Arthritis Severity and Medical Comorbidities Are Prognostic of Worse Outcomes Following Arthroscopic Rotator Cuff Repair in Patients With Concomitant Glenohumeral Osteoarthritis

Rajiv P. Reddy, B.S., Shaquille Charles, M.Sc., David A. Solomon, M.D., Soheil Sabzevari, M.D., Jonathan D. Hughes, M.D., Bryson P. Lesniak, M.D., and Albert Lin, M.D.

Purpose: To assess demographic factors, comorbidities, radiographic variables, and injury patterns as potential prognostic indicators of poor functional and patient-reported outcomes following arthroscopic rotator cuff repair in patients with concomitant glenohumeral osteoarthritis.

Methods: A retrospective review of consecutive patients with glenohumeral osteoarthritis who underwent arthroscopic supraspinatus repairs between 2013 and 2018 with a minimum of 1-year follow up was performed. Demographic variables included age, tobacco use, alcohol use, diabetes, sex, hypercholesterolemia, and body mass index while injury patterns included partial- versus full-thickness tear, bicep tendon involvement, and osteoarthritis severity. Multivariate linear regression was used to identify independent predictors of visual analog pain scale (VAS), subjective shoulder value (SSV), and American Shoulder and Elbow Surgeons (ASES) score as well as active range of motion (ROM) in forward flexion (FF) and external rotation (ER). Binary logistic regression was used to identify predictors of repair failure as well as postoperative strength in FF and ER.

Results: In total, 91 patients (mean age 61.48 ± 9.4 years) were identified with an average follow up of 26.3 ± 5.7 months. Repair failures occurred in 9.9% (9/91 patients) of the total cohort. Postoperative outcomes were significantly improved with regards to visual analog pain scale, subjective shoulder value, ASES score, ROM in FF, FF strength, and external rotation strength compared with preoperative baseline. Obesity (P = .023) and diabetes (P = .010) were significant independent predictors of greater pain scores postoperatively. Obesity (P = .029) and tobacco use (P = .007) were significant predictors of lower ASES scores postoperatively. Finally, moderate-to-severe osteoarthritis was a significant risk factor for poor ROM and strength in FF postoperatively compared to mild osteoarthritis (P = .029). No variables were predictive of repair failure.

Conclusions: Tobacco use, obesity, and diabetes are associated with worse pain and patient-reported outcomes following arthroscopic rotator cuff repair in the context of glenohumeral OA. In addition, moderate-to-severe OA is associated with worse strength and forward flexion compared to those with mild OA.

Level of Evidence: Level III, retrospective cohort study.

Glenohumeral osteoarthritis (OA) is a common degenerative pathology, affecting 16.1% to 20.1% of adults older than the age of 65 years. As such, it is often seen clinically as a comorbidity in patients who present with rotator cuff pathology. Studies have shown that anywhere between 23% and 76% of patients with rotator cuff tears also have glenohumeral OA.

Management of rotator cuff tears in patients with concomitant glenohumeral OA varies and is still debated. Treatment may be dependent on the degree of shoulder OA and the size of the rotator cuff tear. For
those with mild OA and partial rotator cuff tears, treatment often is initiated with conservative management, including physical therapy and steroid injections.12 For those with severe OA and larger rotator cuff tears, reverse or anatomic total shoulder arthroplasty has been shown to have favorable outcomes.12-14 However, recent studies have demonstrated good-to-excellent outcomes following arthroscopic rotator cuff repair in the setting of glenohumeral OA.12,15,16 Studies comparing rotator cuff repair (RCR) in patients with glenohumeral OA with those without have shown no difference in repair failure rates.17—19 In addition, one study found no differences in range of motion (ROM), strength, or patient-reported outcomes between the 2 groups.18 whereas others found slightly lower postoperative ROM among patients with glenohumeral OA.17,19 Few studies, however, have evaluated the subset of patients in this population who would benefit most from RCR. Risk factors for poor outcomes of RCR in patients presenting with concomitant glenohumeral OA have not been established. Identifying the risk factors for poor outcomes may promote optimal patient selection and would allow for more informative pre- and postoperative patient counseling.

The purpose of this study was to assess demographic factors, comorbidities, radiographic variables, and injury patterns as potential prognostic indicators of poor functional and patient-reported outcomes (PROs) following arthroscopic RCR in patients with concomitant glenohumeral OA. We hypothesized that tobacco use, obesity, diabetes, and increased severity of OA would be predictive of diminished patient-reported/functional outcomes and repair failure.

Methods

Study Design and Patient Collection

This was a retrospective cohort study that reviewed electronic medical records of patients with glenohumeral OA who underwent a primary RCR performed by 2 fellowship-trained orthopaedic sports medicine surgeons from 2013 to 2018. Institutional review board approval was obtained at the University of Pittsburgh for this retrospective chart review, STUDY20030061. A waiver of consent was granted by the institutional review board at the University of Pittsburgh. Inclusion criteria were patients older than 30 years of age with concomitant glenohumeral OA and supraspinatus tear (both partial- and full-thickness tears as well as with concomitant infraspinatus/subscapularis tears), who underwent primary arthroscopic surgical repair and had a minimum of 1-year postoperative follow-up data. Exclusion criteria included previous RCR, open RCR, previous infection of symptomatic shoulder, and insufficient follow-up data. The patient outcomes reported in this study are from the same cohort as one used in a previously published study by Reddy et al.19

Demographic Variables and Injury Patterns

Baseline demographic variables of age, body mass index (BMI), and sex were recorded, along with several comorbidities, including diabetes, hypercholesterolemia, alcohol use, and tobacco use. Age was analyzed as a continuous variable whereas obesity (BMI >30), sex, diabetes, alcohol/tobacco use, and hypercholesterolemia were analyzed as nominal bimodal variables.

