at the time of index surgery; (2) Had a rotator cuff tear measuring 0-5 cm; (3) Had a preoperative plain radiograph; (4) Had a preoperative magnetic resonance imaging (MRI); and (5) Had a minimum of 2 year follow-up after their index RCR procedure. Patients were excluded if they had any of the following: (1) Open physes; (2) Post-traumatic osteoarthritis; (3) Post-dislocation glenohumeral arthropathy; (4) Avascular necrosis; (5) Prior surgical intervention on the ipsilateral shoulder; and/or (6) Autoimmune conditions such as rheumatoid arthritis. The data was collected and stored using REDCap electronic data capture tools hosted at OrthoCarolina Research Institute[4].

The primary outcome variable was the rate of conversion to TSA or RTSA within 2 years from the index surgery. Secondary outcomes were clinical patient-reported outcome measures (PROs) including American Shoulder and Elbow Surgeons (ASES) score, Single Assessment Numeric Evaluation (SANE), VAS for pain, and Veterans RAND 12-Item Health Survey (VR-12).

Demographical information such as age, sex, body mass index (BMI), smoking history, diabetes, and injury mechanism (ultra-low *vs* low *vs* high energy) where applicable was obtained. Using preoperative plain radiographs and MRI, the Samilson-Prieto Classification (Figure 2), Goutallier classification, and Warner atrophy grade were obtained to assess GHOA severity, fatty degeneration of rotator cuff muscles, and muscle atrophy, respectively. Each patient was classified based on the presence of GHOA in the setting of a small, medium, or large rotator cuff tear (Figure 3). The different rotator cuff tear sizes, largely based on level of retraction, were determined by two independent fellowship trained sports medicine and shoulder orthopedic surgeons using MRI imaging. Coronal oblique images were obtained and used to identify the tears, and were classified as either small (< 1 cm) medium (1-3 cm) and massive (\leq 5 cm).

The procedural variables captured using operative notes included: surgical technique, fixation technique, and concomitant procedures (*e.g.*, distal clavicle excision, subacromial decompression, capsular release, debridement, chondroplasty, biceps tenotomy, and/or biceps tenodesis). Postoperative variables were measured: complications, re-operation (s) and the type of secondary procedure. PROs following surgery were collected during routine clinical follow-up at 2 or more years. Patients without the standard of care 2-year follow-up were contacted *via* phone or email to answer questions regarding PROs, subsequent rotator cuff re-tear, or re-operation outside of our institution.

Statistical analysis

All data underwent descriptive statistical analysis using SAS version 9.4 (SAS Institute, Cary, NC; <http://www.sas.com/software/sas9>). Two groups were defined based on presence or absence of primary GHOA and stratified based on rotator cuff tear size. For normally distributed continuous data, mean and standard deviation, were reported. For non-parametric continuous data, median and interquartile range were reported. Frequencies and proportions were reported for categorical variables. A Wilcoxon rank sum test was used for non-parametric continuous variables and a two-sample t test was used for normally distributed data. For categorical variables, a chi-square test (or Fisher's exact test, where appropriate) was used for comparisons between groups. Significance was determined by an alpha level of 0.05.

RESULTS

Between January 2010 and June 2017, 71 patients were identified that underwent arthroscopic RCR of small to large tears with the presence of GHOA. These patients were subsequently matched with 71 patients without GHOA that underwent the same procedure.

The demographics of the comparison study groups can be found in Table 1. The median age at time of rotator cuff repair was 64 years (IQR 60, 70) for patients in both groups. They had an exact match by sex and 57.7% (41/71) of repairs were performed in males in each respective group. Median BMI at the time of repair was 29.8 (IQR 26.7, 33.2) and 28.5 (IQR 25.5, 31) respectively. In patients with GHOA, 57.7% (41/71) reported having never smoked tobacco products, 40.8% (29/71) have smoked previously and 1.4% (1/71) were actively smoking. In patients without GHOA, 60.6% (43/71) reported having never smoked tobacco products, 33.8% (24/71) have smoked previously and 5.6% (4/71) were actively smoking.

