JSES International 7 (2023) 586–591

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

# Progression of symptomatic bilateral rotator cuff disease

Karch M. Smith, MD[a,*], Christopher E. Clinker, BS[a], Zachary A. Cutshall, MD[a], Chao-Chin Lu, PhD[b], Christopher D. Joyce, MD[c], Peter N. Chalmers, MD[c], Robert Z. Tashjian, MD[c]

[a]Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT, USA
[b]Division of Epidemiology, Department of Internal Medicine, University of Utah, Salt Lake City, UT, USA
[c]Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT, USA

ARTICLE INFO

*Keywords:*
Rotator cuff tear
Rotator cuff tendinopathy
Bilateral rotator cuff tear
Laterality
Tear progression
Shoulder
Natural history

*Level of Evidence:* Level III; Retrospective Case-Control Design; Prognosis Study

**Background:** Prior studies have demonstrated that conservatively treated rotator cuff tears and rotator cuff tendinopathy may continue to progress. It is unclear whether that rate of progression differs between sides in patients with bilateral disease. This study evaluated the likelihood of progression of rotator cuff disease as confirmed via magnetic resonance imaging (MRI) in individuals with symptomatic bilateral pathology, treated conservatively for a minimum of 1 year.

**Methods:** We identified patients with bilateral rotator cuff disease confirmed via MRI within the Veteran's Health Administration electronic database. A retrospective chart review via the Veteran's Affairs electronic medical record was performed. Progression was determined using 2 separate MRIs with a minimum of 1 year apart. We defined progression as (1) a progression from tendinopathy to tearing, (2) an increase from partial-thickness to full-thickness tearing, or (3) an increase in tear retraction or tear width of at least 5 mm.

**Results:** Four hundred eighty MRI studies from 120 Veteran's Affair patients with bilateral, conservatively treated rotator cuff disease were evaluated. Overall, 42% (100/240) of rotator cuff disease had progressed. No significant difference was found between progression of right vs. left rotator cuff pathology, with right shoulder pathology progressing at a rate of 39% (47/120), while left shoulder disease progressed at a rate of 44% (53/120). The likelihood of disease progression was associated with less initial tendon retraction ($P$ value = .016) and older age ($P$ value = .025).

**Conclusions:** Rotator cuff tears are no more likely to progress on the right, as compared to the left side. Older age and less initial tendon retraction were found to be predictors of disease progression. These suggest that higher activity level may not associate with greater progression of rotator cuff disease. Future prospective studies evaluating progression rates between dominant vs. nondominant shoulders are warranted.



Rotator cuff disease is the most common shoulder condition treated by orthopedic surgeons.[4,18] The incidence rotator cuff pathology, including both partial-thickness and full-thickness tearing and tendinopathy, increases significantly with patient age.[2,8] Previous studies have demonstrated that conservatively treated rotator cuff tears (RCTs), both symptomatic and asymptomatic, may continue to progress or enlarge.[7,10-12,14,16,17,19,20,24,29,30] A recent study also demonstrated that symptomatic rotator cuff tendinopathy progressed to partial-thickness or full-thickness tearing at a rate of 39% with a mean follow-up of 3.4 years.[23] Understanding the risk and rate of progression of both rotator cuff tearing and tendinopathy is essential as it guides the formulation of patient-specific surgical indications.

Several structural tear features and patient-specific factors have been found to associate with tear progression. Symptomatic tear progression is associated with age more than 60 years, smoking, recurrence of shoulder pain, initial muscle fatty infiltration, medium-sized tears, full-thickness tears, tendon retraction, and subscapularis involvement.[7,17,19,22,24,30] Currently, no factors have been found to significantly associate with progression of rotator cuff tendinopathy to tearing; however, the literature is sparse.[23] There is growing evidence to suggest that rotator cuff pathology

This study was performed under the University of Utah Institutional Review Board as approved protocol #IRB_00111481.
The work for this manuscript was performed at the University of Utah and the local Veteran's Affair (VA) Health System.

*Corresponding author: Karch M. Smith, BA, Department of Orthopaedic Surgery, 590 Wakara Way, Salt Lake City, UT, USA.
*E-mail address:* smithkarch@gmail.com (K.M. Smith).