Injury characteristics including partial- versus full-thickness tear, tear size, Goutallier classification, biceps tendon involvement, and severity of OA (mild vs moderate-to-severe) were also collected based on preoperative imaging and corroborated by intraoperative assessment. All high-grade partial-thickness tears (defined as >50% tearing of the footprint confirmed on intraoperative assessment) were completed to full tears and then repaired.

Severity of OA was classified by a musculoskeletal radiologist using radiographic parameters according to the Samilson-Prieto classification modified by Gerber,20,21 which classifies arthrosis into 4 grades (normal, mild, moderate, and severe) based on size of humeral/glenoid exostosis and joint narrowing. Moderate and severe OA were combined into one category because those with moderate-to-severe OA could potentially be candidates for shoulder arthroplasty whereas patients with mild OA would be more likely to be managed with more conservative or joint-preserving options. Arthroscopic RCR was pursued in these patients because they were felt to have symptoms consistent with primary rotator cuff pathology but also had background OA noted on imaging, which was either asymptomatic or causing mild mechanical pain.

Outcomes

Primary outcomes included PROs of subjective shoulder value (SSV), visual analog pain scale (VAS), and American Shoulder and Elbow Surgeons (ASES) score; active (ROM) outcomes in forward flexion (FF) and external rotation (ER); as well as strength outcomes in FF and ER.

The secondary outcome was failure of repair, defined as a symptomatic retear confirmed on postoperative magnetic resonance imaging (MRI). Postoperative MRI, however, was not standard protocol for all patients in the study but rather for those with suspected symptomatic failure. These patients returned to clinic postoperatively complaining of recurring pain and were subsequently found to have imaging confirming retear.

All preoperative primary outcomes were determined at the last clinic visit before surgery and all postoperative primary outcomes were determined at the
12-month or final follow-up clinic visit postoperatively. Shoulder ROM and strength were assessed at 12 months postoperatively.

FF and ER ROM were measured in their respective planes and strength testing was conducted with manual muscle grading from 0 to 5 based on previously validated methodology, with a 5 representing maintained muscle activation against examiner’s full resistance, a 4 representing muscle activation against examiner’s partial resistance, and a 3 representing muscle activation only against gravity or with no examiner resistance.22 FF strength was tested with the patient in a standing position with the shoulder flexed to 90° in the scapular abduction plane. ER strength was tested with the elbow in 90° of flexion and the shoulder in a neutral position.

A follow-up period of 1 year was used because multiple studies have shown that most RCR outcomes achieve the minimal clinically important difference (MCID) at 6 months postoperatively, with a much lower proportion achieving the MCID at 1 year.23,24 The MCID for VAS ranges from 1.5 to 2.4, whereas the MCID for ASES ranges from 11.1 to 27.1.23-27 Although the MCID for SSV following RCR is unknown, a value of 26.6 can be extrapolated from other pathologies.28,29 Regarding functional outcomes, ER is also typically regained within 1 year and FF is often restored by 3 months for small tears and 6 months for medium to large tears.30 Furthermore, a vast majority of repair failures occur within 6 months of surgery.31

### Postoperative Rehabilitation Protocol

Postoperative rehabilitation was standardized for all patients. All patients were fitted with a sling for 4 weeks postoperatively. Physical therapy was initiated at 2 weeks postoperatively starting with passive ROM exercises, including passive FF, passive ER, and pendulums as tolerated. Active ROM exercises as well as active-assisted exercises were gradually initiated at 6 weeks postoperatively as tolerated. Finally, shoulder-strengthening exercises were introduced starting at 12 weeks.

### Statistical Analysis

Univariate analyses were conducted using either independent samples t test, χ² analysis, Mann–Whitney U test, or Fisher exact test. Multivariate linear regression modeling was used to identify risk factors for poor outcomes regarding VAS, SSV, and ASES score as well as active ROM in FF, ER, and internal rotation. Binary logistic regression analysis was used to identify predictors of operative failure following RCR as well as postoperative strength in FF, ER, and internal rotation.

Independent variables included in the regression analyses were demographic characteristics of age, tobacco use, alcohol use, diabetes, sex, hypercholesterolemia, and obesity (BMI ≥30 vs BMI <30); and injury characteristics of tear size (partial vs full-thickness tear), bicep tendon involvement, and severity of OA (mild vs moderate-to-severe) characterized by the Samilson-Prieto classification. Significance level was set to P < .05.

A power analysis was performed. Given the cohort sample size, this study was able to achieve 89% power to detect an effect size of 0.5 with an alpha is 0.05 using a multiple linear regression analysis for VAS.