Table 1 Demographic information

	With GHOA					Without GHOA				
	Tear size group					Tear size group				
	Overall (<i>n</i> = 142)	Case overall (<i>n</i> = 71)	Small (0-1 cm) (<i>n</i> = 21)	Medium (1-3 cm) (<i>n</i> = 28)	Large (3-5 cm) (<i>n</i> = 22)	Control overall (<i>n</i> = 71)	Small (0-1 cm) (<i>n</i> = 28)	Medium (1-3 cm) (<i>n</i> = 30)	Large (3-5 cm) (<i>n</i> = 13)	
Age (in yr) at surgery, median (IQR)	64 (60, 70)	64 (60, 70)	63 (62, 67)	63 (58, 67.5)	66 (62, 71)	64 (60, 70)	63 (59.5, 68.5)	65 (61, 70)	63 (61, 69)	
BMI, median (IQR)	29.2 (25.8, 32.9)	29.8 (26.7, 33.2)	32.9 (29.4, 35.9)	28.1 (24.5, 30.8)	29 (27.3, 33.2)	28.5 (25.5, 31)	29.9 (27, 31)	27.2 (24.5, 30.4)	27.5 (24.7, 32.1)	
Time (in yr) since DOS, median (IQR)	8.1 (6.9, 9.3)	8.2 (6.9, 9.3)	8 (7.1, 9.4)	8 (6.4, 9.3)	8.3 (7.1, 8.9)	8.1 (6.8, 9.3)	8.3 (6.8, 9.6)	8 (7.5, 8.8)	7.8 (6.9, 9.3)	
Tear size, median (IQR)	2 (1, 3)	2 (1, 3.5)	1 (1, 1)	2 (1.7, 2.6)	4 (3.5, 4)	1.5 (1, 2.5)	.5 (.5, 1)	2 (1.5, 2.5)	4 (3.7, 4.3)	
Male	82 (57.7)	41 (57.7)	10 (47.6)	13 (46.4)	18 (81.8)	41 (57.7)	13 (46.4)	19 (63.3)	9 (69.2)	
Sex, <i>n</i> (%)										
Female	60 (42.3)	30 (42.3)	11 (52.4)	15 (53.6)	4 (18.2)	30 (42.3)	15 (53.6)	11 (36.7)	4 (30.8)	
Smoking, <i>n</i> (%)										
Never	84 (59.2)	41 (57.7)	16 (76.2)	14 (50.0)	11 (50.0)	43 (60.6)	19 (67.9)	19 (63.3)	5 (38.5)	
Previous	53 (37.3)	29 (40.8)	5 (23.8)	13 (46.4)	11 (50.0)	24 (33.8)	7 (25.0)	10 (33.3)	7 (53.8)	
Current	5 (3.5)	1 (1.4)	0 (0)	1 (3.6)	0 (0)	4 (5.6)	2 (7.1)	1 (3.3)	1 (7.7)	
Diabetes, <i>n</i> (%)										
No	115 (81.0)	57 (80.3)	18 (85.7)	24 (85.7)	15 (68.2)	58 (81.7)	22 (78.6)	27 (90.0)	9 (69.2)	
Yes	27 (19.0)	14 (19.7)	3 (14.3)	4 (14.3)	7 (31.8)	13 (18.3)	6 (21.4)	3 (10.0)	4 (30.8)	
Preoperative samilson-prieto score, <i>n</i> (%)										
None	71 (50.0)	1 (1.4)	0 (0)	1 (3.6)	0 (0)	70 (98.6)	28 (100.0)	29 (96.7)	13 (100.0)	
Mild (< 3 mm)	62 (43.7)	61 (85.9)	18 (85.7)	27 (96.4)	16 (72.7)	1 (1.4)	0 (0)	1 (3.3)	0 (0)	
Moderate (3 mm-7 mm)	9 (6.3)	9 (12.7)	3 (14.3)	0 (0)	6 (27.3)	0 (0)	0 (0)	0 (0)	0 (0)	
Goutallier classification, <i>n</i> (%)										
Grade 0 (normal muscle)	95 (66.9)	47 (66.2)	18 (85.7)	19 (67.9)	10 (45.5)	48 (67.6)	23 (82.1)	20 (66.7)	5 (38.5)	
Grade 1 (some fatty-streaks)	36 (25.4)	18 (25.4)	2 (9.5)	7 (25.0)	9 (40.9)	18 (25.4)	5 (17.9)	8 (26.7)	5 (38.5)	
Grade 2 (< 50% fatty-muscle atrophy)	11 (7.7)	6 (8.5)	1 (4.8)	2 (7.1)	3 (13.6)	5 (7.0)	0 (0)	2 (6.7)	3 (23.1)	
Muscle atrophy (warner grading system), <i>n</i> (%)										0 (0)
None	107 (75.4)	50 (70.4)	18 (85.7)	21 (75.0)	11 (50.0)	57 (80.3)	24 (85.7)	24 (80.0)	9 (69.2)	
Mild	29 (20.4)	17 (23.9)	2 (9.5)	5 (17.9)	10 (45.5)	12 (16.9)	4 (14.3)	5 (16.7)	3 (23.1)	
Moderate	6 (4.2)	4 (5.6)	1 (4.8)	2 (7.1)	1 (4.5)	2 (2.8)	0 (0)	1 (3.3)	1 (7.7)	
Primary GHOA, <i>n</i> (%)										
No	71 (50.0)	0 (0)	0 (0)	0 (0)	0 (0)	71 (100.0)	28 (100.0)	30 (100.0)	13 (100.0)	
Yes	71 (50.0)	71 (100.0)	21 (100.0)	28 (100.0)	22 (100.0)	0 (0)	0 (0)	0 (0)	0 (0)	

GHOA: Glenohumeral osteoarthritis; BMI: Body mass index; DOS: Date of surgery.

Using the Samilson-Prieto classification to grade GHOA severity, 85.9% (61/71) had a grade of 1 (mild or < 3 mm), and 12.7% (9/71) had a grade of 2 (moderate or 3 mm - 7 mm). Goutallier classification of the rotator cuff revealed that patients with GHOA: 66.2% (47/71) had a grade of 0 (normal muscle), 25.4% (18/71) had a grade of 1 (some fatty streaks), and 8.5% (6/71) had a grade of 2 (less than

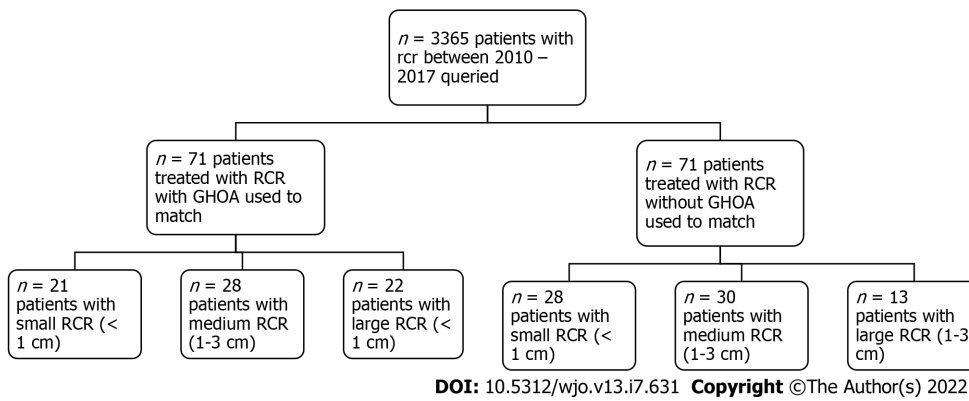


Figure 1 CONSORT flow diagram of patients included in study. RCR: Rotator cuff repair; GHOA: Glenohumeral osteoarthritis.

