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Degenerative Rotator Cuff Tears: Refining Surgical Indications Based on Natural History Data

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Abstract

Degenerative rotator cuff tears are the most common cause of shoulder pain and have a strong association with advanced aging. There is considerable variation in surgeons' perceptions regarding the recommended treatment for patients with painful rotator cuff tears. Natural history studies have better outlined the risks of tear enlargement, progression of muscle degeneration and decline in function over time. This information combined with known factors that potentially influence the rate of successful tendon healing such as age, tear size and severity of muscle degenerative changes can be used to better refine appropriate surgical indications. Although conservative treatment can be successful in the management of many of these tears, there are risks to nonoperative treatment as well. The application of natural history data can stratify atraumatic degenerative tears according to the risk of nonoperative treatment and better identify tears where early surgical intervention should be considered.

Keywords

Rotator Cuff; Degenerative; Natural History; Surgical Indications; Treatment

Background

Rotator cuff disease is the most common cause of shoulder disability and is especially prevalent in the aging population¹. Many authors have suggested that rotator cuff disease is a natural aging phenomenon given the strong association with age and the fact that most tears are asymptomatic^{2,3}. Cadaveric and in vivo imaging studies have shown rates of asymptomatic rotator cuff tears increase proportionally with age, with 20% of patients in their 60s and up to 80% of patients over 80 years-old having tears². Yamaguchi et al found that patients with a painful cuff tear age 66 years or older have a 50% chance of having a contralateral rotator cuff tear that is often unknown to the patient⁴. Asymptomatic tears have been shown to develop pain in approximately 30–40% of patients within 2 to 5 years^{16,19–21}.

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Additionally, male gender, dominant arm, history of heavy labor, certain acromial characteristics and genetic factors correlate with rotator cuff tears^{5,6}.

Although the natural history of degenerative rotator cuff tears has recently been better defined, there remain many unanswered questions regarding risk factors for disease progression, in particular pain development. Natural history studies are fundamental for developing appropriate treatment algorithms. Despite the high prevalence of rotator cuff pathology, substantial controversy exists regarding the optimal treatment of symptomatic rotator cuff disease⁷. Trends in nonoperative management and rotator cuff repair have varied significantly over time⁸. Further complicating matters, it has been shown that symptom duration does not correlate with rotator cuff tear severity or other patient factors⁹. Clinical guidelines provided by the American Academy of Orthopaedic Surgeons on the treatment of rotator cuff disease are largely weak or inconclusive due to a lack of high-quality evidence. Their recommendations highlight the need for further research to better define the natural history of rotator cuff disease and the results of both operative and nonoperative intervention to further refine treatment recommendations¹⁰.

Tear Characteristics – Degenerative Cuff Disease

The insertional anatomy of the rotator cuff must be considered when discussing degenerative rotator cuff tears. Mochizuki et al showed that the supraspinatus footprint on the greater tuberosity was much smaller than previously thought. The insertion extends a mean of 12.6 mm in the anterior to posterior direction into a tapered insertion that is much smaller laterally than medially. The infraspinatus tendon curves anteriorly covering a mean of 32.7 mm of the superior and posterior greater tuberosity in the sagittal plan¹¹ (Figure 1). Previous studies of the infraspinatus tendon footprint cited a range from 16 to 29 mm in the anterior to posterior dimension. Mochizuki et al highlighted the morphology of infraspinatus tendon as curving superiorly onto the greater tuberosity sweeping lateral the supraspinatus insertion. These findings are clinically relevant in that many tears classified as isolated to the supraspinatus tendon based upon previous anatomic definitions actually also involve the infraspinatus tendon.