https://doi.org/10.1016/j.jseint.2023.04.005

**Table I**
Reliability statistics.

| Variable | Interobserver reliability | Intraobserver reliability, first investigator | Intraobserver reliability, second investigator |
|---|---|---|---|
| Tendon retraction | 0.915 | 0.995 | 0.938 |
| Tear width | 0.78 | 0.968 | 0.944 |
| Cable width | 0.591 | 0.937 | 0.865 |
| Tear thickness | 0.615 | 1 | 1 |
| Partial type | 0.639 | 1 | 0.743 |
| Tendinopathy grade | 0.405 | 0.811 | 0.837 |
| Cable intact | 0.922 | 1 | 1 |
| Goutallier supraspinatus | 1 | 1 | 1 |
| Goutallier infraspinatus | 0.94 | 1 | 1 |
| Tangent sign | 1 | 1 | 1 |
| Subscapularis tear | 1 | 1 | 1 |
| Progression | 1 | 1 | 1 |

occurs partly secondary to systemic factors—as age, dyslipidemia, osteoporosis, smoking, diabetes, hypogonadism, and genetic predispositions associate with tendon healing.[3,5,6,21,25,27,28] Additionally, Keener et al concluded that in individuals with asymptomatic RCTs, hand dominance associates with RCT progression;[10,12] however, other reports have demonstrated that in symptomatic disease, shoulder activity level does not associate with tear progression.[1,12,30] Studying individuals with bilateral rotator cuff disease provides a valuable insight into the influence of activity upon tear progression as systemic factors should be the same between sides, while the dominant (usually right) side is more active than the nondominant (usually left) side.

Therefore, the purpose of this study was to determine the likelihood of progression of rotator cuff disease confirmed via magnetic resonance imaging (MRI) in individuals with symptomatic bilateral disease treated conservatively for a minimum of 1 year. We hypothesized that rates of tear and tendinopathy progression would be greater in the right than in the left side.

## Materials and methods

### *Patient selection*

Adult patients (aged >18 years) who received treatment from October 1, 1999 to March 1, 2020 for shoulder pain were found via Current Procedural Terminology and International Classification of Diseases codes and their medical records were reviewed retrospectively. Patients with rotator cuff tendinopathy, a partial-thickness tear, or a full-thickness tear on index MRI of bilateral shoulders with a subsequent MRI at least 1 year apart met criteria for inclusion. Nonoperative treatment in between scans was permitted, including physical therapy or corticosteroid injections. Patients whose imaging was inadequate or inaccessible via the Joint Legacy Viewer were also excluded. We excluded patients with unilateral disease who have been previously studied.[7,23] We also excluded those who underwent shoulder surgery between MRI scans or before the index scan or those who had fewer than a year between MRI scans.

### *Data collection*

A retrospective chart review of the Veteran's Affair's (VA's) electronic medical record system was performed to collect patient characteristics and demographics—including age, sex, body mass index, diabetes mellitus, hyperlipidemia, osteoporosis, hypogonadism, and smoking status.

RCT measurements were performed by 2 of the authors. A subset of 52 MRIs (26 shoulders, 13 patients) was initially measured by both investigators, and interobserver and intraobserver reliability were measured. Intraobserver reliability was calculated in a blinded fashion approximately 2 weeks apart. The remainder of the cohort's imaging was evaluated independently by either investigator once the investigators were shown to have acceptable reliability (Table I). MRIs were obtained on 1.5-T MRI scanners with a slice thickness of 2 mm.

Rotator cuff disease structural characteristics assessed via MRI included disease morphology (tendinopathy vs. partial-thickness vs. full-thickness), tendon retraction, anteroposterior tear length, anterior rotator cable integrity, subscapularis tear, and supraspinatus or infraspinatus atrophy (Goutallier grade). Partial-thickness tears were further characterized based on their location (articular, intrasubstance, or bursal). Anteroposterior tear length was measured on T2 sagittal images and lateral-to-medial tendon retraction was measured on T2 coronal images, both in whole millimeters. The anterior rotator cable (measured on T2 sagittal images) was considered intact if the anterior supraspinatus footprint (immediately posterior to the biceps tendon/groove) was intact for more than 3 mm posterior to the biceps.[11] A concomitant subscapularis tear (measured on T1 and T2 axial images) was included in the analysis only if it was a full-thickness tear. Fatty infiltration of the supraspinatus or infraspinatus was considered to be significant if it was Goutallier grade 3 or 4. Goutallier grades were primarily measured on T1 sagittal images on the most lateral slice where the scapular spine was still connected to the scapular body; however, it was occasionally measured on coronal T1 images if the sagittal image was of poor quality. Disease progression was defined as (1) an increase from tendinopathy to a partial-thickness or full-thickness tear, (2) an increase from a partial-thickness to a full-thickness tear, or (3) an increase in tear width or retraction of at least 5 mm.[29]

### *Statistical analysis*

Descriptive statistics were determined using patient-specific demographic data and rotator cuff disease structural features. Interobserver and intraobserver reliabilities were calculated to establish consistency between the 2 independent investigators. For discrete variables, $\kappa$ was measured and a priori set 0.6 as the minimum acceptable reliability. For continuous variables, the intraclass correlation coefficient was calculated and a priori set 0.75 as the minimum acceptable reliability (Table I). Discrete variables were analyzed for patients whose disease progressed and those whose disease did not progress using $\chi 2$ and Fisher's exact tests as appropriate. Continuous variables were also compared between those who progressed and those who did not progress using Student's *t*-tests and Mann–Whitney U tests as appropriate depending on data normality as determined using the Kolmogorov–Smirnov test. A multivariate logistic regression analysis was not conducted given that only 2 variables associated with progression.