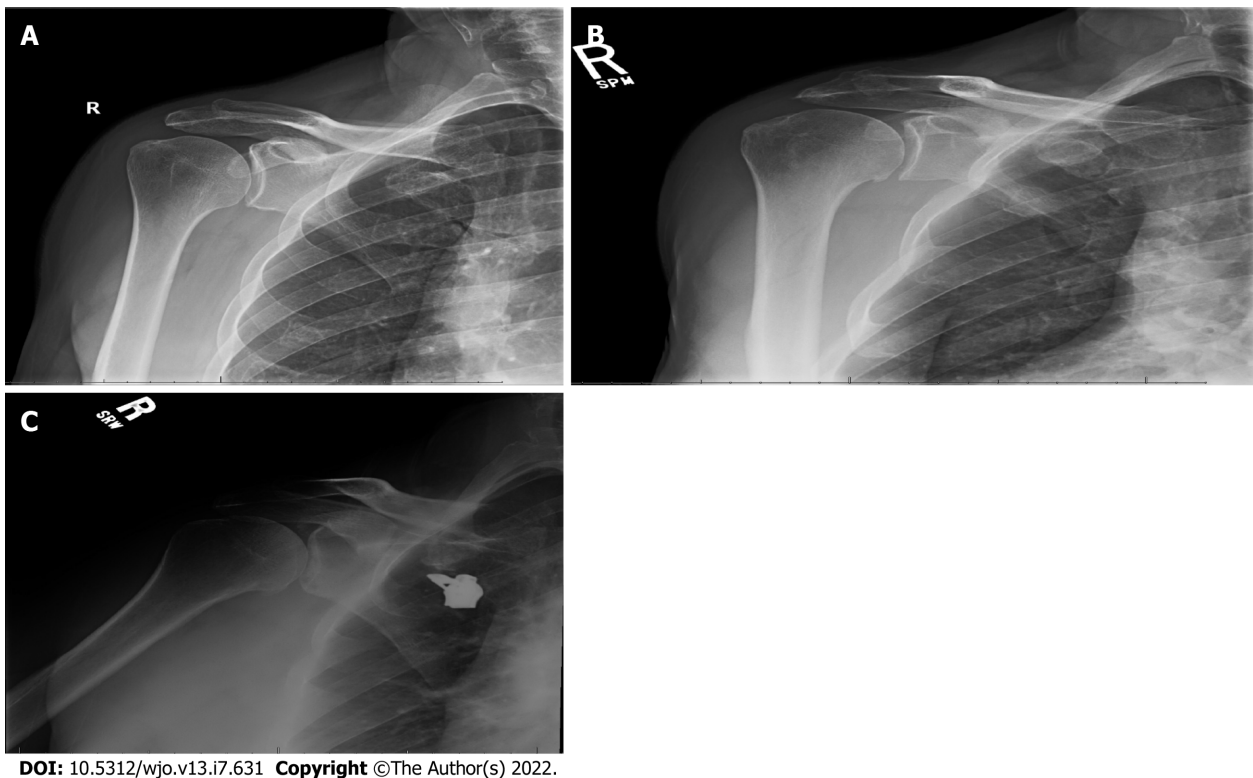


Figure 2 Anteroposterior radiograph. A: Anteroposterior radiograph of right shoulder demonstrating Samilson-Prieto grade 0 (normal); B: Anteroposterior radiograph of right shoulder demonstrating Samilson-Prieto grade 1 (mild); C: Anteroposterior radiograph of right shoulder demonstrating Samilson-Prieto grade 2 (moderate).

50% fatty muscle atrophy). In comparison, the Goutallier classification of the rotator cuff for patients without GHOA revealed: 67.6% (48/71) with grade of 0, 25.4% (18/71) with a grade of 1, and 7.0% (5/71) with a grade of 2. Finally, in patients with GHOA the Warner grading system for muscle atrophy revealed: 70.4% (50/71) with no atrophy, 23.9% (17/71) with mild atrophy, and 5.6% (4/71) with moderate atrophy. For patients without GHOA, the Warner grading system for muscle atrophy revealed: 80.3% (57/71) with no atrophy, 16.9% (12/71) with mild atrophy, and 2.8% (2/71) with moderate atrophy.

Detailed data regarding RCR surgical technique, type of anchors used, fixation method and concurrent procedures for patients with or without GHOA stratified by rotator cuff tear size can be found in [Table 2](#).

The re-operation rate was 15.5% (11/71) and 8.5% (6/71) in patients with GHOA and without GHOA respectively. The mean follow-up period for both groups was 12.45 mo, with a range from 0-104 mo for the GHOA group, and 0-94 mo for the patients without GHOA. Within two years after rotator cuff repair, 2.8% (2/71) patients with GHOA underwent TSA or RTSA in the ipsilateral shoulder compared to 1.4% (1/71) patients without GHOA. Both patients developed rotator cuff arthropathy and pain with range of motion, and eventually underwent RTSA. The non GHOA patient eventually underwent an