### Results

#### Patient Demographics and Comorbidities

A total of 232 patients who underwent primary arthroscopic RCR of a supraspinatus tear were reviewed, of whom 112 had concomitant glenohumeral OA. Of these 112 patients, 19 were excluded due to insufficient follow-up and 2 were excluded as they were revision repairs. The remaining 91 patients had 1-year follow up and met the remaining inclusion criteria to be included in the analysis. The resulting cohort had an average age of 61.48 ± 9.4 years and an average follow-up of 26.3 ± 5.7 months from initial surgery date. Of the 91 patients, 46 were male (50.5%), 14 used tobacco products (15.4%), 43 consumed alcohol (47.3%), 14 were diabetic (15.4%), and 28 (30.8%) had hypercholesterolemia. Average BMI was 30.9 ± 4.6, with 40.7% classified as having obesity (BMI ≥30). The demographic variables are detailed in Table 1.

#### Injury Patterns

Of the 91 patients, 57 patients experienced a full-thickness tear of the supraspinatus (62.6%), whereas 34 patients had partial-thickness tears of the supraspinatus (37.4%) with an overall mean tear size of 15.5 mm. The Goutallier classification of the supraspinatus tendons was as follows: 45% grade 0, 13.2% grade 1, 19.8% grade 2, 5.5% grade 3, 5.5% grade 4, and 11% unspecified. Goutallier classification were similar between patients with and without obesity (grade 0: 49.0% vs 53.3%; grade 1: 17.6% vs 10.0%; grade 2: 19.6% vs 26.7%; grade 3: 5.9% vs 6.7%; and grade 4: 7.8% vs 3.3%; P = .758).

Based on the Samilson–Prieto classification radiologically,
70 patients had mild OA (76.9%), whereas 21 had moderate-to-severe OA (23.1%). Finally, 63.5% of the patients had concomitant bicep tendon pathology as well. Injury and repair patterns are shown in Table 2.

Preoperative Baseline
Preoperative PROs were as follows: VAS of 7.2 ± 1.9, SSV of 54 ± 22%, and ASES of 52 ± 25. Preoperatively, patients had a mean FF ROM of 146 ± 35° and ER ROM of 47 ± 13°. In addition, only 22.5% and 44.9% of patients had 5/5 strength preoperatively in FF and ER, respectively. Preoperative baselines are outlined in Table 3.

Patient-Reported Outcomes
Postoperative VAS was 1.8 ± 2.8, significantly decreased compared with preoperative VAS by an average of 5.4 points (P < .001). MCID for VAS was achieved in 74.7% (68/91 patients) postoperatively. Postoperative ASES was 58 ± 23, significantly increased compared with preoperative ASES by an average of 6 points (P = .048). MCID for ASES was achieved in 60.6% (20/33 patients). Finally, postoperative SSV was 83 ± 18%, a significant increase from preoperative baseline by 29% (P < .001) (Table 3). MCID for SSV was achieved in 69.2% (63/91 patients).

Obesity (β = 1.59, P = .023) and diabetes (β = 1.46, P = .010) were found to be predictive of increased postoperative VAS pain scores (Table 4). Obesity (β = –24.48, P = .029) and tobacco use (β = –50.16, P = .007) were predictive of lower ASES scores.

Table 2. Injury Patterns and Treatment Variables for Study Cohort

| Clinical Variable                  | GH Arthritis (n = 91) |
|-----------------------------------|-----------------------|
| Single-row repair                 | 17/79 (21.5%)         |
| Double-row repair                 | 62/79 (78.5%)         |
| Partial thickness                 | 34 (37.4%)            |
| Full thickness                    | 57 (62.6%)            |
| Mild OA                           | 70 (76.9%)            |
| Moderate-to-severe OA             | 21 (23.1%)            |
| Tear size, mm (range)             | 15.5 (6-45)           |
| Nonpathologic biceps              | 33/88 (37.5%)         |
| Goutallier classification         |                       |
| Grade 0                           | 41 (45.0%)            |
| Grade 1                           | 12 (13.3%)            |
| Grade 2                           | 18 (19.8%)            |
| Grade 3                           | 5 (5.5%)              |
| Grade 4                           | 5 (5.5%)              |
| Unspecified                       | 10 (11.0%)            |
| Biceps procedures                 |                       |
| None                              | 47/91 (51.6%)         |
| Arthroscopic tenodesis            | 17/91 (18.7%)         |
| Open tenodesis                    | 9/91 (9.9%)           |
| Tenotomy                          | 18/91 (19.8%)         |

GH, glenohumeral; OA, osteoarthritis.

