

Symptomatic Rotator Cuff Tear Progression: Conservatively Treated Full- and Partial-Thickness Tears Continue to Progress



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Purpose: To determine the likelihood of and risk factors for tear progression among patients with a symptomatic partial or full-thickness rotator cuff tears (RCTs) who return with continued shoulder pain and obtain subsequent magnetic resonance imaging (MRI) and to identify various patient factors and MRI findings associated with rotator cuff tear progression. **Methods:** We performed a retrospective review of MRI studies from Veteran's Affairs patients with conservatively treated partial- or full-thickness rotator cuff tears. Patient characteristics and demographics were obtained via chart review. Tear characteristics were measured on MRI obtained a minimum of 1 year apart. We defined progression as either (1) an increase from a partial to a full-thickness tear or (2) an increase in tear width or retraction of at least 5 mm. Statistical analysis using χ^2 , Fisher exact, Student *t*, and Mann–Whitney *U* test was then performed as appropriate, looking for factors involved in RCT progression. **Results:** We evaluated 412 MRI studies from 206 Veteran's Affairs patients with conservatively treated partial- or full-thickness rotator cuff tears from October 1999 to March 2020. Overall, 61% of RCTs had progressed at a mean of 3.2 ± 2.3 years follow-up. Among all patients, 74% of full-thickness tears progressed in size, 42% of partial-thickness tears progressed in size, and 29% of partial-thickness tears progressed to full-thickness tears. On univariate analysis, full-thickness tears ($P < .001$), disruption of the anterior rotator cuff cable ($P = .001$), subscapularis involvement ($P = .004$), tear retraction ($P < .001$), and tear width ($P < .001$) all increased the likelihood of progression. On multivariate analysis, full-thickness tears ($P < .001$) and subscapularis involvement ($P = .045$) were correlated with progression. **Conclusions:** RCTs progress over time in terms of size of tear and from partial- to full-thickness tears. There is an increased risk of tear progression in patients with full-thickness tears when compared with partial-thickness tears along with subscapularis tear involvement. Rates of progression are larger than previously reported rates for both partial- and full-thickness tears, noting that our study population were those patients who continued to be symptomatic from their tears. **Level of Evidence:** Level IV, prognostic case series.

Rotator cuff tears (RCTs) are a well-known cause of shoulder pain and dysfunction. Rotator cuff tearing, either partial- or full-thickness tearing, increases significantly with age.^{1,2} Several studies have reported the natural history of RCTs, examining symptomatic and asymptomatic partial- and

full-thickness tear progression or enlargement.³⁻¹⁵ Partial-thickness tears progress less often and at a slower rate than full-thickness tears, with symptomatic and asymptomatic full-thickness tears progressing at a rate of 50% at 2 to 3 years.^{3,7-9} Understanding the natural history of RCT progression improves the ability

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for appropriate treatment selection, either operative or nonoperative. Although informative, previous studies are limited by small sample sizes.

Various patient factors and tear characteristics have been associated with tear progression or enlargement. Symptomatic tear progression has been associated with recurrence of shoulder pain, longer duration from initial injury, age greater than 60 years, initial fatty infiltration of the muscle (greater Goutallier grade), medium-sized tears, full-thickness tears, tears with 1 to 4 cm of retraction, and smoking.^{9,10,12,13,15} Asymptomatic tear progression also has been investigated and is associated with full-thickness tears versus partial-thickness tears,^{4,6,8,14} dominant arm,⁶ fatty atrophy,² and development of pain.^{4,8,11} Larger studies improve the ability to identify other factors (i.e., concomitant subscapularis injury, disruption of the rotator cuff anterior cable, hormonal dysregulation, etc.) associated with tear progression, improving the ability to triage patients who may be more appropriately treated with surgical or nonsurgical treatment.