Table 2 Operative data and type of operation

	With GHOA					Without GHOA			
	Tear size group					Tear size group			
	Overall (<i>n</i> = 142)	Overall Case (<i>n</i> = 71)	Small (0-1 cm) (<i>n</i> = 21)	Medium (1-3 cm) (<i>n</i> = 28)	Large (3-5 cm) (<i>n</i> = 22)	Overall Control (<i>n</i> = 71)	Small (0-1 cm) (<i>n</i> = 28)	Medium (1-3 cm) (<i>n</i> = 30)	Large (3-5 cm) (<i>n</i> = 13)
Single row, <i>n</i> (%)									
No	124 (87.3)	60 (84.5)	16 (76.2)	24 (85.7)	20 (90.9)	64 (90.1)	26 (92.9)	26 (86.7)	12 (92.3)
Yes	18 (12.7)	11 (15.5)	5 (23.8)	4 (14.3)	2 (9.1)	7 (9.9)	2 (7.1)	4 (13.3)	1 (7.7)
Double row, <i>n</i> (%)									
Yes	122 (85.9)	60 (84.5)	17 (81.0)	23 (82.1)	20 (90.9)	62 (87.3)	24 (85.7)	26 (86.7)	12 (92.3)
No	20 (14.1)	11 (15.5)	4 (19.0)	5 (17.9)	2 (9.1)	9 (12.7)	4 (14.3)	4 (13.3)	1 (7.7)
Medial row, <i>n</i> (%)									
Yes	138 (97.2)	69 (97.2)	19 (90.5)	28 (100.0)	22 (100.0)	69 (97.2)	28 (100.0)	28 (93.3)	13 (100.0)
No	4 (2.8)	2 (2.8)	2 (9.5)	0 (0)	0 (0)	2 (2.8)	0 (0)	2 (6.7)	0 (0)
Lateral row, <i>n</i> (%)									
Yes	120 (84.5)	61 (85.9)	18 (85.7)	23 (82.1)	20 (90.9)	59 (83.1)	24 (85.7)	24 (80.0)	11 (84.6)
No	22 (15.5)	10 (14.1)	3 (14.3)	5 (17.9)	2 (9.1)	12 (16.9)	4 (14.3)	6 (20.0)	2 (15.4)
Arthrotunnel, <i>n</i> (%)									
No	139 (97.9)	71 (100.0)	21 (100.0)	28 (100.0)	22 (100.0)	71 (100.0)	28 (100.0)	28 (93.3)	12 (92.3)
Yes	3 (2.1)		0 (0)	0 (0)	0 (0)		0 (0)	2 (6.7)	1 (7.7)
Medial row fixation type, <i>n</i> (%)									
Missing for 6 patients									
Suture tied	135 (95.1)	67 (94.4)	19 (90.5)	26 (92.9)	22 (100.0)	68 (95.8)	28 (100.0)	28 (93.3)	12 (92.3)
Knotless	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
Medial row anchor type, <i>n</i> (%)									
Missing for 11 patients									
PEEK	86 (60.6)	53 (74.6)	16 (76.2)	21 (75.0)	16 (72.7)	33 (46.5)	16 (57.1)	12 (40.0)	5 (38.5)
Knotted	35 (24.6)	10 (14.1)	2 (9.5)	5 (17.9)	3 (13.6)	25 (35.2)	10 (35.7)	11 (36.7)	4 (30.8)
Knotless	7 (4.9)	0 (0)	0 (0)	0 (0)	0 (0)	7 (9.9)	1 (3.6)	5 (16.7)	1 (7.7)
Plastic	3 (2.1)	3 (4.2)	1 (4.8)	0 (0)	2 (9.1)	0 (0)	0 (0)	0 (0)	0 (0)
Lateral row fixation type, <i>n</i> (%)									
Missing for 23 patients									
Knotless	90 (63.4)	46 (64.8)	13 (61.9)	16 (57.1)	17 (77.3)	44 (62.0)	20 (71.4)	18 (60.0)	6 (46.2)
Suture tied	29 (20.4)	15 (21.1)	5 (23.8)	7 (25.0)	3 (13.6)	14 (19.7)	4 (14.3)	6 (20.0)	4 (30.8)
Lateral row anchor type, <i>n</i> (%)									
Missing for 29 patients									
PEEK	70 (49.3)	28 (39.4)	12 (57.1)	8 (28.6)	8 (36.4)	42 (59.2)	21 (75.0)	15 (50.0)	6 (46.2)
Plastic	20 (14.1)	20 (28.2)	3 (14.3)	8 (28.6)	9 (40.9)	0 (0)	0 (0)	0 (0)	0 (0)
Knotted	17 (12.0)	6 (8.5)	1 (4.8)	4 (14.3)	1 (4.5)	11 (15.5)	3 (10.7)	4 (13.3)	4 (30.8)

Knotless	6 (4.2)	3 (4.2)	1 (4.8)	1 (3.6)	1 (4.5)	3 (4.2)	0 (0)	3 (10.0)	0 (0)
Concurrent procedures									
Distal clavicle excision, <i>n</i> (%)									
Yes	79 (55.6)	41 (57.7)	15 (71.4)	16 (57.1)	10 (45.5)	38 (53.5)	16 (57.1)	17 (56.7)	5 (38.5)
No	63 (44.4)	30 (42.3)	6 (28.6)	12 (42.9)	12 (54.5)	33 (46.5)	12 (42.9)	13 (43.3)	8 (61.5)
Subacromial decompression, <i>n</i> (%)									
Yes	142 (100.0)	71 (100.0)	21 (100.0)	28 (100.0)	22 (100.0)	71 (100.0)	28 (100.0)	30 (100.0)	13 (100.0)
Capsular release, <i>n</i> (%)									
No	133 (93.7)	66 (93.0)	20 (95.2)	25 (89.3)	21 (95.5)	67 (94.4)	26 (92.9)	30 (100.0)	11 (84.6)
Yes	9 (6.3)	5 (7.0)	1 (4.8)	3 (10.7)	1 (4.5)	4 (5.6)	2 (7.1)	0 (0)	2 (15.4)
Labral debridement, <i>n</i> (%)									
No	125 (88.0)	63 (88.7)	20 (95.2)	24 (85.7)	19 (86.4)	62 (87.3)	24 (85.7)	26 (86.7)	12 (92.3)
Yes	17 (12.0)	8 (11.3)	1 (4.8)	4 (14.3)	3 (13.6)	9 (12.7)	4 (14.3)	4 (13.3)	1 (7.7)
Chondroplasty, <i>n</i> (%)									
No	120 (84.5)	54 (76.1)	14 (66.7)	20 (71.4)	20 (90.9)	66 (93.0)	25 (89.3)	28 (93.3)	13 (100.0)
Yes	22 (15.5)	17 (23.9)	7 (33.3)	8 (28.6)	2 (9.1)	5 (7.0)	3 (10.7)	2 (6.7)	0 (0)
Biceps tenotomy, <i>n</i> (%)									
No	92 (64.8)	44 (62.0)	11 (52.4)	20 (71.4)	13 (59.1)	48 (67.6)	18 (64.3)	23 (76.7)	7 (53.8)
Yes	50 (35.2)	27 (38.0)	10 (47.6)	8 (28.6)	9 (40.9)	23 (32.4)	10 (35.7)	7 (23.3)	6 (46.2)
Biceps tenodesis, <i>n</i> (%)									
No	99 (69.7)	54 (76.1)	20 (95.2)	19 (67.9)	15 (68.2)	45 (63.4)	18 (64.3)	17 (56.7)	10 (76.9)
Yes	43 (30.3)	17 (23.9)	1 (4.8)	9 (32.1)	7 (31.8)	26 (36.6)	10 (35.7)	13 (43.3)	3 (23.1)
If biceps tenodesis, <i>n</i> (%)									
Suprapectoral	37 (26.1)	11 (15.5)	0 (0)	5 (17.9)	6 (27.3)	26 (36.6)	10 (35.7)	13 (43.3)	3 (23.1)
Subpectoral	6 (4.2)	6 (8.5)	1 (4.8)	4 (14.3)	1 (4.5)	0 (0)	0 (0)	0 (0)	0 (0)