Table 3. Comparison Between Outcomes Preoperatively Versus Postoperatively After Rotator Cuff Repair in Patients With Glenohumeral Osteoarthritis

| Outcome                  | Preoperative (n = 91) | Postoperative (n = 91) | P Value |
|--------------------------|-----------------------|------------------------|---------|
| Repair failure, %        | NA                    | 1.8 ± 2.8              | .99     |
| VAS                      | 7.2 ± 1.9             | 54 ± 22                | .74     |
| SSV, %                   | 69.2% achieving MCID  | 83 ± 18                | .048    |
| ASES                     | 52 ± 25 (n = 33)      | 58 ± 23                | .606% achieving MCID (n = 33) |
| ROM FF, °                | 146 ± 35              | 154 ± 21               | .012    |
| ROM ER, °                | 47 ± 13               | 47 ± 12                | .737    |
| ROM IR (level), %        |                       |                       |         |
| T1-T12                   | 71.4                  | 83.1                   | .000    |
| L1-L5                    | 22.6                  | 14.3                   | .000    |
| Sacrum                   | 6.0                   | 2.6                    | .000    |
| Strength FF (MMT, %)     |                       |                       |         |
| ≤3/5                     | 2.2                   | 0.0                    | .000    |
| 4/5                      | 65.3                  | 17.8                   | .000    |
| 5/5                      | 22.5                  | 82.2                   | .000    |
| Strength ER (MMT, %)     |                       |                       |         |
| ≤3/5                     | 1.2                   | 0.0                    | .000    |
| 4/5                      | 53.9                  | 14.4                   | .000    |
| 5/5                      | 44.9                  | 85.6                   | .000    |
| Strength IR (MMT, %)     |                       |                       |         |
| ≤3/5                     | 0                     | 0                      | .003    |
| 4/5                      | 26.4                  | 5.7                    | .000    |
| 5/5                      | 73.6                  | 94.3                   | .000    |

NOTE: Significance set at P value < .05 (bold).

ASES, American Shoulder and Elbow Surgeons score; ER, external rotation; FF, forward flexion; GH, glenohumeral; IR, internal rotation; L, lumbar; MMT, manual muscle test; NA, not available; ROM, range of motion; SSV, subjective shoulder value; T, thoracic; VAS, visual analog scale.
postoperatively (Table 4). No demographic variables or injury patterns were predictive of SSVs (Table 4).

**ROM Outcomes**

Average postoperative FF ROM was $154 \pm 21^\circ$, whereas ER ROM was $47 \pm 12^\circ$. Postoperative FF ROM was significantly improved from preoperative baseline by 8 degrees ($P = .012$), but postoperative ER ROM was not significantly improved ($P = .737$) (Table 3). Demographic variables were not predictive of decreased ROM in FF or ER (Table 5). Injury patterns were not prognostic indicators for ER ROM (Table 5). However, compared with mild OA, patients with moderate-to-severe OA were less likely to have full strength in FF (odds ratio 0.226; 95% confidence interval 0.059-0.868; $P = .03$) (Table 6).

**Strength Outcomes**

In postoperative strength testing, 82% of patients had 5/5 FF strength and 86% had 5/5 ER strength, both significantly improved from 22.5% and 44.9%, respectively ($P < .001$ for both) (Table 3). No demographic variables or injury patterns were predictive of strength outcomes in ER (Table 6). However, compared with mild OA, patients with moderate-to-severe OA were less likely to have full strength in FF (odds ratio 0.226; 95% confidence interval 0.059-0.868; $P = .03$) (Table 6).

**Repair Failure Outcomes**

Symptomatic repair failure occurred in 9.9% (9/91 patients) of the total cohort at the minimum of 1-year follow up (Table 3). Failure occurred at similar rates in patients with partial-thickness and full-thickness tears, at 8.8% (3/34 patients) and 10.5% (6/57 patients), respectively. No demographic variables or injury patterns were prognostic indicators of repair failure (Table 7).

**Discussion**

Overall, we found that certain risk factors in the OA population may predict greater pain scores, worse ASES scores, and decreased ROM.

---

**Table 4.** Summary of Multivariate Linear Regression for Patient-Reported Outcomes by Demographic and Injury Patterns

|                     | Coefficient ($\beta$) | 95% CI ($\beta$) | $P$ Value |
|---------------------|-----------------------|-----------------|-----------|
| **VAS (n = 91)**    |                       |                 |           |
| Age                 | 0.020                 | $-0.058$ to $0.097$ | .615      |
| Obesity (BMI $\geq 30$) | 1.593              | $0.225$ to $2.961$ | .023      |
| Female sex          | 0.914                 | $-0.415$ to $2.244$ | .174      |
| Tobacco use         | 1.455                 | $-0.824$ to $3.734$ | .206      |
| Alcohol use         | $-0.133$              | $-1.494$ to $1.227$ | .845      |
| Diabetes            | 2.967                 | $0.751$ to $5.183$ | .010      |
| Hypercholesterolemia| 0.215                 | $-1.456$ to $1.886$ | .797      |
| Partial-thickness tear (as opposed to full-thickness tear) | 0.095 | $-1.341$ to $1.531$ | .895      |
| Concomitant bicep tendon pathology | $-0.376$ | $-1.757$ to $1.005$ | .588      |
| Moderate-to-severe OA (as opposed to mild OA) | 0.165 | $-1.340$ to $1.669$ | .827      |
| **ASES (n = 33)**   |                       |                 |           |
| Age                 | $-0.032$              | $-1.180$ to $1.116$ | .954      |
| Obesity (BMI $\geq 30$) | $-24.478$          | $-46.250$ to $-2.706$ | .029      |
| Female sex          | 12.175                | $-10.107$ to $34.457$ | .268      |
| Tobacco use         | $-50.155$             | $-84.757$ to $-15.552$ | .007      |
| Alcohol use         | 3.026                 | $-17.048$ to $23.099$ | .756      |
| Diabetes            | $-23.973$             | $-51.860$ to $3.914$ | .088      |
| Hypercholesterolemia| $-5.425$              | $-32.991$ to $22.144$ | .686      |
| Partial-thickness tear (as opposed to full-thickness tear) | $-6.943$ | $-31.220$ to $17.334$ | .557      |
| Concomitant bicep tendon pathology | $-3.232$ | $-15.914$ to $22.377$ | .728      |
| Moderate to severe OA (as opposed to mild OA) | $-17.000$ | $-38.417$ to $4.417$ | .113      |
| **SSV (n = 91)**    |                       |                 |           |
| Age                 | $-0.109$              | $-0.707$ to $0.489$ | .716      |
| Obesity (BMI $\geq 30$) | $-1.705$            | $-12.147$ to $8.737$ | .745      |
| Female sex          | $-4.300$              | $-14.576$ to $5.977$ | .405      |
| Tobacco use         | $-4.033$              | $-21.116$ to $13.051$ | .638      |
| Alcohol use         | 4.292                 | $-5.852$ to $14.437$ | .400      |
| Diabetes            | 6.702                 | $-9.531$ to $22.936$ | .411      |
| Hypercholesterolemia| $-5.246$              | $-17.886$ to $7.395$ | .409      |
| Partial-thickness tear (as opposed to full-thickness tear) | $-0.803$ | $-11.303$ to $9.698$ | .879      |
| Concomitant bicep tendon pathology | $-5.848$ | $-16.525$ to $4.829$ | .277      |
| Moderate-to-severe OA (as opposed to mild OA) | $-7.397$ | $-18.945$ to $4.188$ | .206      |