Degenerative rotator cuff tears develop from age-related changes that may be directly related to the poor vascularity of the rotator crescent. Along a continuum, tears likely progress from tendinopathy to partial to full-thickness tears over time. Prior theories that degenerative tears begin at the anterior supraspinatus tendon insertion adjacent to the biceps tendon have been challenged by prospective research. Kim et al mapped the common locations of asymptomatic and symptomatic full-thickness degenerative cuff tears in 272 patients using ultrasound measuring the distance from the anterior tear margin to the biceps tendon. Only 33% of tears involved the most anterior aspect of the supraspinatus tendon (Figure 2). The most common location of tears involved an area 13–17mm posterior to the biceps tendon. Small full-thickness tears most commonly involved an area 15mm posterior to the biceps tendon suggesting that degenerative tears most commonly originate here¹². This region correlates with the infraspinatus and supraspinatus junction commonly described as the rotator crescent which is bordered by the rotator cable¹¹. Isolated small and medium-sized tears with or without disruption of the anterior supraspinatus tendon were compared by

Namdari et al¹³. They found that anterior supraspinatus disrupted tears had a larger tear size and possessed greater supraspinatus muscle degeneration. However, no differences in baseline or post-surgical functional outcomes (ASES 92 vs. 93) or healing rates (93% vs. 86%) for anterior supraspinatus intact versus disrupted tears were seen¹³.

Disruption of the rotator cuff tendon is felt to lead to muscular fatty infiltration and atrophy secondary to tendon retraction and impaired force transmission. Rotator cuff tear size and location are directly related to patterns of fatty muscle degeneration. Kim et al demonstrated that fatty degeneration was nearly exclusive to full-thickness tears¹⁴. Thirty-five percent of the shoulders had evidence of fatty degeneration on ultrasound and tears with fatty degeneration had a greater width and length than those without. In this cohort, disruption of the anterior supraspinatus insertion (anterior cable) was the most important predictor of supraspinatus muscle degeneration while larger tear size was the best predictor of infraspinatus muscle degeneration¹⁴.

Natural History

Tear Enlargement and Pain Progression

Defining the risks of tear progression and symptom development are critical in developing treatment algorithms and can be best understood by looking at natural history studies. The natural history of degenerative rotator cuff tears has been recently defined in asymptomatic patients followed prospectively. Given that rotator cuff disease is often bilateral, screening the contralateral shoulder in patients with a painful rotator cuff tear provides a valuable study group where no treatment intervention is needed^{4,15}. Keener et al examined risks of cuff tear enlargement and pain development in 224 asymptomatic shoulders with known full-thickness tears(118), partial-thickness tears(56), and intact rotator cuffs(50) followed annually with ultrasound and clinical examination¹⁶ (Table 1). At 5-years of follow-up, the risk of tear enlargement of 5mm or greater was 49%. Tear severity (full-thickness vs. partial-thickness) and hand dominance were associated with a greater enlargement risks; however, subject age, gender and baseline tear size were not. The risks of tear enlargement were 22% and 50% at 2 and 5-years, respectively, for full-thickness and 11% and 35% for partial-thickness tears. This data suggests that although tear progression is common, the timeline is relatively slow. Keener et al investigated tear progression in anterior supraspinatus intact compared to disrupted tears in 139 patients with minimum 2-year follow-up. They found no statistical difference in the risk of enlargement, time to enlargement, or magnitude of enlargement between groups. Although, there was a trend toward greater enlargement risks and quicker time to enlargement in the cable-disrupted (67%, 2.2 years) vs. intact (52%, 3.2 years, $p=0.09$ and $p=0.37$, respectively) tears¹⁷.

The factors important for pain development in shoulders with asymptomatic tears are not clearly defined¹⁸. Interestingly, in patients presenting with a painful rotator cuff tear, disease severity does not correlate well with VAS pain scores. Both Mall¹⁵, and Keener et al¹⁷ have prospectively demonstrated that tear enlargement is a risk factor for pain development; however, there are not absolute correlations. In the study by Keener et al, 46% of asymptomatic shoulders developed pain over a 5-year period¹⁷. Although the risk of pain development was approximately 70% more likely if enlargement occurred, 37% of the newly

painful shoulders did not enlarge and 38% of enlarged tears remained asymptomatic. Pain development was associated a clinically significant decline in shoulder function. There are clearly factors other than tear enlargement that play a role in pain development in shoulders with degenerative tears and it is important to remember that other potential pain generators may play a role in symptom onset.