GHOA: Glenohumeral osteoarthritis; PEEK: Polyether ether ketone.

RTSA for rotator cuff arthropathy. Beyond the two year follow-up 4 patients with GHOA and 2 patients without GHOA underwent the conversion to TSA or RTSA. Complication rates after initial rotator cuff repair was 23.9% (17/71) and 18.3% (13/71) for patients with GHOA and without GHOA respectively and 12.7% (9/71) of patients with GHOA experienced rotator cuff re-tear after RCR compared to 11.3% (8/71) of patients without GHOA as determined by post op MRI or intra-operative findings (Table 3).

The Median VR-12 mental health component summary scores were 58.3 (IQR 44.8, 61.3) and 56.5 (IQR 47.5, 61.7) and the median VR-12 physical health component summary scores were 49.6 (IQR 40.2, 52.4) and 47.6 (IQR 36.6, 53.7) in patients with and without GHOA respectively. The overall median ASES score for the right shoulder was 98.3 (IQR 93.3, 100) in patients with or without GHOA; overall median ASES score for the left shoulders were 100 (IQR 91.7, 100) and 96.7 (86.7, 100) respectively. Finally, the overall median SANE score was 95 (IQR 90, 100) and 95 (IQR 85, 100) in patients with or without GHOA respectively. PROs did not show any significant difference according to rotator cuff tear size when patients with GHOA were compared with patients without GHOA (Table 4).

Table 3 Postoperative complications

	With GHOA					Without GHOA			
	Tear size group					Tear size group			
	Overall (<i>n</i> = 142)	Case Overall (<i>n</i> = 71)	Small (0-1cm) (<i>n</i> = 21)	Medium (1-3cm) (<i>n</i> = 28)	Large (3-5cm) (<i>n</i> = 22)	Control Overall (<i>n</i> = 71)	Small (0-1cm) (<i>n</i> = 28)	Medium (1-3cm) (<i>n</i> = 30)	Large (3-5cm) (<i>n</i> = 13)
Reoperation post RCR, <i>n</i> (%)									
No	125 (88.0)	60 (84.5)	19 (90.5)	23 (82.1)	18 (81.8)	65 (91.5)	26 (92.9)	28 (93.3)	11 (84.6)
Yes	17 (12.0)	11 (15.5)	2 (9.5)	5 (17.9)	4 (18.2)	6 (8.5)	2 (7.1)	2 (6.7)	2 (15.4)
Complications, <i>n</i> (%)									
Missing for 1 patient									
No	111 (78.2)	53 (74.6)	16 (76.2)	22 (78.6)	15 (68.2)	58 (81.7)	22 (78.6)	24 (80.0)	12 (92.3)
Yes	30 (21.1)	17 (23.9)	4 (19.0)	6 (21.4)	7 (31.8)	13 (18.3)	6 (21.4)	6 (20.0)	1 (7.7)
Wound issues, <i>n</i> (%)									
Missing for 131 patients									
No	11 (7.7)	9 (12.7)	2 (9.5)	3 (10.7)	4 (18.2)	2 (2.8)	0 (0)	2 (6.7)	0 (0)
Infection, <i>n</i> (%)									
Missing for 131 patients									
No	11 (7.7)	9 (12.7)	2 (9.5)	3 (10.7)	4 (18.2)	2 (2.8)	0 (0)	2 (6.7)	0 (0)
Stiffness, <i>n</i> (%)									
Missing for 126 patients									
Yes	8 (5.6)	5 (7.0)	3 (14.3)	1 (3.6)	1 (4.5)	3 (4.2)	1 (3.6)	2 (6.7)	0 (0)
No	8 (5.6)	7 (9.9)	0 (0)	3 (10.7)	4 (18.2)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Rotator cuff retear, <i>n</i> (%)									
Missing for 122 patients									
Yes	17 (12.0)	9 (12.7)	0 (0)	4 (14.3)	5 (22.7)	8 (11.3)	3 (10.7)	4 (13.3)	1 (7.7)
No	3 (2.1)	2 (2.8)	2 (9.5)	0 (0)	0 (0)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Other complication, <i>n</i> (%)									
Missing for 128 patients									
No	8 (5.6)	4 (5.6)	1 (4.8)	2 (7.1)	1 (4.5)	4 (5.6)	1 (3.6)	2 (6.7)	1 (7.7)
Yes	6 (4.2)	3 (4.2)	1 (4.8)	1 (3.6)	1 (4.5)	3 (4.2)	2 (7.1)	1 (3.3)	0 (0)
Other complication description, <i>n</i> (%)									
Pain	1 (0.7)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Block related neuropraxia	1 (0.7)	1 (1.4)	0 (0)	1 (3.6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Weakness	1 (0.7)	1 (1.4)	0 (0)	0 (0)	1 (4.5)	0 (0)	0 (0)	0 (0)	0 (0)
Median nerve neuropathy	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	1 (3.6)	0 (0)	0 (0)
Greater tuberosity fx	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	1 (3.6)	0 (0)	0 (0)
Heterotopic ossification	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
1 st reoperation diagnosis, <i>n</i> (%)									
Other	13 (9.2)	9 (12.7)	2 (9.5)	4 (14.3)	3 (13.6)	4 (5.6)	1 (3.6)	1 (3.3)	2 (15.4)
Stiffness	3 (2.1)	2 (2.8)	0 (0)	1 (3.6)	1 (4.5)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Hardware pain	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	1 (3.6)	0 (0)	0 (0)
1 st reoperation other diagnosis, <i>n</i>									