**NOTE.** Significance set at $P$ value < .05 (bold).

ASES, American Shoulder and Elbow Surgeons score; BMI, body mass index; OA, osteoarthritis; SSV, subjective shoulder value; VAS, visual analog scale.
scores, and diminished ROM/strength outcomes postoperatively. Obesity and diabetes were significant predictors of greater pain scores postoperatively. In addition, obesity and tobacco use were significant predictors of lower ASES scores postoperatively. Finally, moderate-to-severe OA was a significant risk factor for decreased ROM and strength in FF postoperatively compared with mild OA. No risk factors were predictive of SSV, ROM/strength in ER, and symptomatic repair failure.

It is important to note that the suboptimal outcomes in patients with severe OA as opposed to mild OA were

Table 5. Summary of Multivariate Linear Regression for Range of Motion by Demographic and Injury Patterns

| Demographic or Injury Pattern | Coefficient (β) | 95% CI (β) | P Value |
|--------------------------------|----------------|-----------|--------|
| Forward flexion (n = 91)      |                |           |        |
| Age                           | -0.091         | -0.647 to 0.464 | .744   |
| Obesity (BMI ≥30)             | 3.125          | -6.767 to 13.017 | .531   |
| Female sex                    | 0.293          | -9.075 to 9.660  | .951   |
| Tobacco use                   | -8.541         | -22.500 to 3.417 | .227   |
| Alcohol use                   | 0.896          | -8.773 to 10.565 | .854   |
| Diabetes                      | -6.632         | -22.170 to 8.906  | .398   |
| Hypercholesterolemia          | 3.173          | -9.590 to 15.936  | .622   |
| Partial-thickness tear        | 0.532          | -9.464 to 10.529  | .916   |
| Concomitant bicep tendon pathology | 0.495 | -9.335 to 10.325  | .920   |
| Moderate-to-severe OA         | -12.423        | -23.483 to -1.363 | .028   |
| External rotation (n = 91)    |                |           |        |
| Age                           | 57.336         | -0.461 to 0.186  | .401   |
| Obesity (BMI ≥30)             | 0.431          | -5.163 to 6.025  | .878   |
| Female sex                    | -0.251         | -5.556 to 5.055  | .925   |
| Tobacco use                   | -3.449         | -11.412 to 4.515 | .391   |
| Alcohol use                   | 3.604          | -1.883 to 9.090  | .195   |
| Diabetes                      | 2.880          | -5.900 to 11.661 | .515   |
| Hypercholesterolemia          | -6.054         | -13.272 to 1.164 | .099   |
| Partial-thickness tear        | 0.130          | -5.567 to 5.827  | .964   |
| Concomitant bicep tendon pathology | 1.106 | -6.699 to 4.487  | .695   |
| Moderate-to-severe OA         | -1.449         | -7.796 to 4.899  | .878   |

NOTE. Significance set at P value < .05 (bold).
BMI, body mass index; OA, osteoarthritis.