The purposes of this study were to determine the likelihood of and risk factors for tear progression among patients with symptomatic partial- or full-thickness RCTs who return with continued shoulder pain and obtain subsequent magnetic resonance imaging (MRI) and to identify various patient factors and MRI findings associated with rotator cuff tear progression. We hypothesized that RCTs would tend to progress over time at greater rates than previously reported and that there would be various tear characteristics and patient risk factors not previously identified that associate with these greater rates of progression.

Methods

Patient Selection

This study was approved by the institutional review board associated with our institution (approved protocol #IRB_00111481) and the local Veteran's Affairs (VA) Health System. Adult patients (>18 years of age) treated over a 20-year period (October 1, 1999, to March 1, 2020) for shoulder pain were identified via

Current Procedural Terminology and International Classification of Diseases codes (Appendix Table 1, available at www.arthroscopyjournal.org) and retrospectively reviewed. Patients were included if they had a partial- or full-thickness RCT identified on MRI and subsequent MRI with longer than 1 year between scans. Patients had to be treated nonoperatively, although they could be treated with conservative measures including physical therapy and corticosteroid injections. We excluded patients whose imaging was not accessible via the VA medical imaging system, the Joint Legacy Viewer database. Patients also were excluded if they had no evidence of a tear, underwent a rotator cuff repair between MRI scans or before first scan, or if they had less than a year between scans.

Data Collection

Retrospective chart review via the VA's computerized patient record system was performed to collect patient characteristics and demographics. Age, sex, body mass index (BMI), diabetes mellitus, hyperlipidemia, osteoporosis, hypogonadism, and smoking status were collected.

MRI cuff tear measurements (to the nearest 0.1mm) were completed by 2 of the authors. A subset of 67 patients (134 MRIs) was initially measured by both investigators, and inter- and intraobserver reliability were calculated. Intraobserver reliability was performed in a blinded fashion approximately 1 week apart. Once the tear measurements were shown to have acceptable reliability (Table 1), the remainder of the cohort's imaging was evaluated independently by either investigator. MRIs were performed via the VA Healthcare System on 1.5-T MRI scanners with 2-mm slice thickness.

RCT characteristics evaluated on MRI included tear morphology (partial- vs full-thickness), anteroposterior (AP) tear length, tendon retraction, anterior rotator cable integrity, associated subscapularis tear, and supraspinatus atrophy (Goutallier grade). Partial tears were differentiated based on whether they were articular, intrasubstance, or bursal. AP tear length (measured on T2 sagittal images) and lateral-to-medial tear retraction (measured on T2 coronal images) were measured in tenths of millimeters. The anterior rotator

Table 1. Reliability Statistics

Variable	Interobserver	Interobserver 1	Interobserver 2	Interobserver Average
κ				
Thickness	0.801	0.989	0.773	0.881
Goutallier supra	0.756	0.774	0.947	0.861
Subscapularis tear	0.795	0.716	0.49	0.60
Intraclass correlation coefficients				
Tendon retraction	0.981 [0.972-0.987]	0.995 [0.993-0.996]	0.971 [0.957-0.980]	
AP tear length	0.954 [0.933-0.968]	0.998 [0.984-0.992]	0.878 [0.826-0.916]	
Anterior cable width	0.757 [0.626-0.846]	0.849 [0.775-0.900]	0.754 [0.618-0.847]	

AP, anteroposterior.