(%)									
Rotator cuff arthropathy	4 (2.8)	3 (4.2)	0 (0)	2 (7.1)	1 (4.5)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
Rotator cuff retear	4 (2.8)	3 (4.2)	0 (0)	2 (7.1)	1 (4.5)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Inflammatory arthritis	1 (0.7)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Glenohumeral arthritis	1 (0.7)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Retear RTC, rotator cuffarthropathy	1 (0.7)	1 (1.4)	0 (0)	0 (0)	1 (4.5)	0 (0)	0 (0)	0 (0)	0 (0)
Greater tuberosity fracture	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	1 (3.6)	0 (0)	0 (0)
Rotator cuff arthropathy	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
1 st reoperation procedure, <i>n</i> (%)									
Conversion to RTSA	8 (5.6)	5 (7.0)	1 (4.8)	2 (7.1)	2 (9.1)	3 (4.2)	1 (3.6)	0 (0)	2 (15.4)
Other	6 (4.2)	3 (4.2)	0 (0)	2 (7.1)	1 (4.5)	3 (4.2)	1 (3.6)	2 (6.7)	0 (0)
Lysis of adhesions	2 (1.4)	2 (2.8)	0 (0)	1 (3.6)	1 (4.5)	0 (0)	0 (0)	0 (0)	0 (0)
Conversion to TSA	1 (0.7)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
1 st reoperation other procedure, <i>n</i> (%)									
Revision rotator cuff repair	4 (2.8)	3 (4.2)	0 (0)	2 (7.1)	1 (4.5)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Removal of heterotopicossification	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	0 (0)	1 (3.3)	0 (0)
Removal of hardware, RTC debridement	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	1 (3.6)	0 (0)	0 (0)
2 nd reoperation post RCR, <i>n</i> (%)									
Missing for 1 patient									
No	14 (9.9)	10 (14.1)	1 (4.8)	5 (17.9)	4 (18.2)	4 (5.6)	1 (3.6)	2 (6.7)	1 (7.7)
Yes	2 (1.4)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
2 nd reoperation diagnosis, <i>n</i> (%)									
Other	2 (1.4)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
2 nd reoperation other diagnosis, <i>n</i> (%)									
Insufficiency due to subscapularis failure	1 (0.7)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Instability	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
2 nd reoperation procedure, <i>n</i> (%)									
Other	2 (1.4)	1 (1.4)	1 (4.8)	0 (0)	0 (0)	1 (1.4)	0 (0)	0 (0)	1 (7.7)
Conversion to TSA/RTSA within 2 yr post index DOS, <i>n</i> (%)									
No	139 (97.9)	69 (97.2)	20 (95.2)	28 (100.0)	21 (95.5)	70 (98.6)	28 (100.0)	30 (100.0)	12 (92.3)
Yes	3 (2.1)	2 (2.8)	1 (4.8)	0 (0)	1 (4.5)	1 (1.4)	0 (0)	0 (0)	1 (7.7)

GHOA: Glenohumeral osteoarthritis; RCR: Rotator cuff repair; RTSA: Reverse tota shoulder arthroplasty; TSA: Total shoulder arthroplasty.

DISCUSSION

The results demonstrate the conversion to shoulder arthroplasty, patient-reported clinical outcome scores, and rates of re-operation were no different when comparing RCR done in the setting of GHOA *vs* without GHOA in short-term follow-up. Our results indicate that the presence of GHOA at the time of RCR did not seem to influence the progression of GHOA. There is general agreement within literature that severe primary GHOA is an appropriate indication for TSA or RTSA[14,15]. Additionally, rotator cuff tear arthropathy, rotator cuff insufficiency, and superior migration of humeral head - is considered another indication for RTSA[14-16]. While GHOA and rotator cuff tears both contribute to morbidity due to decreased shoulder function, there are limited studies evaluating the outcomes of