Table 6. Odds of Full (5/5) Postoperative Strength in Forward Flexion and External Rotation by Demographic and Injury Patterns

| Demographic or Injury Pattern | Odds of 5/5 Strength in Forward Flexion | 95% CI | P Value |
|-------------------------------|----------------------------------------|-------|--------|
| Forward flexion (n = 91)      |                                        |       |        |
| Age                           | 0.990                                  | 0.916-1.070 | .806   |
| Obesity (BMI ≥30)             | 2.682                                  | 0.609-11.808 | .192   |
| Female sex                    | 0.785                                  | 0.205-3.003  | .055   |
| Tobacco use                   | 0.342                                  | 0.065-1.810  | .207   |
| Alcohol use                   | 1.466                                  | 0.409-5.253  | .557   |
| Diabetes                      | 0.939                                  | 0.127-6.721  | .939   |
| Hypercholesterolemia          | 1.215                                  | 0.208-7.087  | .829   |
| Partial-thickness tear        | 4.235                                  | 0.815-22.000 | .086   |
| Concomitant bicep tendon pathology | 1.354 | 0.349-5.253  | .661   |
| Moderate-to-severe OA         | 0.226                                  | 0.059-0.868  | .030   |
| External rotation (n = 91)    |                                        |       |        |
| Age                           | 1.011                                  | 0.935-1.093  | .784   |
| Obesity (BMI ≥30)             | 1.120                                  | 0.265-4.731  | .877   |
| Female sex                    | 0.678                                  | 0.174-2.635  | .574   |
| Tobacco use                   | 0.217                                  | 0.043-1.105  | .066   |
| Alcohol use                   | 0.842                                  | 0.225-3.155  | .799   |
| Diabetes                      | 1.055                                  | 0.148-7.523  | .957   |
| Hypercholesterolemia          | 0.564                                  | 0.095-3.347  | .528   |
| Partial-thickness tear        | 2.733                                  | 0.567-13.159 | .210   |
| Concomitant bicep tendon pathology | 0.842 | 0.207-3.431  | .810   |
| Moderate-to-severe OA         | 0.325                                  | 0.082-1.282  | .109   |

NOTE. Significance set at P value < .05 (bold).
BMI, body mass index; CI, confidence interval; OA, osteoarthritis.
related to objective functional outcomes (FF strength and ROM) rather than subjective PROs. This may indicate that patients with severe OA may expect similar satisfaction and subjective results, regardless of their relative functional deficits postoperatively. Worse pain and ASES scores, however, were associated with other lifestyle factors and comorbidities including obesity, tobacco use, and diabetes. Furthermore, other injury characteristics besides OA severity, including tear thickness and concomitant bicep pathology, did not seem to affect outcomes. Regardless of risk factors, however, the results of this study indicate that RCR remains an excellent treatment option in patients with concomitant glenohumeral OA. All postoperative PROs, ROMs, and strength outcomes improved significantly from their preoperative baselines except for ER ROM.

The risk factors for poor RCR outcomes in patients with glenohumeral OA are not well understood. Previous studies, however, have assessed prognostic factors for RCR in the general population.32 This study found that obesity (defined as BMI ≥30) was a predictor of greater pain scores and decreased ASES scores postoperatively in patients with glenohumeral OA. Obesity has been associated with fatty degeneration of the rotator cuff and has been proposed as an explanation for worse outcomes in this population.33 However, in this study, there was no significant difference in the supraspinatus Goutallier classification between obese and non-obese patients. While comparative studies, including Warrender et al.34 and Kessler et al.35 have shown worse repair outcomes in patients with obesity, retrospective review studies with multivariate analyses have failed to identify obesity as an independent risk factor for poor outcomes.36,37

We found that tobacco use was an independent predictor of decreased ASES scores postoperatively in patients with glenohumeral OA. Although the evidence in the general population remains conflicting,38 a study by Naimark et al.39 of 126 RCRs using regression analysis also revealed worse improvement in ASES scores among smokers. This may be due to nicotine’s potent vasoconstictive effects which may decrease oxygen delivery to soft tissues and negatively affect healing.60

We found diabetes to be associated with increased VAS pain scores postoperatively in patients with glenohumeral OA. This is consistent with the literature in the general population, as Sayegh et al.41 and Berglund et al.42 both demonstrated that patients with diabetes mellitus undergoing arthroscopic RCR experienced more pain and had poorer ASES scores at 6 and 12 months. These findings have been attributed to significantly reduced collagen fiber cross-linking and fibrocartilage formation in the setting of hyperglycemia.43

Finally, we found severity of OA to be a negative prognostic factor for postoperative strength and ROM during FF in patients with glenohumeral OA. Patients with severe glenohumeral OA, when treated surgically, are often treated with shoulder arthroplasty. As such, most of the literature regarding RCR in patients with glenohumeral OA involves cases with mild OA.17,18 However, a previous comparative study with this same patient cohort found that RCR may be a successful treatment with outcomes comparable with those without OA, and may still be a viable treatment option in patients with moderate-to-severe glenohumeral OA but with decreased strength and ROM outcomes compared with mild OA.19

**Limitations**

This study is not without limitations. First, as a retrospective cohort study, the sample size is limited by the inclusion criteria. The limited sample size may be a reason that this study found no significant predictors of repair failure, as there were only 9 repair failures. Second, retear outcomes were measured based on symptomatic failure confirmed on MRI. As MRI was not standard for all patients, asymptomatic retears may have been missed. Third, this study included supraspinatus tears with concomitant infraspinatus/subscapularis tears, which may serve as a confounder for functional ROM and strength outcomes. Finally, this study may contain selection bias, as some patients in