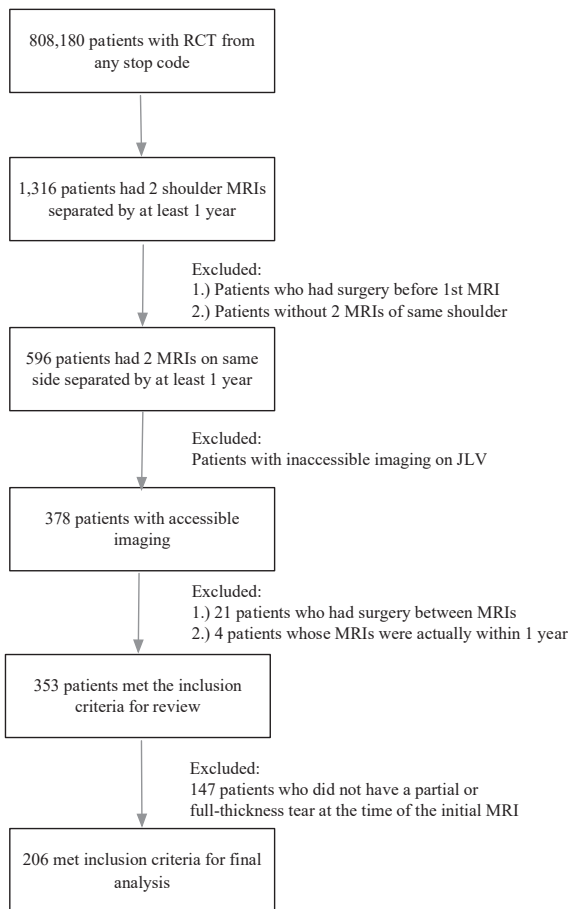


Fig 1. Patient selection flowchart. (JLV, Joint Legacy Viewer; MRI, magnetic resonance imaging; RCT, rotator cuff tear.)

cable (measured on T2 sagittal images) was considered intact if it had continuity from the posterior edge of the biceps groove to the anterior aspect of the tear. A subscapularis tear (measured on T1 and T2 axial images) was included in analysis only if it was a full-thickness tear. Fatty infiltration of the supraspinatus was considered to be significant if it was Goutallier grade 3 or 4. Goutallier grades were measured on T1 sagittal images on the scapular Y slice. Tear progression was defined as either (1) an increase from a partial to a full-thickness tear or (2) an increase in tear width or retraction of at least 5 mm.¹⁴

Statistical Methods

Descriptive statistics were calculated using the retrospectively collected data. Both inter- and intraobserver reliabilities were calculated. For discrete variables, we calculated κ and a priori set 0.6 as the minimum acceptable reliability. For continuous variables, we calculated the intra-class correlation coefficient and a priori set 0.75 as the minimum acceptable reliability (Table 1). For the progression analysis, patients with 1 to 2 years’ follow-up were considered to have a minimum of 1-year follow-up, patients with 2 to 5 years’

follow-up were considered to have a minimum of 2 years’ follow-up, and patients with >5 years’ follow-up were considered to have a minimum of 5 years’ follow-up. Discrete variables were compared between patients who progressed and those who did not progress using χ^2 and Fisher exact tests as appropriate based upon cell volumes. Continuous variables were compared between those who progressed and those who did not progress using Student *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 conducted including those variables found to be significant on univariate analysis. R^2 values were estimated using the Nagelkerke method.

Results

Patient Demographics

Initial Current Procedural Terminology code query identified 378 patients with a rotator cuff diagnosis and

Table 2. Cohort Characteristics

Variables	Value
Demographics	
Right side	55% (114/206)
Age, y	60 ± 10
BMI	30 ± 5
Time between scans, y	3.2 ± 2.3
Male sex	94% (193/206)
Risk factors	
Diabetes	34% (70/206)
Osteoporosis	2% (3/206)
Tobacco	21% (43/206)
Hyperlipidemia	75% (154/206)
Hypogonadism	5% (10/193)
First time point tear measurements	
Full tear	59% (121/206)
Partial tear	41% (85/206)
Articular partial tear	61% (52/85)
Bursal partial tear	20% (17/85)
Intrasubstance partial tear	19% (16/85)
Cable intact	64% (132/206)
Subscapularis torn	10% (20/206)
Supraspinatus atrophy	12% (24/201)
Tendon retraction, mm	16 ± 15
Tear width, mm	16 ± 13
Second time point tear measurements	
Full tear	71% (146/206)
Partial tear	27% (55/206)
No tear	2% (5/206)
Articular partial tear	62% (34/55)
Bursal partial tear	24% (13/55)
Intrasubstance partial tear	15% (8/55)
Cable intact	45% (93/206)
Subscapularis torn	17% (35/206)
Supraspinatus atrophy	26% (53/201)
Tendon retraction, mm	25 ± 18
Tear width, mm	23 ± 15

NOTE. Discrete variables are displayed as % (N), and continuous variables are displayed as mean ± standard deviation. BMI, body mass index.