Multiple other studies with variable methodologies have attempted to define the tear enlargement risks in both asymptomatic and painful shoulders. Moosmayer et al prospectively followed 50 full-thickness degenerative rotator cuff tears for 3-years showing that 36% of patients developed symptoms. The symptomatic group had a larger increase in tear size, greater progression of muscle degeneration and more biceps pathology on follow-up imaging compared to those remaining asymptomatic¹⁹. In patients with symptomatic full-thickness tears managed nonoperatively, Safran et al demonstrated that 49% of tears increased in size within 2-years using ultrasound. The only variable associated with increased pain was tear enlargement at the time of follow-up²⁰. Using MRI, Maman et al retrospectively reviewed 59 patients with rotator cuff tears with imaging a different time points. They found that age greater than 60 years, full-thickness tears and fatty infiltration were all associated with tear progression, occurring in 19% at 18-months and 48% with follow-up beyond 18 months²¹. Moosmayer et al reported the findings of a selected subgroup of 49 subjects with small and medium-sized full-thickness tears followed for a mean of 8.8 years managed nonoperatively²². The authors excluded 23 shoulders requiring surgery during the study period. This study demonstrated great variability in the magnitude of tear enlargement (mean tear width increase was 8.3 mm). One third of the tears increased greater than 10 mm (half of these greater than 20 mm). Progression of degenerative muscle changes was noted in half the subjects. Shoulder function remained stable if the tear size increase was less than 10mm. Declining ASES and Constant scores were noted with tear enlargement greater than 20 mm and progression of muscle degeneration.

Progression of Muscle Degeneration

It has been well-recognized that larger and more chronic rotator tears are associated with a greater likelihood of advanced fatty muscle degeneration compared to smaller tears. However, the timeline for the progression of muscle degeneration and the risk factors for these changes have not been well-defined. Muscle degenerative changes are thought to be clinically relevant as they have been linked to poorer clinical outcomes and lower tendon healing rates following surgery (Figure 3). A recent report prospectively examined the risks of fatty muscle degeneration progression using ultrasonography²³. In a cohort of 156 full-thickness tears (the majority being small or medium-sized), 55% had some degree of fatty muscle degeneration during a follow-up period of 6.0 years. The presence of muscle degeneration was linked to older age and larger tear size at baseline. Progression of muscle degeneration was more common in tears that enlarged (43% vs. 20%). Progression of fatty muscle changes in enlarged tears was more common in tears that were larger at enrollment (13.0mm vs. 10.0mm), tears with a greater magnitude of enlargement (9.0mm vs. 5.0mm) and when the anterior supraspinatus was torn (53% vs. 17%). Although there was considerable variability in temporal progression of muscle changes compared to enlargement

events, the median time from an enlargement event to progression of muscle degeneration was 1.0 and 1.1 years for the supraspinatus and infraspinatus, respectively.

Factors Affecting Rotator Cuff Healing

When considering operative treatment, it is paramount to understand factors that influence rotator cuff healing. Although the correlation between successful tendon healing and clinical outcomes is debated, it is generally felt that better and more consistent clinical results are obtained following a successful tendon healing. Therefore, identification of factors that better predict and surgical strategies that improve tendon healing are important in identifying optimal surgical candidates. Park et al. reported on 339 patients undergoing arthroscopic rotator cuff repair for small and medium-sized tears²⁴. They found patient age, tear size, and fatty infiltration of the cuff muscles to be important risk factors in the development of recurrent rotator cuff tears. Multiple other studies have consistently shown that patient age, tear size, and fatty muscle infiltration are key factors in predicting tendon healing following rotator cuff repair.