Table 4 Patient-reported outcomes

	Overall (n = 142)	With GHOA, Small tear (0-1 cm) (n = 21)	Without GHOA, Small tear (0-1 cm) (n = 28)	P value	With GHOA, Medium tear (1-3 cm) (n = 28)	Without GHOA, Medium tear (1-3 cm) (n = 30)	P value	With GHOA, Large tear (3-5 cm) (n = 22)	Without GHOA, Large tear (3-5 cm) (n = 13)	P value
MCS, median (IQR)	57.1 (46.5, 61.6)	60.9 (37.6, 64.1)	56.3 (44.4, 61.5)	> 0.99	59.3 (44.6, 61.3)	58.3 (50, 62.8)	> 0.99	54.4 (48, 57.9)	51 (47.3, 60.2)	> 0.99
PCS, median (IQR)	49.1 (40, 52.6)	40.2 (29.6, 49.1)	51.4 (42.4, 55)	0.148	50 (44.9, 51.8)	46.4 (35.1, 50.8)	> 0.99	52.7 (49.7, 55.4)	41.8 (34.4, 53.3)	> 0.99
VAS pain, median (IQR)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	> 0.99	0.0 (0.0, 1.0)	0.0 (0.0, 1.0)	> 0.99	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	> 0.99
VAS instability, median (IQR)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	> 0.99	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	-	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	-
ASES shoulder right, median (IQR)	98.3 (93.3, 100)	100 (95, 100)	99.2 (95, 100)	> 0.99	98.3 (91.7, 100)	95 (91.7, 100)	> 0.99	98.3 (93.3, 98.3)	100 (95, 100)	> 0.99
ASES shoulder left, median (IQR)	98.3 (90, 100)	100 (85, 100)	98.3 (91.7, 100)	> 0.99	100 (93.3, 100)	95.8 (87.5, 100)	> 0.99	100 (91.7, 100)	90 (66.7, 100)	> 0.99
SANE, median (IQR)	95 (85, 100)	96.5 (90, 100)	100 (92.5, 100)	> 0.99	100 (95, 100)	95 (80, 100)	> 0.99	90 (85, 95)	85 (50, 100)	> 0.99

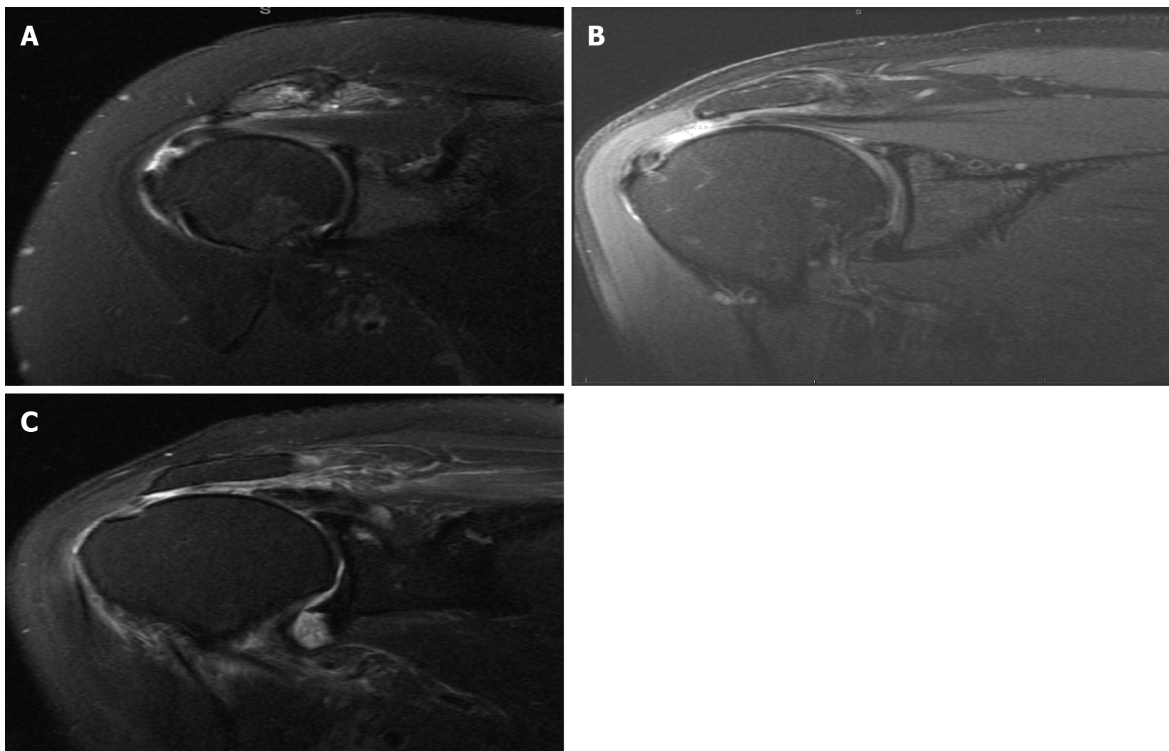
MCS: Veterans RAND 12-Item Health Survey mental health component summary scores; PCS: Veterans RAND 12-Item Health Survey physical health component summary score; VAS: Visual analogue scale; ASES: American shoulder and elbow surgeons score; SANE: Single assessment numeric evaluation.

joint-preserving treatment *via* RCR in the setting of GHOA.

A recent study by Jeong *et al*[8] retrospectively evaluated the clinical outcomes of large to massive RCR in patients with and without mild GHOA. The authors found that preoperative and postoperative variables (VAS scores, ROM, muscle strength, University of California, Los Angeles (UCLA) scores, and Constant scores) at final follow-up (2 years) showed no significant differences between the two groups. Our study also included VAS and similarly did not show any significant difference between groups at final follow up period of 2 years. Jeong *et al*[8] reported mean VAS scores in patients with large to massive tears with mild GHOA and without mild GHOA to be 0.3 ± 0.7 and 0.3 ± 0.8 , respectively which are similar to our overall median VAS score of 0.0 (IQR 0.0, 0.0). These combined results indicate that patients with small to large rotator cuff repairs in the setting of mild to moderate GHOA can expect to have a pain score close to 0 after a minimum of 2 years after RCR.

A study by Kukkonen *et al*[10] evaluated outcomes using Constant scores in patients with or without GHOA after undergoing supraspinatus tendon repair with tear sizes ranging from 0.5 cm to 2.5 cm. Both pre and post-operative Constant scores were significantly lower in patients with GHOA. These results differ from ours and Jeong *et al*'s which showed no difference in PROs in patients with or without GHOA[8]. Kukkonen *et al*'s study only included males, had final follow-up of 1 year, and used the Kellgren-Lawrence classification to determine GHOA severity and status[10]. In contrast, our study and the study by Jeong *et al*[8] included males and females with a follow-up of 2 years and used the Samilson-Prieto classification for GHOA grading. A study of radiographic classifications of GHOA found that the Kellgren-Lawrence provided inferior inter-observer agreement in diagnosis of GHOA compared to Samilson-Prieto due to the challenge of identifying minor joint space narrowing in the non-weight bearing shoulder joint[17]. The aforementioned finding may limit comparative value of studies using different radiographic classification methods.