Table 3. Tear Progression Time Points

Time, y	Partial Tears	Full Tears	Total Cohort
1	39% (12/31)	72% (31/43)	58% (43/74)
2	40% (16/40)	71% (41/58)	58% (57/98)
5	57% (8/14)	85% (17/20)	74% (25/34)

NOTE. The percent and number of patients with tear progression at each time point.

shoulder MRIs of the same side performed at least 1 year apart with accessible imaging. Of these patients, 21 were excluded as they underwent a rotator cuff repair between scans and 4 were excluded because there was less than a year between scans. Of the remaining 353 patients, 147 had no evidence of RCT the initial scan, and thus were excluded, leaving 206 patients in the final study cohort (Fig 1).

Of the 206 patients included in the study, 94% were male with an average age of 60 years and an average BMI of 30. In total, 55% of the RCTs were right sided, and 75% of patients had hyperlipidemia, 34% had diabetes, 21% currently used tobacco, 5% had hypogonadism, and 2% had an official diagnosis of osteoporosis (Table 2).

Tear Characteristics

Measurements of tear thickness (partial or full), Goutallier grade of supraspinatus, associated full-thickness subscapularis tear, tendon retraction, AP tear length, and anterior cable width were found to have acceptable inter- and intraobserver reliability (Table 1). At initial MRI, 59% of patients had full-thickness tears and 41% had partial-thickness tears. Of the partial tears seen on initial imaging, 58% were articular, 22% were bursal, and 20% were intra-substance. The anterior rotator cable was intact in 64%, subscapularis was torn in 10%, and fatty atrophy was present in the supraspinatus in 12% of patients. The average AP tear width was 16 ± 13 mm and average tendon retraction was 16 ± 15 mm.

Tear Progression

Overall, 61% of the cohort were considered to have progression on their second MRI performed at a mean of 3.2 ± 2.3 years follow-up according to our parameters of (1) an increase from a partial to a full-thickness tear or (2) an increase in tear width or retraction of at least 5 mm (Table 3). 74% of full-thickness tears progressed. In total, 42% of partial-thickness tears progressed. Among partial tears, 29% progressed to full-thickness tears whereas 13% just progressed in size (Tables 3 and 4).

Patients with tears were then subdivided into groups based on minimum follow-up: 1, 2, or 5 years. Partial-thickness tears tended to progress over time, with increasing rates of progression over time. Of 31 tears

evaluated at 1 year, 6% could no longer be seen to be torn, 55% did not progress, 13% progressed to larger partial-thickness tears, and 26% progressed to full-thickness tears. Of 40 tears evaluated at 2 years, 8% could no longer be seen to be torn, 53% did not progress, 15% progressed to larger partial-thickness tears, and 25% progressed to full-thickness tears. Of 14 tears evaluated at 5 years, 43% did not progress, 7% progressed to larger partial-thickness tears, and 50% progressed to full-thickness tears (Table 4). Full-thickness tears also progressed over time. Of 43 tears evaluated at 1 year, 72% progressed; of 58 tears evaluated at 2 years, 71% progressed; and of 20 tears evaluated at 5 years, 85% progressed. None of the full-thickness tears in our cohort healed spontaneously.

Risk Factors for Tear Progression

Univariate analysis showed that full-thickness tears were significantly more likely to progress when compared with partial-thickness tears ($P = .001$). Other factors associated with tear progression included rotator cable integrity ($P = .001$), subscapularis involvement ($P = .004$), tear retraction ($P < .001$), and tear width ($P < .001$, Table 5). Hypogonadism also was associated with tear progression ($P = .049$), but very few patients had hypogonadism and, thus, this finding is very fragile. Age, BMI, time between scans, supraspinatus atrophy, sex, diabetes status, osteoporosis, tobacco use, and hyperlipidemia were not associated with tear progression (Table 5).