## Results

### *Patient demographics*

Initial Current Procedural Terminology code query identified 808,180 patients who had a rotator cuff–related diagnosis of which 1316 had 2 shoulder MRIs on the same side at least 1 year apart. Among these patients, 341 patients had bilateral rotator cuff–related diagnoses. Of these, 170 were excluded as they

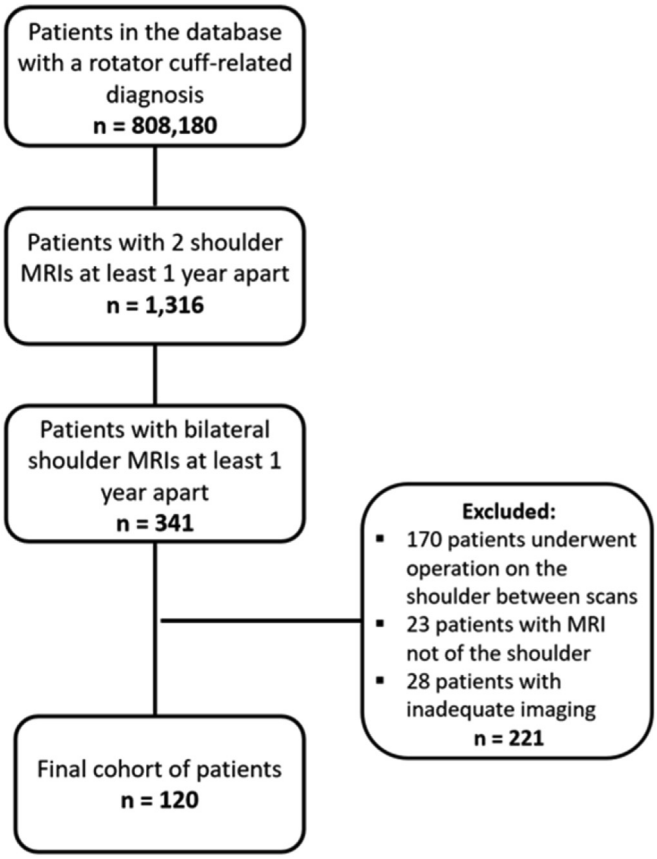


**Figure 1** Flow chart representing inclusion and exclusion criteria with the resultant final cohort. *MRI*, magnetic resonance imaging.

underwent an operation of the shoulder (rotator cuff repair, arthroscopy, subacromial decompression, etc.) between scans, 23 were excluded because the MRI was not of the shoulder, and 28 were excluded due to inadequate imaging (only one image of the shoulder, unilateral only, unreadable, or unable to load). This left 120 patients (240 shoulders, 480 MRIs) in the final cohort (Fig. 1).

Among the 120 patients who met the inclusion criteria, 92% were male with an average age of 56 ± 10 years and an average body mass index of 30 ± 4. Overall, 38% of the patients had diabetes, 30% currently used tobacco, 66% had hyperlipidemia, 6% had hypogonadism, and 2% had osteoporosis (Table II).

*Rotator cuff imaging characteristics*

Measurements of tendon retraction, tear width, tear thickness, partial thickness subtype (bursal, intrasubstance, or articular), whether the anterior rotator cable was intact, Goutallier score, presence of a concomitant subscapularis tear, and whether the disease progressed were found to have acceptable interobserver and intraobserver reliability. The investigators were not shown to have adequate inter-rater reliability in measuring anterior cable width and tendinopathy grade; thus, these measurements were not performed for the rest of the cohort and were excluded from the analysis (Table I).

The average time between MRI scans was 3.6 ± 2.1 years (1-11.9) for right shoulders and 3.8 ± 2.5 years (1-12.1) for left shoulders. The proportion of patients who underwent surgery after the second MRI was 18% (21/120). For the right shoulders, at the initial MRI scan, 1% (1/117) had no disease, 40% (47/117) had tendinopathy, 32% (37/117) demonstrated evidence of partial-thickness tearing, and 27% (32/117) demonstrated evidence of full-thickness tearing. Of the partial-thickness tears, 11% (4/37) were bursal-sided tears, 70% (26/37) were articular tears, and 19% (7/37) were intrasubstance. For left shoulders, at the initial MRI scan, 3% (4/117) had no disease, 47% (55/117) had tendinopathy, 27% (31/117) demonstrated evidence of partial-thickness tearing, and 23% (27/117) demonstrated evidence of full-thickness tearing. Of the partial-thickness tears, 7% (2/31) were bursal-sided tears, 74% (23/31) were articular tears, and 19% (6/31) were intrasubstance. At the index scan, a concomitant subscapularis tear was found in 7% (8/120) right shoulders and 4% (5/120) left shoulders. Additionally, tendon retraction was found to be 14.8 ± 8.2 mm and 13.1 ± 9.4 mm at the index scan for right and left shoulders, respectively (Table III).