Overall, the results of our PROs after a short to medium term follow-up period show favorable results in VR-12, VAS, ASES, and SANE regardless of tear size or presence of GHOA. In patients with mild to moderate GHOA, there were no significant differences in all categories of PROs when comparing to patients without GHOA stratified by small to large rotator cuff tears. The minimal clinical important difference (MCID) was established to define minimum difference in PROs that is required to provide a clinically relevant benefit for patients rather than relying on statistically significant differences. The MCID for VR-12 PCS, MCS, VAS pain, ASES, and SANE following RCR has been reported to be 4.94, 5.99, 1.4, 21.0, and 11.80 respectively[18,19]. VR-12 PCS was the only PROs that showed MCID when patients with small or large rotator cuff tears were compared by presence or absence of GHOA. Surprisingly, patients with mild to moderate GHOA and small RCR had worse VR-



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Figure 3 Magnetic resonance imaging. A: Magnetic resonance imaging demonstrating small (0-1 cm) tear of rotator cuff; B: Magnetic resonance imaging demonstrating medium (1-3 cm) tear of rotator cuff; C: Magnetic resonance imaging demonstrating large (3-5 cm) tear of rotator cuff.

12 PCS scores. A literature review of histopathology of rotator cuff tears showed that inflammatory cell infiltrate and number of blood vessels are inversely correlated with tear size[20]. Immunohistochemistry has also shown torn rotator cuff tendons with lower vascularity have fewer new nerve fibers and is linked to lower chronic pain[21].

The rate of conversion to TSA or RTSA within 2 years after RCR were low for patients with and without GHOA at 2.8% (2/71) and 1.4% (1/71), respectively. This is the first study to report conversion to TSA or RTSA as an outcome variable while comparing outcomes following RCR in patients with or without GHOA. Results of previous studies, which showed that the progression of GHOA did not negatively affect PROs at final follow-up in patients who underwent RCR or arthroscopic debridement of massive irreparable rotator cuff tears[8,22,23], led us to hypothesize patients with GHOA would have conversion rate to TSA or RTSA are comparable with patients without GHOA. The results of our study report good PROs and very low conversion rates to shoulder arthroplasty after RCR with concomitant GHOA.

Due to the retrospective design, there are aspects to patient selection and classification that may introduce confounding biases. The heterogeneous nature of the patients with regard to demographics, surgical technique, and being treated by multiple surgeons at a single academic institution may limit the ability to make accurate comparisons between groups. Furthermore, no preoperative PROs were obtained which may have served as a baseline measure to observe any improvements or exacerbations following RCR. Our follow-up period may be reflective of short-term outcomes with a lack of findings for longer-term outcomes (greater than 5 years or 10 years). However, a recent study by Manderle *et al* [24] showed that the vast majority of RCR patients achieve MCID, substantial clinical benefit and patient acceptable symptomatic state for various PROs within 1 year. Therefore, our minimum 2-year follow-up period may be sufficient to evaluate and make comparisons of the postoperative PROs following RCR in this patient population.

CONCLUSION

This study reveals comparable outcomes in patients following small, medium, and large RCR with or without GHOA. Within a clinical follow-up period of 2 years, there were low rates of conversion to TSA or RTSA and no significant statistical differences found in PROs between patients with and without GHOA. In patients with mild to moderate GHOA and small to large rotator cuff tears, RCR is an effective means of surgical intervention that allows for joint-preservation and satisfactory PROs at short and medium-term follow-up.

ARTICLE HIGHLIGHTS

Research background

This study showed that patient reported outcomes in patients that have undergone a rotator cuff repair procedure, in the setting of Glenohumeral Osteoarthritis (GHOA) are favorable at short term (IE less than 2 year) follow-up. The rate of conversion to arthroplasty for these patients was also very low, indicating satisfaction with their outcomes.

Research motivation

There is a paucity of literature surrounding this topic, rotator cuff repair (RCR) in the setting of GHOA, so we felt it necessary to add to the literature with our own set of data in hopes of providing clinicians with more data surrounding this topic.

Research objectives

To determine patient report outcomes and rate of conversion to arthroplasty for patients with GHOA after undergoing a rotator cuff repair procedure. With favorable outcomes, and low conversion rates to arthroplasty, these objectives were realized in our data set.

Research methods

This was a retrospective cohort study with patient follow-up *via* questionnaire by phone, email, or in person *via* clinic visits.

Research results

Our results showed a low rate of conversion to arthroplasty in both subgroups after undergoing RCR. Patient reported outcomes using standardized scales were also quite favorable in both subgroups.

Research conclusions

Our study showed favorable outcomes with regards to patient reported outcomes. A low conversion rate to arthroplasty was also noted in the short term follow-up.

Research perspectives

The future direction of our research will include longer term patient follow-up (IE greater than 5-10 years) to ascertain data on conversion to arthroplasty in the GHOA patient.

FOOTNOTES

Author contributions: Saltzman BM, Fleischli JE, Connor PM and Hamid N developed the idea for the project; Hong IS, Rao AJ, CarlLee TL, and Meade JD contributed to formulating, writing, and revising the documents; Hurwit DJ, Scarola G, Trofa DP, and Schiffern SC contributed to development of the data analysis, manuscript revisions and formulation of project; all authors have agreed to be responsible for the final version of the manuscript.

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STROBE statement: The authors have read the STROBE Statement—checklist of items, and the manuscript was prepared and revised according to the STROBE Statement—checklist of items.

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