In the multivariate analysis, both subscapularis involvement and partial- versus full-thickness tear status were independently correlated with tear progression (Table 6). We found a tear progression odds ratio of 0.21 (95% confidence interval 0.05-0.38) with an intact subscapularis and a tear progression odds ratio of 3.20 (95% confidence interval 1.73-4.67) with a full-thickness vs partial-thickness tear. A model constructed with these 2 variables could correctly predict tear progression in 68% of cases within our dataset. However, using the R^2 method, these 2 variables only explained 15% of the variation in progression.

Discussion

We determined that tear progression was associated with longer duration of time from injury, full-thickness

Table 4. Partial Tear Progression Time Points

Time, y	Partial-No	Unprogressed	Progressed	Partial-Full Tear
	Tear	Partial Tear	Partial Tear	
1	6% (2/31)	55% (17/31)	13% (4/31)	26% (8/31)
2	8% (3/40)	53% (21/40)	15% (6/40)	25% (10/40)
5	0% (0/14)	43% (6/14)	7% (1/14)	50% (7/14)

NOTE. The percent and number of patients with tear progression at each time point among partial tears.

Table 5. Univariate Analysis of Risk Factors for Tear Progression

Variable	Nonprogressed	Progressed	P Value
Demographics			
Male sex	93% (75/81)	94% (118/125)	.602
Age, y	59 ± 11	61 ± 10	.097
BMI	30 ± 6	30 ± 5	.098
Time between scans, y	2.8 ± 1.7	3.5 ± 2.5	.104
Medical risk factors			
Diabetes	35% (28/81)	34% (42/125)	.886
Osteoporosis	1% (1/81)	2% (2/125)	.831
Tobacco use	21% (17/81)	21% (26/125)	1.000
Hyperlipidemia	72% (58/81)	77% (96/125)	.402
Hypogonadism	9% (7/75)	3% (3/118)	.049
Tear characteristics			
Full-thickness tear	40% (32/81)	71% (89/125)	<.001
Cable intact	78% (63/81)	54% (68/125)	.001
Supraspinatus atrophy	9% (7/79)	13% (16/123)	.365
Subscapularis torn	2% (2/81)	14% (18/125)	.004
Tear width, mm	12 ± 11	18 ± 13	<.001
Tear retraction, mm	13 ± 16	18 ± 14	<.001

NOTE. Discrete variables are displayed as % (N), and continuous variables are displayed as mean ± standard deviation.

tears, associated full-thickness subscapularis tears, a disrupted anterior rotator cuff cable, larger anteroposterior tears, and larger tendon retraction. The average tear width and tendon retraction of tears that progressed was 18 mm compared with 12 mm and 13 mm, respectively, for those that did not progress. At 5 years, we identified rates of progression of 85% for full-thickness tears and 57% for partial-thickness tears, which is significantly greater than previously reported rates of progression.¹⁰ We also identified that disruption of the anterior rotator cuff cable on univariate analysis and the addition of a full-thickness subscapularis tear on multivariate analysis associated with rotator cuff tearing, which has not previously been reported in previous natural history studies.