Patient age plays an important role in cuff tendon healing following surgery. Early literature from Harryman et al revealed a strong correlation with rotator cuff healing and patient age with older patients more likely demonstrating recurrent defects²⁵. Boileau et al reviewed the healing rates and functional outcome of 65 consecutive patients with full-thickness tears treated with arthroscopic cuff repair²⁶. They reported complete healing in 71% of patients noting age to be strongly correlated with tendon healing. Patients with a healed repair were on average 10 years younger (57.8 ± 9.4 years) than those with a failed repair (68 ± 7.6 years). Furthermore, for patients under age 55 years the healing rate was 95% and for patients over 65 years the healing rate dropped to 43%²⁶. Oh et al reported on 187 patients undergoing arthroscopic or mini-open rotator cuff repair with a minimum follow-up of one year²⁷. The average age of patients with an intact repair CT arthrogram was 58 years compared to 63 years for those patients with a retear. They also found that tendon retraction and fatty infiltration of the infraspinatus were risk factors for poor healing. This highlights the influence of age and other intrinsic tear characteristics on rotator cuff healing.

Tear size has been shown in multiple studies to influence healing rates after repair. Galatz et al reported on the structural integrity of large and massive rotator cuff tears after arthroscopic cuff repair²⁸. Recurrent tendon defects were identified in 94% of shoulders. Although advances in surgical techniques have improved upon the healing rates of arthroscopic cuff repair, tear size continues to be one of the primary determinants of successful tendon healing. Park et al studied a large cohort of patients with small to medium-sized rotator cuff tears and found that patients with tears >2 cm had a healing rate of 65% compared to 89% healing with tears ≤ 2 cm in size²⁴. More recent literature from Tashjian et al has shown that tear retraction plays an important role in tendon healing following repair of degenerative cuff tears²⁹. They investigated 42 patients undergoing arthroscopic rotator cuff repair reporting an overall healing rate of 86%. Tendon healing was seen in 92% of tears when the musculotendinous junction was lateral to the glenoid compared to 56% healing in tears with retraction of the musculotendinous junction medial to the glenoid.

Both fatty infiltration (FI) and muscular atrophy are well established risk factors influencing tendon healing following rotator cuff repair. Park et al found grade 2 and higher fatty degeneration of the infraspinatus to be an independent risk factor for recurrent tears²⁴. Chung et al reviewed the results of 272 patients undergoing arthroscopic cuff repair³⁰. Increased FI of the supraspinatus, infraspinatus, and subscapularis was associated with decreased tendon healing. Furthermore, with multivariate analysis, increased FI of the infraspinatus was an independent risk factor for recurrent tendon defects following repair. Kim et al also found FI of the infraspinatus to be an independent risk factor for a recurrent cuff tear with multivariate analysis of 132 patients following repair of full-thickness cuff tears³¹.

It is thought that rotator cuff tears resulting from acute injuries are more likely to heal than degenerative rotator cuff tears after surgical repair. Similar to tendon injuries elsewhere, it makes biologic sense that the healing environment is optimal in the acute setting before chronic degenerative changes have occurred. While this concept is common dogma, research supporting this notion is limited. Tan et al studied the effects of recent trauma and tendon healing in 1300 patients undergoing arthroscopic cuff repair³². There was no significant difference in the healing rates between patients who reported shoulder pain secondary to a specific event compared to tears with a more insidious pain onset. In patients who reported a traumatic event, delaying surgery greater than 24 months correlated with decreased tendon healing. Other studies have demonstrated a benefit of earlier surgical treatment for traumatic rotator cuff tears. Petersen et al investigated 36 shoulders with acute rotator cuff tears and found improved functional outcomes for patients that underwent surgery less than 4 months after injury compared to those greater than 4 months³³.