### Table 7. Odds of Repair Failure by Demographic and Injury Patterns

| Variable (n = 91) | Odds Ratio of Repair Failure | 95% CI | P Value |
|-------------------|-----------------------------|--------|---------|
| Age               | 1.020                       | 0.921-1.130 | .702    |
| Obesity (BMI ≥30) | 0.867                       | 0.714-1.052 | .148    |
| Female sex        | 5.749                       | 0.962-34.376 | .055    |
| Tobacco use       | 2.559                       | 0.290-22.580 | .398    |
| Alcohol use       | 2.028                       | 0.390-10.350 | .400    |
| Diabetes          | 2.920                       | 0.388-21.961 | .298    |
| Hypercholesterolemia | 1.244                     | 0.233-11.884 | .445    |
| Partial-thickness tear (as opposed to full-thickness tear) | 0.403 | 0.059-2.762 | .355 |
| Concomitant bicep tendon pathology | 0.214 | 0.039-1.161 | .074 |
| Moderate-to-severe OA (as opposed to mild OA) | 0.191 | 0.018-1.993 | .166 |

*BMI, body mass index; CI, confidence interval; OA, osteoarthritis.*
the initial cohort were excluded due to lack of 1-year follow up. Those lost to follow-up may have had better outcomes than those who continued to follow up at 1 year.

Conclusions

Tobacco use, obesity, and diabetes are associated with worse pain and PROs following arthroscopic RCR in the context of glenohumeral OA. In addition, moderate-to-severe OA is associated with worse strength and FF compared with those with mild OA.