**Table II**
Patient cohort characteristics.

| Variable | Value |
|---|---|
| Demographics | |
| Male gender | 92% (105/114) |
| Age | 56 ± 10 (28 to 74) |
| BMI | 30 ± 4 (18 to 42) |
| Risk factors | |
| Diabetes | 38% (43/114) |
| Osteoporosis | 2% (2/114) |
| Tobacco | 30% (34/114) |
| Hyperlipidemia | 66% (75/114) |
| Hypogonadism | 6% (7/114) |

*BMI*, body mass index.
Discrete variables are shown as % (N).

*Rotator cuff disease progression with regard to laterality*

Overall, rotator cuff tendinopathy or RCT enlargement or progression occurred at a rate of 42% (100/240) irrespective of time between scans, 41% (24/58) with 1-2 years in between scans, 41% (53/130) with 2-5 years of follow-up, and 44% (23/52) with 5 or more years in between index and subsequent MRI. Right shoulder pathology progressed at a rate of 39% (47/120), while left shoulder pathology progressed at a rate of 44% (53/120) irrespective of time between scans (Table IV). In the univariate analysis, rotator cuff disease progression was not found to be associated with laterality (Table V, Fig. 2).

*Risk factors for progression*

The likelihood of rotator cuff disease progression was found to be associated with less initial tendon retraction ($P$ value = .016) and older age ($P$ value = .025). Progression was not found to be associated with diabetes, osteoporosis, hyperlipidemia, or hypogonadism. Progression was also not found to be associated with various structural characteristics including thickness, rotator cable integrity, rotator cuff fatty atrophy, or concomitant full-thickness subscapularis tears (Table V). Multivariate analysis was not performed given only 2 variables were found to associate with disease progression.

## Discussion

This study found that disease progression of both right and left shoulders occurred at similar rates (39% and 44%, respectively) and progression was not found to be associated with laterality. Given that progression was associated with older age and was not associated with laterality, higher activity level may not associate with progression. Our analysis of patients within the VA medical system

**Table III**
Rotator cuff imaging characteristics for both right and left sides.

| Variable | Right side (n = 120) | Left side (n = 120) |
|---|---|---|
| Time between MRI scans | 3.6 ± 2.1 (1.0-11.9) | 3.8 ± 2.5 (1.0-12.1) |
| Surgically treated after MRI 2 | 18% (21/120) | 18% (21/120) |
| First time point measurements | | |
| Thickness | | |
| No disease | 1% (1/117) | 3% (4/117 |
| Tendinopathy | 40% (47/117) | 47% (55/117) |
| Partial | 32% (37/117) | 27% (31/117) |
| Full | 27% (32/117) | 23% (27/117) |
| Partial type | | |
| Bursal | 11% (4/37) | 7% (2/31) |
| Articular | 70% (26/37) | 74% (23/31) |
| Intrasubstance | 19% (7/37) | 19% (6/31) |
| Cable intact | 88% (106/120) | 93% (112/120) |
| Supraspinatus Goutallier | | |
| 0 | 55% (66/120) | 61% (73/120) |
| 1 | 37% (44/1230) | 33% (39/120) |
| 2 | 6% (7/120) | 5% (6/120) |
| 3 | 2% (2/120) | 1% (1/120) |
| 4 | 1% (1/120) | 1% (1/120) |
| Infraspinatus Goutallier | | |
| 0 | 62% (74/120) | 76% (91/120) |
| 1 | 34% (41/120) | 20% (24/120) |
| 2 | 4% (5/120) | 4% (5/120) |
| Tangent positive | 5% (6/120) | 6% (7/120) |
| Subscap tear | 7% (8/120) | 4% (5/120) |
| Tendon retraction (mm) | 14.8 ± 8.2 | 13.1 ± 9.4 |
| Tear width (mm) | 13.8 ± 6.8 | 13.3 ± 6.6 |
| Second time point measurements | | |
| Thickness | | |
| No disease | 2% (2/119) | 2% (2/116) |
| Tendinopathy | 29% (34/119) | 32% (37/116) |
| Partial | 30% (36/119) | 30% (35/116) |
| Full | 40% (47/119) | 36% (42/116) |
| Partial type | | |
| Bursal | 16% (6/38) | 16% (6/37) |
| Articular | 63% (24/38) | 54% (20/37) |
| Intrasubstance | 21% (8/38) | 30% (11/37) |
| Cable intact | 67% (80/120) | 82% (98/119) |
| Supraspinatus Goutallier | | |
| 0 | 44% (53/120) | 48% (57/120) |
| 1 | 38% (45/120) | 38% (46/120) |
| 2 | 10% (12/120) | 10% (12/120) |
| 3 | 6% (7/120) | 2% (2/120) |
| 4 | 3% (3/120) | 3% (3/120) |
| Infraspinatus Goutallier | | |
| 0 | 54% (65/120) | 62% (74/119) |
| 1 | 31% (37/120) | 29% (35/119) |
| 2 | 11% (13/120) | 8% (9/119) |
| 3 | 3% (4/120) | 1% (1/119) |
| 4 | 1% (1/120) | 0% (0/119) |
| Tangent positive | 11% (13/120) | 11% (13/120) |
| Subscap tear | 7% (8/120) | 5% (6/120) |
| Tendon retraction (mm) | 17.0 ± 9.8 | 16.4 ± 10.0 |
| Tear width (mm) | 16.0 ± 7.6 | 15.2 ± 6.3 |