Clinical Outcomes – Higher Level Evidence

There have been multiple prospective studies documenting excellent outcomes following surgical repair of degenerative rotator cuff tears^{34,35}. More recently there have been several prospective randomized trials comparing surgical versus nonsurgical management of rotator cuff tears. Moosmayer et al performed a randomized trial comparing physical therapy to operative treatment for traumatic and degenerative rotator cuff tears. The authors originally reported the outcomes of 103 patients with a minimum follow-up of one-year³⁶. In patients with small to medium-sized rotator cuff tears they found significantly greater improvements in ASES and Constant scores for the patients undergoing surgical treatment. Long-term follow-up continued to demonstrate statically significant improvements in ASES and Constant scores for patients undergoing surgery; however, these improvements were not considered clinically relevant at 5-years follow-up as the differences failed to reach the minimal clinically importance difference (MCID) threshold.³⁷ The crossover rate increased to 24% by two years with 12 of the 51 patients initially randomized to physical therapy undergoing surgical repair. The authors found that 37% of the patients treated with physical therapy had greater than 5mm increase in tear size on 5-year follow-up ultrasound. The authors supported an initial trial of physical therapy for small to medium-sized rotator cuff tears; however, cautioned that without surgery, many tears have an increased risk of enlargement and decreased function.

Kukkonen et al performed a randomized controlled trial comparing the outcomes of physical therapy, acromioplasty and physical therapy, or rotator cuff repair for 160 patients with full-thickness degenerative rotator cuff tears³⁸. They found no significant difference in functional scores or patient satisfaction between groups at two-years. The authors recommend physical therapy as the preferred initial treatment for isolated supraspinatus tears, with a caveat that many tears treated without repair increase in size at short-term follow-up. Heerspink et al conducted a prospective randomized trial investigating operative versus nonoperative treatment in 56 patients with degenerative rotator cuff tears³⁹. At one-year follow-up there was a significant improvement in VAS pain scores for patients treated with cuff repair; however, no significant difference was seen in Constant scores between groups. A subgroup analysis of healing data within revealed that patients with intact repairs demonstrated significant improvements in pain and functional outcome when compared to patients treated nonoperatively.

Although these studies suggest an advantage of surgery over conservative treatment of rotator cuff tears at short-term follow-up when patients are randomized at baseline presentation, the magnitude of the clinical relevance of these findings is challenged by defined MCID thresholds. Importantly, these studies do not make a distinction between tears with varying risk factors for progression and do not adequately address the potential downsides of nonoperative treatment over time. These include the tear enlargement risks, degenerative muscle change progression and the subsequent deleterious effects of cuff repair healing seen with advancing age.

Redefining Surgical Indications Based on Natural History Data

Informed decision making for the treatment of degenerative rotator cuff tears should entail a complete discussion of the risks and benefits of both operative and nonoperative treatment. Conservative treatment is a well-accepted treatment method for atraumatic full-thickness rotator cuff tears in the short term⁴⁰. In many patients with significant medical comorbidities or advanced age this may well be the preferred treatment. However, we are faced with a challenge when deciding the best treatment for younger patients with full-thickness tears that possess a high likelihood of disease progression. Natural history studies have better clarified tears with a higher risk of progression, highlighting an opportunity to refine surgical indications. Delayed surgical intervention in higher risk tears may allow tear enlargement and/or the development of irreversible muscle changes, which, when combined with the deleterious effects of aging will decrease the rate of successful tendon healing⁴¹. Many studies have demonstrated both increased tear size and progression of muscle degeneration within two-years. Additionally, Chalmers et al have documented increased radiographic progression of arthritic changes in patients with degenerative rotator cuff tears followed prospectively⁴².

There are certain tear characteristics that warrant consideration for either close surveillance or recommendation for early surgical intervention. Based on the natural history data, tears can be stratified according to the short-term risks of developing features previously shown to adversely affect healing rates and clinical outcomes of surgery (Table 2). These risks must be taken in the context of specific patient (age) and tear-related factors (size, cable integrity

and fatty muscle degeneration) already present at the time of clinical presentation. Shoulder pain severity is highly variable across tear sizes and pain can often be managed, at least short-term, conservatively. We feel that anatomic and patient related features that affect surgical results are better objective criteria rather than pain severity for consideration for early surgical intervention.