References
1. Saltzman BM, Leroux TS, Verma NN, Romeo AA. Glenohumeral osteoarthritis in the young patient. J Am Acad Orthop Surg 2018;26:e361-e370.
2. Hashemi SM, Khamene SMH, Naderi-Nabi B, Ghasemi M. Effects of ultrasound-guided intraarticular botox vs corticosteroids for shoulder osteoarthritis. Anaesthesia Pain Intensive Care 2018;22:355-360.
3. Kobayashi T, Takagishi K, Shitara H, et al. Prevalence of and risk factors for shoulder osteoarthritis in Japanese middle-aged and elderly populations. J Shoulder Elbow Surg 2014;23:613-619.
4. Neogi T. The epidemiology and impact of pain in osteoarthritis. Osteoarthr Cartil 2013;21:1145-1153.
5. Ibounig T, Simons T, Launonen A, Paavola M. Glenohumeral osteoarthritis: An overview of etiology and diagnostics. Scand J Surg 2021;110:441-451.
6. Kruckeberg BM, Leland DP, Bernard CD, et al. Incidence of and risk factors for glenohumeral osteoarthritis after anterior shoulder instability: A US population–based study with average 15-year follow-up. Orthop J Sport Med 2020;8:232596712096251.
7. Oh JH, Chung SW, Oh CH, et al. The prevalence of shoulder osteoarthritis in the elderly Korean population: Association with risk factors and function. J Shoulder Elbow Surg 2011;20:756-763.
8. Ibrahim M, Kartus J-T, Steigen SE, Olsen R, Meknas K. More tendon degeneration in patients with shoulder osteoarthritis. Knee Surg Sport Traumatol Arthros 2019;27:267-275.
9. Hsu H-C, Luo Z-P, Stone JJ, Huang T-H, An K-N. Correlation between rotator cuff tear and glenohumeral degeneration. Acta Orthop Scand 2003;74:89-94.
10. Le BTN, Wu XL, Lam PH, Murrell GAC. Factors predicting rotator cuff retears. Am J Sports Med 2014;42:1134-1142.
11. Miller C, Savoie FH. Glenohumeral abnormalities associated with full-thickness tears of the rotator cuff. Orthop Rev 1994;23:159-162.
12. Ansson CB, Muh SJ. Optimal management of glenohumeral osteoarthritis. Orthop Rev Res 2018;10:9-18.
13. Gunther SB, Tran SK. Long-term follow-up of total shoulder replacement surgery with inset glenoid implants for arthritis with deficient bone. J Shoulder Elbow Surg 2019;28:1728-1736.
14. Khazzam M, Gee AO, Pearl M. Management of glenohumeral joint osteoarthritis. J Am Acad Orthop Surg 2020;28:781-789.
15. Kukkonen J, Äärimaa V, Joukainen A, Lehtinen J. The effect of glenohumeral osteoarthritis on the outcome of isolated operatively treated supraspinatus tears. J Orthop Sci 2013;18:405-409.
16. Millett PJ, Fritz EM, Frangiamore SJ, Mannava S. Arthroscopic management of glenohumeral arthritis. J Am Acad Orthop Surg 2018;26:745-752.
17. Kim DH, Min SG, Lee HS, et al. Clinical outcome of rotator cuff repair in patients with mild to moderate glenohumeral osteoarthritis. Knee Surg Sport Traumatol Arthrosc 2021;29:998-1005.
18. Jeong HY, Jeon YS, Lee DK, Rhee YG. Rotator cuff tear with early osteoarthritis: How does it affect clinical outcome after large to massive rotator cuff repair? J Shoulder Elbow Surg 2019;28:237-243.
19. Reddy RP, Solomon DA, Hughes JD, Lesniak BP, Lin A. Clinical outcomes of rotator cuff repair patient in patients with concomitant glenohumeral osteoarthritis. J Shoulder Elbow Surg 2022;31:S25-S33.
20. Elsharkawi M, Cakir B, Reichel H, Kappe T. Reliability of radiologic glenohumeral osteoarthritis classifications. J Shoulder Elbow Surg 2013;22:1063-1067.
21. Gerber C, Rahm SA, Catanzano S, Farshad M, Moor BK. Latissimus dorsi tendon transfer for treatment of irreparable posterosuperior rotator cuff tears: Long-term results at a minimum follow-up of ten years. J Bone Joint Surg Am 2013;95:1920-1926.
22. Williams M. Manual muscle testing, development and current use. Phys Ther Rev 1956;36:797-805.
23. Manderle BJ, Gowd AK, Liu JN, et al. Time required to achieve clinically significant outcomes after arthroscopic rotator cuff repair. Am J Sports Med 2020;48:3447-3453.
24. Louwerens JKG, van den Bekerom MPI, van Royen BJ, Eygendaal D, van Noort A, Sierevelt IN. Quantifying the effect of glenohumeral osteoarthritis in the young patient. Acta Orthop Scand 2003;74:89-94.
25. Kim DM, Kim TH, Kholinne E, et al. Clinical outcomes of rotator cuff repair in patients with concomitant glenohumeral osteoarthritis. J Shoulder Elbow Surg 2019;28:237-243.
26. Tashjian RZ, Shin J, Broschinsky K, et al. Minimal clinically important difference, substantial clinical benefit, and patient acceptable symptomatic state after arthroscopic rotator cuff repair. J Shoulder Elbow Surg 2020;29:1406-1411.
27. Cvjetanovich GL, Gowd AK, Liu JN, et al. Establishing clinically significant outcome after arthroscopic rotator cuff repair. J Shoulder Elbow Surg 2019;28:939-948.
28. Su F, Allahabadi S, Bongbong DN, Feeley BT, Lansdown DA. Minimal clinically important difference, substantial clinical benefit, and patient acceptable symptomatic state of outcome measures relating to shoulder pathology and surgery: A systematic review. Curr Rev Musculoskelet Med 2021;14:27.
29. van de Water ATM, Shields N, Davidson M, Evans M, Taylor NF. Reliability and validity of shoulder function outcome measures in people with a proximal humeral fracture. Disabil Rehabil 2014;36:1072-1079.
30. Harris JD, Ravindra A, Jones GL, Butler RB, Bishop JY. Setting patients’ expectations for range of motion after arthroscopic rotator cuff repair. *Orthopedics* 2013;36: e172-e178.
31. Iannotti JP, Deutsch A, Green A, et al. Time to failure after rotator cuff repair: A prospective imaging study. *J Bone Joint Surg Am* 2013;95:965-971.
32. Sahni V, Narang AM. Review Article: Risk factors for poor outcome following surgical treatment for rotator cuff tear. *J Orthop Surg* 2016;24:265-268.
33. Matson AP, Kim C, Bajpai S, Green CL, Hash TW, Garrigues GE. The effect of obesity on fatty infiltration of the rotator cuff musculature in patients without rotator cuff tears. *Shoulder Elbow* 2019;11:30-38 (1 suppl).
34. Warrender WJ, Brown OL, Abboud JA. Outcomes of arthroscopic rotator cuff repairs in obese patients. *J Shoulder Elbow Surg* 2011;20:961-967.
35. Kessler KE, Robbins CB, Bedi A, Carpenter JE, Gagnier JJ, Miller BS. Does increased body mass index influence outcomes after rotator cuff repair? *Arthroscopy* 2018;34:754-761.
36. Namdari S, Baldwin K, Glaser D, Green A. Does obesity affect early outcome of rotator cuff repair? *J Shoulder Elbow Surg* 2010;19:1250-1255.
37. Kuptniratsaikul V, Laohathaimongkol T, Umprai V, Yeekian C, Prasathaporn N. Pre-operative factors correlated with arthroscopic reparability of large-to-massive rotator cuff tears. *BMC Musculoskelet Disord* 2019;20:1-11.
38. Raman J, Walton D, MacDermid JC, Athwal GS. Predictors of outcomes after rotator cuff repair-A meta-analysis. *J Hand Ther* 2017;30:276-292.
39. Naimark M, Robbins CB, Gagnier JJ, et al. Impact of smoking on patient outcomes after arthroscopic rotator cuff repair. *BMJ Open Sport Exerc Med* 2018;4:e000416.
40. Baumgarten KM, Gerlach D, Galatz LM, et al. Cigarette smoking increases the risk for rotator cuff tears. *Clin Orthop Relat Res* 2010;468:1534-1541.
41. Sayegh ET, Gooden MJ, Lowenstein NA, Collins JE, Matzkin EG. Patients with diabetes mellitus experience poorer outcomes after arthroscopic rotator cuff repair. *JSES Int* 2022;6:91-96.
42. Berglund DD, Kurowicki J, Giveans MR, Horn B, Levy JC. Comorbidity effect on speed of recovery after arthroscopic rotator cuff repair. *JSES OPEN ACCESS* 2018;2:60-68.
43. Bedi A, Fox AJS, Harris PE, et al. Diabetes mellitus impairs tendon-bone healing after rotator cuff repair. *J Shoulder Elbow Surg* 2010;19:978-988.