*MRI*, magnetic resonance imaging.
Discrete variables are shown as % (N) and continuous variables are shown as mean ± standard deviation (range).

**Table IV**
Tear and tendinopathy progression rates for both right and left sides.

| | Right | Left | Total cohort |
|---|---|---|---|
| Overall | 39% (47/120) | 44% (53/120) | 42% (100/240) |
| 1-2 years | 43% (12/28) | 40% (12/30) | 41% (24/58) |
| 2-5 years | 37% (25/67) | 44% (28/63) | 41% (53/130) |
| > 5 years | 40% (10/25) | 48% (13/27) | 44% (23/52) |

**Table V**
Univariate analysis of risk factor for tear and tendinopathy progression.

| Variable | Not progressed | Progressed | *P* value |
|---|---|---|---|
| Initial tendon retraction | 16 ± 9 | 12 ± 8 | **.016** |
| Initial tear width | 14 ± 7 | 12 ± 6 | .11 |
| Age | 54.7 ± 10.1 | 57.4 ± 8.5 | **.025** |
| BMI | 30.8 ± 4.6 | 29.7 ± 4.2 | .054 |
| Time between scans | 3.7 ± 2.3 | 3.7 ± 2.4 | .907 |
| Female gender | 9% (12/140) | 6% (6/100) | .456 |
| Right side | 52% (73/140) | 47% (47/100) | .432 |
| Full thickness tear | 27% (37/137) | 23% (22/97) | .055 |
| Cable intact | 90% (126/140) | 92% (92/100) | .597 |
| Supra atrophy | 44% (61/140) | 40% (40/100) | .493 |
| Infra atrophy | 31% (43/140) | 32% (32/100) | .668 |
| Tangent positive | 6% (8/140) | 5% (5/100) | .81 |
| Subscapularis tear | 8% (11/140) | 2% (2/100) | .079 |
| Diabetes | 37% (52/140) | 36% (36/100) | .856 |
| Osteoporosis | 2% (3/140) | 1% (1/100) | .495 |
| Tobacco use | 28% (39/140) | 31% (31/100) | .597 |
| Hyperlipidemia | 62% (87/140) | 71% (71/100) | .154 |
| Hypogonadism | 7% (10/140) | 6% (6/100) | .726 |

*MRI*, magnetic resonance imaging; *BMI*, body mass index.
Structural MRI measurements are represented in millimeters. Discrete variables are shown as % (N) and continuous variables are shown as mean ± standard deviation.
Values represented in bold were found to be statistically significant ($P < .05$).

demonstrated that disease progression occurred at an overall rate of 42% (100/240). Older age and initial tendon retraction positively associated with tear progression, while other comorbidities—including diabetes, osteoporosis, hyperlipidemia, and hypogonadism—were not found to associate rotator cuff pathology progression.

Rotator cuff disease—both tendinopathy and tendon tears—demonstrated disease progression at an overall rate of 42% (100/240) and increasing in percentage over time. Our analysis found a slightly lower rate of progression when compared to other studies examining RCTs alone, and a similar rate of progression when compared to the rate of rotator cuff tendinopathy progressing to partial-thickness or full-thickness tears. Mall et al reported that 40% of symptomatic partial-thickness tears progressed to full-thickness tears at 2 years of follow-up.[16] Kartus et al found that 35% of symptomatic partial-thickness tears progressed to full-thickness tears after arthroscopic subacromial decompression at an average follow-up rate of 8 years.[9] Yamamoto et al evaluated 171 patients with symptomatic RCTs at an average of 19 months apart and found that 47% progressed with an average progression of 2.3 cm in length and 1.7 cm in width. Safran et al studied 51 full-thickness tears in patients aged 60 years and less and found that 49% increased in size (>5 mm) at an average of 29 months. With regard to rotator cuff tendinopathy progression, a prior study demonstrated that among symptomatic individuals, 39% progressed from tendinopathy to tearing, similar to our results.[23] Our study was consistent with the overall trend within the literature that time is an independent risk factor for both partial-thickness and full-thickness tears to progress and for tendinopathy to progress to tears.