Our analysis showed that partial-thickness tears can progress to full-thickness tears, increasing in percentage with longer duration of time. In total, 26% of partial-thickness tears in the ≥1-year follow up group, 25% of ≥2-year follow-up group, and 50% of the ≥5-year follow-up group had progressed to full-thickness tears. Our study found a slightly greater rate of progression to full-thickness tears than what has previously been reported. However, the overall trend is consistent with existing literature, suggesting that time is an independent risk factor of partial- to full-thickness tear progression. Mall et al.⁸ found that 40% of partial-thickness tears that became symptomatic progressed to full-thickness tears with 2-year follow up. Kartus et al.³ found that 35% of symptomatic partial-thickness tears progressed to full-thickness after scope subacromial decompression at an average of 8 years. Maman et al.⁹ found that in 30 patients with

supraspinatus tears and good muscle quality only 3 tears progressed at 2 years. Based on these rates, it is reasonable to say that partial-thickness tears that continue to be symptomatic have up to a 50% progression rate to full-thickness tears at 5 years, with an additional 7% of patients progressing to a larger partial-thickness tear at the same time point.

We determined that 74% of symptomatic full-thickness RCTs progress in size on a second MRI at an average of 3.3 years from the initial MRI. We found that full-thickness tears were 3 times more likely to progress than partial-thickness tears. Multivariate analysis showed that a tear was 5 times more likely to progress with an associated full-thickness subscapularis tear which has not been previously identified. A model constructed with these 2 variables could correctly predict tear progression in 68% of cases within our dataset. Full-thickness tears have previously been shown to progress at greater rates than partial-thickness tears. Yamamoto et al.¹⁵ 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.¹³ studied 51 full-thickness tears in patients 60 and younger and found that 49% increased in size (>5 mm) at an average of 29 months. They also noted that pain at follow-up correlated with tear progression (56% pain vs 25% no pain). Using this information may help the provider properly counsel their patient that their symptomatic full-thickness tear has an almost 75% chance of progressing at an average of 3.3 years after the first MRI and if they have an associated full-thickness subscapularis tear, their odds of progression are even greater.

We were able to confirm in univariate analysis findings consistent with other authors including an association of tear progression with AP tear size and tendon retraction. We found that tears with an average AP tear size of 18 mm and an average tendon retraction of 18 mm were the most likely to progress. Previous studies reported that medium-sized tears (1-3 cm as defined by DeOrio et al.) were the most likely to progress.^{10,12,15} The rotator cable, described by Burkhart et al.¹ as the suspension bridge of the shoulder, is a thickened band of tissue that runs anterior to posterior at the margin of the rotator crescent of the supraspinatus and

Table 6. Multivariate Analysis of Risk Factors for Tear Progression

Variable	P Value	Odds Ratio (95% CI)	R ² Change
Full-thickness tear	<.001	3.20 (1.73-4.67)	0.114
Subscapularis intact	.045	0.21 (0.05-0.38)	0.035

CI, confidence interval.

infraspinatus tendons in the shoulder. Within our cohort, a torn rotator cable was associated with progression. In patients with no tear progression, 78% had an intact rotator cable whereas in patients with tear progression, 54% had an intact rotator cable (Table 5). This is in contrast to a previous study, where no difference in tear progression was found whether or not the rotator cable was intact or not.⁵ While the finding was only significant in univariate testing, rotator cable disruption appears to be another risk factor to identify on a patient's MRI and to include in the provider's discussion with the patient on the probability of their tear progressing.

Limitations

This study is not without limitations. The retrospective nature of this study along with the fact that all patients included were treated at VA hospitals introduce inherent biases and limit generalizability, particularly with regards to sex as most included patients were male. There were fewer patients in our 5-year follow up cohort compared with our 1- and 2-year follow-up cohorts. This may create a selection bias and inflate the perceived rate of progression with time as those patients who followed up at 5 years were more likely to be symptomatic due to their tear progression. Progression of rotator cuff tears was evaluated, however, whether progression affects patient outcomes was not evaluated. There is inherent selection bias introduced by our study design to only examine patients with 2 MRIs.

Conclusions

Symptomatic RCTs progress over time in terms of size of tear and from partial- to full-thickness tears. There is an increased risk of tear progression in patients with full-thickness tears when compared with partial-thickness tears along with subscapularis tear involvement. Rates of progression are larger than previously reported rates for both partial- and full-thickness tears, noting that our study population were those patients who continued to be symptomatic from their tears.

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