Low-risk tears include those with low risk of tear enlargement and progression of muscle degeneration or tears with poor healing capacity. In these tears there are lower risks of short-term tear progression or the optimal window for surgery has been missed. These include tears at both ends of the disease spectrum: partial-thickness rotator cuff tears as well as larger tears with advanced fatty muscle degeneration (Grade III/IV Goutallier changes) and/or proximal humeral migration. Atraumatic tears in patients older than 65–70 years of age, although still reasonable surgical candidates, have a lower healing rate and consideration for initial conservative treatment is warranted. Included in this group are atraumatic full-thickness tears up to 15mm in size with an intact anterior supraspinatus tendon and healthy muscles as the short-term risks of tear progression are relatively low. There is time to maximize conservative treatment without impacting the results of later surgery if conservative treatment fails.

Medium risk tears include those with moderate risk of short-term tear progression in individuals with good healing capacity (under 62–65 years old). These include atraumatic full-thickness tears 15 mm or larger, tears with disruption of the anterior supraspinatus tendon and previously painful shoulders with recent trauma (acute on chronic tears). These risks are amplified if there is already early fatty muscle degeneration as these tears possess a greater risk of progression of muscle degeneration over time. Acute on chronic rotator cuff tears represent a unique challenge in distinguishing if there was a preexisting tear and, if so, how much of the tear represents acute enlargement (Figure 4). One study suggested MRI features which may distinguish acute from chronic tears⁴³. Acute tears have less muscle fatty degeneration, often possessed a wavy or kinked appearing central tendon and are often associated with perimuscular edema. The amount of tendon retraction was not reliable in distinguishing between acute and chronic tears. For medium risk tears an informed discussion of treatment options with the patient is warranted. Surveillance physical or imaging examinations, such as ultrasound, should be considered to assess potential tear progression with successful conservative treatment. Patients should be counseled not to ignore an increase in shoulder weakness as this may herald tear enlargement.

High risk tears represent those with the greatest risk of disease progression or tears that possess a high rate of tendon healing due to their acuity. In these shoulders, surgical intervention has the greatest potential to interrupt the natural history of an untreated cuff tear. Included are acute traumatic full-thickness tears, especially those 15 mm or larger, in a previously healthy shoulder. Also included are acute on chronic tears with a dramatic loss of function such as pseudoparalysis and/or profound external rotation weakness. An important consideration for these tears is the quality of the involved muscles, which should possess minimal fatty degenerative changes. Strong consideration for surgical repair is warranted for tears such as these patients 65 years or younger.

Conclusions

In recent years an improved knowledge of the natural history of degenerative rotator cuff tears has strengthened our understanding of this disease process. When the risks of disease progression are coupled with the known factors that influence tendon healing following rotator cuff repair we can better refine surgical indications. The optimal treatment for tears must be individualized based upon clinical presentation and various patient and tear related factors.

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Figure 1.

Insertional rotator cuff anatomy according to Mochizuki in an illustration of the superior right proximal humerus. HH = humeral head, LT = lesser tuberosity, GT = greater tuberosity, SSP-I = supraspinatus insertion, ISP-I = infraspinatus insertion¹¹. (Mochizuki, T, Sugaya, H, Uomizu, M, Maeda, K, Matsuki, K, Sekiya, I, Muneta, T, Akita, K: Humeral Insertion of the Supraspinatus and Infraspinatus. New Anatomical Findings Regarding the Footprint of the Rotator Cuff. *J Bone Joint Surg Am* 2008;90:962–9.)

Figure 2.

A: Anterior Cable Intact Tear. Typical appearance of degenerative rotator cuff tear. Tear involves the supraspinatus and anterior infraspinatus within the rotator crescent. The anterior attachment of the supraspinatus is intact preventing severe retraction of the supraspinatus tendon. * = biceps tendon. B: Anterior Cable Disrupted Tear. This degenerative cuff tear involves the anterior supraspinatus tendon uncovering the biceps tendon. More severe retraction of the supraspinatus muscle is seen. * = biceps tendon.

Figure 3.