We found that older age associated with tear enlargement or tendinopathy progression to tearing. Symptomatic tear progression has been shown to associate with age more than 60 years, smoking, recurrence of shoulder pain, initial fatty infiltration of the muscle belly, medium-sized tears, full-thickness tears, tendon retraction, and subscapularis involvement.[7,17,19,22,24,30] A retrospective analysis of conservatively treated rotator cuff tendinopathy in the VA population reported that no factors associated with tendinopathy progressing to tear.[23] In our analysis, the mean age of the group that exhibited no progression of rotator cuff disease was 54.7 ± 10.1 years, while the mean age of the group that demonstrated

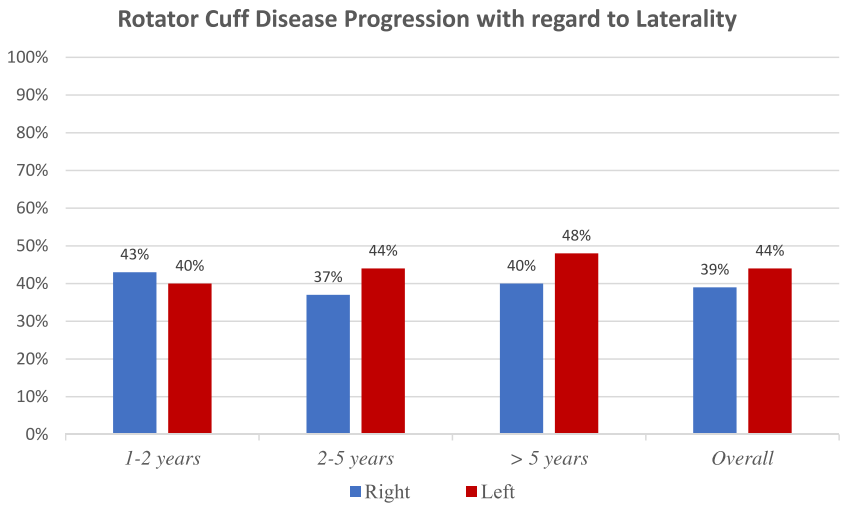


**Figure 2** Tear and tendinopathy progression rates with respect to time for both right and left sides.

progression was 57.4 ± 8.5 years. This difference in age is a relatively small window and may suggest that delaying surgical treatment for full-thickness tears may have impactful prognostic changes on the natural history of the disease even in what would typically be considered younger patients. In this series, "older" patients in general would still be considered young by most surgeons with an average age of 57 years in the progressed group, emphasizing the importance of considering earlier surgical repair in this age group for full-thickness tears of substantial size.

Within our analysis, decreased initial tear retraction was associated with increased progression. Nakamura et al examined RCT progression with regards to tendon retraction in the coronal plane and found that tears that were initially less than 1 cm or more than 4 cm were unlikely to enlarge with time. In their analysis, medium-sized tears (1-2 cm) demonstrated the greatest risk for progression.[22] Our findings are related to those of Nakamura et al in that at a certain threshold of initial tendon retraction, there is decreased risk for disease progression. This may be because if there has been less retraction thus far, there is more progression/retraction that can occur, while if significant retraction has already occurred, there may not be much additional retraction that could occur.

Our analysis demonstrated no statistically significant difference in RCT or tendinopathy progression rates between left and right shoulders. While no prior natural history studies of the rotator cuff have used a cohort of patients with bilateral pathology, RCT progression with regard to hand dominance and self-reported activity level has been examined. Hand dominance has been shown to be a risk factor for tear progression in patients with asymptomatic RCTs.[10,12] Furthermore, a recent study by Ko et al demonstrated that occupational demand correlated with tear enlargement in symptomatic small to medium full-thickness tears.[13] However, Brophy et al showed no association of shoulder activity level with tear severity in a cohort of symptomatic RCTs undergoing nonoperative treatment.[1] Moreover, Keener et al showed that activity level and self-reported occupational or physical demand of the subjects did not correlate with risks of tear enlargement.[12] Our study suggests indirectly that in symptomatic disease, activity level may not correlate with a greater risk of tear enlargement or tendinopathy progression to tearing. While our analysis was limited in that it did not specify dominant, vs. nondominant extremity, dominance may be inferred indirectly as left handedness has a prevalence of less than 10%.[15,26] These findings may suggest that mechanical overuse does not directly leads to rotator cuff disease progression.

*Limitations*

This study has limitations. Because the study was performed retrospectively, it prevents us from diagnostically confirming clinical disease and our analysis, including our demographic and clinical data, relies on the accuracy of the electronic medical record. Because the patients included in this study were identified by code database queries, there is a risk of inadequate identification of the entirety of patients who otherwise would have been appropriate for inclusion. Additionally, all patients included were treated at VA hospitals which may introduce inherent biases and limit generalizability, particularly with regards to sex as the majority of patients were male. Our study is also limited in the study design, which may be conducive to selection bias, in that only individuals who are seeking care are returning for clinic visits and further imaging. The design also suffers from survivorship bias, in that only patients who underwent a second MRI of bilateral shoulders were included in the study. This inherently includes patients who had a higher rate of symptomatic worsening of the shoulder and excludes patients who were subsequently treated surgically, or who improved conservatively after the initial MRI. However, our reported rate of overall disease progression was not higher than other studies. Finally, we are not able to examine hand dominance, and thus it is inferred that the right shoulder is usually dominant.

## Conclusion

RCTs are no more likely to progress on the right, as compared to the left side. Older age and less initial tendon retraction were found to be predictors of disease progression. These suggest that higher activity level may not associate with greater progression of rotator cuff disease. Future prospective studies evaluating progression rates between dominant vs. nondominant shoulders are warranted.

## Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: Peter Chalmers is a paid consultant for Arthrex and Depuy-Mitek, a paid speaker for Depuy, receives intellectual property royalties from Depuy, and serves on the editorial board for the Journal of Shoulder and Elbow Surgery. Robert Tashjian is a paid consultant for Stryker, Zimmer/Biomet, Enovis, and Mitek; has stock in Conextions, INTRAFUSE, and Genesis; receives intellectual

property royalties from Stryker, Shoulder Innovations, and Zimmer/Biomet; receives publishing royalties from Springer and the Journal of Bone and Joint Surgery; and serves on the editorial board for the Journal of Bone and Joint Surgery. The other authors certify that they have no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

## References


1. Brophy RH, Dunn WR, Kuhn JE, MOON Shoulder Group. Shoulder activity level is not associated with the severity of symptomatic, atraumatic rotator cuff tears in patients electing nonoperative treatment. Am J Sports Med 2014;42:1150-4. https://doi.org/10.1177/0363546514526854.
2. Burkhart SS, Esch JC, Jolson RS. The rotator crescent and rotator cable: an anatomic description of the shoulder's "suspension bridge." Arthrosc J Arthrosc Relat Surg 1993;9:611-6.
3. Cancienne JM, Brockmeier SF, Rodeo SA, Werner BC. Perioperative serum lipid status and statin use affect the revision surgery rate after arthroscopic rotator cuff repair. Am J Sports Med 2017;45:2948-54. https://doi.org/10.1177/0363546517717686.
4. Chakravarty K, Webley M. Shoulder joint movement and its relationship to disability in the elderly. J Rheumatol 1993;20:1359-61.
5. Cho NS, Moon SC, Jeon JW, Rhee YG. The influence of diabetes mellitus on clinical and structural outcomes after arthroscopic rotator cuff repair. Am J Sports Med 2015;43:991-7. https://doi.org/10.1177/0363546514565097.
6. Chung S, Oh J, Gong H, Kim JY, Kim S. Factors affecting rotator cuff healing after arthroscopic repair: osteoporosis as one of the independent risk factors. Am J Sports Med 2011;39:2099-107. https://doi.org/10.1177/0363546511415659.
7. Frandsen JJ, Quinlan NJ, Smith KM, Lu C-C, Chalmers PN, Tashjian RZ. Symptomatic rotator cuff tear progression: conservatively treated full- and partial-thickness tears continue to progress. Arthrosc Sports Med Rehabil 2022;4:e1091-6. https://doi.org/10.1016/j.asmr.2022.03.006.
8. Hebert-Davies J, Teefey SA, Steger-May K, Chamberlain AM, Middleton W, Robinson K, et al. Progression of fatty muscle degeneration in atraumatic rotator cuff tears. J Bone Joint Surg Am 2017;99:832-9. https://doi.org/10.2106/JBJS.16.00030.
9. Kartus J, Kartus C, Rostgård-Christensen L, Sernert N, Read J, Perko M. Long-term clinical and ultrasound evaluation after arthroscopic acromioplasty in patients with partial rotator cuff tears. Arthroscopy 2006;22:44-9. https://doi.org/10.1016/j.arthro.2005.07.027.
10. Keener JD, Galatz LM, Teefey SA, Middleton WD, Steger-May K, Stobbs-Cucchi G, et al. A prospective evaluation of survivorship of asymptomatic degenerative rotator cuff tears. J Bone Joint Surg Am 2015;97:89-98. https://doi.org/10.2106/JBJS.N.00099.
11. Keener JD, Hsu JE, Steger-May K, Teefey SA, Chamberlain AM, Yamaguchi K. Patterns of tear progression for asymptomatic degenerative rotator cuff tears. J Shoulder Elbow Surg 2015;24:1845-51. https://doi.org/10.1016/j.jse.2015.08.038.
12. Keener JD, Skelley NW, Stobbs-Cucchi G, Steger-May K, Chamberlain AM, Aleem AW, et al. Shoulder activity level and progression of degenerative cuff disease. J Shoulder Elbow Surg 2017;26:1500-7. https://doi.org/10.1016/j.jse.2017.05.023.