T1 weighted parasagittal MRI images demonstrating rotator cuff muscle health. A: Right shoulder. All cuff muscles healthy. B: Right shoulder. Supraspinatus (thin arrow) with Goutallier grade II changes (fatty change noted but more muscle than fat). Infraspinatus (thick arrow) with grade III changes (equal muscle and fat). Teres minor (*) with advanced fatty infiltration. C: Left Shoulder. Supraspinatus (thin arrow) and Infraspinatus (thick arrow) with grade IV changes (more fat than muscle).

Figure 4.

Acute on chronic rotator cuff tear, right shoulder. A: Coronal T2 weighted MRI image. Large retracted tear of the supraspinatus tendon (thin arrow). B: Coronal T2 weighted MRI image. Retracted and kinked infraspinatus tendon (thin arrow). Intramuscular edema noted within the infraspinatus (thick arrow). C: Parasagittal T2 weighted MRI image. Perimuscular edema noted within the supraspinatus and infraspinatus muscles. D: Parasagittal T1 weighted MRI image. Grade III Goutallier fatty changes within the supraspinatus (thin arrow). Grade I/II Goutallier fatty changes within the infraspinatus (thick arrow).

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Table 1.

Natural history studies of untreated rotator cuff tears.

Study	Study Group	Duration of F/U	Imaging Modality	Results
Moosmayer et al, JBJS 2013	50 asymptomatic full thickness tears	3 years	Ultrasound and MRI	36% developed pain Painful shoulders had greater enlargement (10.6mm vs 3.3 mm) Increased rate of progression of advanced atrophy in the symptomatic group (35% vs 12%) Increased rate of fatty muscle degeneration in the symptomatic group (35% vs 4%)
Maman et al, JBJS 2009	49 nonoperatively managed symptomatic rotator cuff tears	Minimum 6 months	MRI	F/u longer 18 months associated with greater tear progression (48% vs 19%) Age > 60 associated with tear progression (54% vs 17%) 24% of full-thickness and 0% of partial-thickness tears developed muscle atrophy Risk of tear enlargement associated with presence of fatty muscle infiltration
Keener et al, JBJS 2015	Asymptomatic patients with 118 full thickness tears, 56 partial thickness tears, and 50 controls	Mean 5.1 years	Ultrasound	46% developed pain (50% full-thickness, 46% partial-thickness, 28% controls) Tear enlargement occurred in 61% of full-thickness, 44% of partial-thickness and 14% of controls Tear enlargement associated with hand dominance Tear enlargement associated with pain development Tear enlargement associated with cuff muscle degeneration Tear size, age and gender not correlated with enlargement
Safran et al, AJSM 2011	61 symptomatic full thickness rotator cuff tears in 51 patients <60 years of age	2-3 years	Ultrasound	49% enlarged, 43% were stable, 8% decreased in size Correlation of tear enlargement and pain development Age, prior trauma, initial tear size and bilateral tears were not associated with tear enlargement
Fucintese et al, JBJS 2012	24 symptomatic full thickness rotator cuff tears in patients <65 years of age who declined surgery	Mean 42 months	Initial MR Arthrogram, F/U MRI	Mean Constant score was 75 at f/u 11 patients had no tear or smaller tear at f/u 9 patients had no change in tear size 6 patients (25%) had increased tear size Progression of fatty infiltration from 0% to 14% of cohort but none were advanced

Table 2.

Treatment recommendations based on patient and tear characteristics.

Risks of Tear Enlargement/Muscle Degeneration Progression	Patient and Tear Characteristics	Treatment Recommendation
Low Risk	Partial-thickness tears Large tears with advanced muscle changes Degenerative tears in patients >65-70 years Atraumatic full-thickness tears less than 15 mm in size with an intact anterior cable	Maximize conservative treatment, surgery if persistently asymptomatic
Medium Risk	Under age 62-65: Atraumatic full-thickness tears > 15 mm Anterior cable disruption Acute on chronic tears – preserved function	Informed discussion of surgical and nonsurgical options warranted Consider surveillance exams with successful conservative treatment
High Risk	Acute traumatic full-thickness tears Acute on chronic tears with new pseudoparalysis or profound external rotation weakness Minimal muscle degenerative changes Age compatible with healing	Strong consideration for early surgical repair