13. Ko SH, Na SC, Kim MS. Risk factors of tear progression in symptomatic small to medium size full-thickness rotator cuff tear: relationship between occupation ratio of supraspinatus and work level. J Shoulder Elbow Surg 2022;32(3):565-72. https://doi.org/10.1016/j.jse.2022.09.012.
14. Kong BY, Cho M, Lee HR, Choi YE, Kim SH. Structural evolution of non-operatively treated high-grade partial-thickness tears of the supraspinatus tendon. Am J Sports Med 2018;46:79-86. https://doi.org/10.1177/0363546517729164.
15. Kuhlemeier KV. Longevity and left-handedness. Am J Public Health 1991;81:513.
16. Mall NA, Kim HM, Keener JD, Steger-May K, Teefey SA, Middleton WD, et al. Symptomatic progression of asymptomatic rotator cuff tears: a prospective study of clinical and sonographic variables. J Bone Joint Surg Am 2010;92:2623-33. https://doi.org/10.2106/JBJS.I.00506.
17. Maman E, Harris C, White L, Tomlinson G, Shashank M, Boynton E. Outcome of nonoperative treatment of symptomatic rotator cuff tears monitored by magnetic resonance imaging. J Bone Joint Surg Am 2009;91:1898-906. https://doi.org/10.2106/JBJS.G.01335.
18. Monrad N, Ganestam A, Kallemose T, Barfod KW. Alarming increase in the registration of degenerative rotator cuff-related lesions a nationwide epidemiological study investigating 244,519 patients. Knee Surg Sports Traumatol Arthrosc 2018;26:188-94. https://doi.org/10.1007/s00167-017-4626-3.
19. Moosmayer S, Gärtner AV, Tariq R. The natural course of nonoperatively treated rotator cuff tears: an 8.8-year follow-up of tear anatomy and clinical outcome in 49 patients. J Shoulder Elbow Surg 2017;26:627-34. https://doi.org/10.1016/j.jse.2016.10.002.
20. Moosmayer S, Tariq R, Stiris M, Smith H-J. The natural history of asymptomatic rotator cuff tears: a three-year follow-up of fifty cases. J Bone Joint Surg Am 2013;95:1249-55. https://doi.org/10.2106/JBJS.L.00185.
21. Motta G, Amaral M, Rezende E, Pitta R, Vieira T, Duarte M, et al. Evidence of genetic variations associated with rotator cuff disease. J Shoulder Elbow Surg 2013;23:227-35. https://doi.org/10.1016/j.jse.2013.07.053.
22. Nakamura Y, Yokoya S, Mochizuki Y, Harada Y, Kikugawa K, Ochi M. Monitoring of progression of nonsurgically treated rotator cuff tears by magnetic resonance imaging. J Orthop Sci 2015;20:314-20. https://doi.org/10.1007/s00776-014-0680-6.
23. Quinlan NJ, Frandsen JJ, Smith KM, Lu C-C, Chalmers PN, Tashjian RZ. Conservatively treated symptomatic rotator cuff tendinopathy may progress to a tear. Arthrosc Sports Med Rehabil 2022;4:e1449-55. https://doi.org/10.1016/j.asmr.2022.05.004.
24. Safran O, Schroeder J, Bloom R, Weil Y, Milgrom C. Natural history of non-operatively treated symptomatic rotator cuff tears in patients 60 years old or younger. Am J Sports Med 2011;39:710-4. https://doi.org/10.1177/0363546510393944.
25. Smith KM, Hotaling JM, Presson AP, Zhang C, Horns JJ, Cannon-Albright LA, et al. The effect of sex hormone deficiency on the incidence of rotator cuff repair: analysis of a large insurance database. J Bone Joint Surg Am 2022;104:774-9. https://doi.org/10.2106/JBJS.21.00103.
26. Stellman SD, Wynder EL, DeRose DJ, Muscat JE. The epidemiology of left-handedness in a hospital population. Ann Epidemiol 1997;7:167-71.
27. Tashjian RZ, Granger EK, Zhang Y, Teerlink CC, Cannon-Albright LA. Identification of a genetic variant associated with rotator cuff repair healing. J Shoulder Elbow Surg 2016;25:865-72. https://doi.org/10.1016/j.jse.2016.02.019.
28. Tashjian RZ, Hollins AM, Kim H-M, Teefey SA, Middleton WD, Steger-May K, et al. Factors affecting healing rates after arthroscopic double-row rotator cuff repair. Am J Sports Med 2010;38:2435-42. https://doi.org/10.1177/0363546510382835.
29. Yamaguchi K, Tetro AM, Blam O, Evanoff BA, Teefey SA, Middleton WD. Natural history of asymptomatic rotator cuff tears: a longitudinal analysis of asymptomatic tears detected sonographically. J Shoulder Elbow Surg 2001;10:199-203.
30. Yamamoto N, Mineta M, Kawakami J, Sano H, Itoi E. Risk factors for tear progression in symptomatic rotator cuff tears: a prospective study of 174 shoulders. Am J Sports Med 2017;45:2524-31. https://doi.org/10.1177/0363546517709780.