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Association of Rotator Cuff Tear Patterns and Intramuscular Fatty Infiltration on Magnetic Resonance Imaging

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ABSTRACT

Objective: The impact of rotator cuff (RC) tear pattern on intramuscular fatty infiltration (FI) is not well understood. The purpose of our study is to determine if differing RC tear patterns are associated with discordant presentations of intramuscular FI.

Methods: Fifty-one adults with full-thickness tear of the posterosuperior RC on shoulder magnetic resonance imaging (MRI) were identified retrospectively. The study subjects were stratified by RC tear pattern: (1) L-shaped tear cohort, (2) crescent-/U-shaped tear cohort, and (3) complete tear cohort. Clinical information pertaining to age, sex, tear size, trauma history, and length of clinical symptoms was recorded from the institution's picture archiving and communication system. Goutallier grade was assessed on oblique sagittal T1-weighted MRI by two orthopedic surgeons and one orthopedic resident. A musculoskeletal radiologist recorded the shape and size of full-thickness RC tears. Descriptive, correlation, and reliability analyses were performed.

Results: The L-shaped, crescent-/U-shaped, and compete tear cohorts demonstrated significant differences pertaining to tear size ($P < 0.001$) and infraspinatus Goutallier grade ($P = 0.024$), but not supraspinatus Goutallier grade ($P = 0.370$). Age had strong correlation to supraspinatus Goutallier grade ($r_s = 0.712$, $P = 0.031$) and infraspinatus Goutallier grade ($r_s = 0.712$, $P = 0.029$) in the crescent-/U-shaped tear cohort. Tear size had strong correlation to supraspinatus Goutallier grade ($r_s = 0.796$, $P = 0.001$) and infraspinatus Goutallier grade ($r_s = 0.793$, $P = 0.001$) in the complete tear cohort. Moderate interobserver agreement was present for supraspinatus (kappa, 0.484) and infraspinatus (kappa, 0.427) Goutallier grade.

Conclusion: RC tear pattern is associated with different presentations of intramuscular FI at the posterosuperior RC. Full-thickness tears involving the crescent region of the RC cuff are associated with age. Intramuscular FI is associated with RC tear size.

Keywords: Intramuscular fatty infiltration, Magnetic resonance imaging, Rotator cuff tear, Shoulder, Tear pattern

INTRODUCTION

Rotator cuff (RC) tears are common in adults 45 years and older, and the rate of surgical RC repair (RCR) in the United States approaches 275,000 per year.[1,2] However, despite a large number of RCR procedures performed every year, there is also a high prevalence of asymptomatic shoulders with RC tear.[3] Factors that explain differences between symptomatic and asymptomatic presentations in individuals with RC tear are poorly understood.

RC tear pattern is a potential factor influencing the presence of shoulder symptoms and is predictive of post-outcome prognosis in patients requiring surgical intervention.[4,5] Symptomatic RC tears with involvement of the anterior leading edge of the supraspinatus tendon negatively impact shoulder function have increased risk of tear propagation and may be prioritized for early surgical intervention.[6]

The supraspinatus and infraspinatus form the posterosuperior RC. A recent cadaveric study suggests that the footprint of the supraspinatus tendon is a small insertion onto the anteromedial region of greater tuberosity of the humerus at the superior facet, while the infraspinatus tendon footprint insertion is relatively larger, spanning the middle facet, and anterolateral region of the superior facet.[7] The RC cable is a fibrous band extending in an anteroposterior direction, associated with the posterosuperior RC in a perpendicular direction, spanning a region inclusive of the anterior leading edge of the supraspinatus tendon, and the posteroinferior aspect of the infraspinatus tendon.[8,9] The segment of supraspinatus and infraspinatus tendons lateral to the RC cable, and bordered anteriorly and posteriorly by the RC cable, is known as the "crescent" of the posterosuperior cuff.[9]

Most RC tears involve the posterosuperior RC.[10] The most common type of full-thickness RC tear pattern is crescent-shaped tear (40%) followed by L-shaped (30%) and U-shaped (15%) tears and with complete tears of the supraspinatus and infraspinatus tendons occurring less frequently [Figure 1].[4,5,11] Whether the pattern of RC tear is associated with intramuscular fatty infiltration (FI) of the posterosuperior RC is not well understood.

The purpose of our study is to determine if cohorts of symptomatic patients with differing patterns of full-thickness posterosuperior RC tear are associated with dissimilar amounts of FI. We hypothesize that different full-thickness RC tear patterns are associated with non-uniform presentations of FI at the posterosuperior RC.

METHODS

Study population

The study was approved by an institutional review board and complied with the Health Insurance Portability and Accountability Act guidelines. The requirement for patient informed consent was waived for this retrospective study. The study population consisted of men and women ≥18 years. Patients who received magnetic resonance imaging (MRI) of the shoulder between November 2013 and December 2014 were identified through an electronic search of our institution's picture archiving and communication system (PACS). Inclusion criteria were as follows: (1) Radiology final report with a diagnosis of full-thickness supraspinatus tendon tear (STT); (2) confirmation of the full-thickness STT on secondary review of the MRI by a single musculoskeletal radiologist; and (3) the full-thickness STT presenting as L-shaped, U-shaped, crescent-shaped, or a complete tear of the supraspinatus and infraspinatus tendons. Exclusion criteria: (1) Prior RCR surgery or joint replacement; (2) absent or poor quality oblique sagittal T1-weighted MRI sequence; (3) shape of full-thickness STT not conforming to L-shaped, U-shaped, crescent-shaped, or complete tear of the posterosuperior RC; and (4) concurrent abnormal disease process of the supraspinatus muscle. A total of 68 shoulders with full-thickness STT were identified. Seventeen shoulders were excluded from the study for the following reasons: Soft tissue tumor involving the supraspinatus muscle (n = 1), glenohumeral joint replacement (n = 1), poor image quality for the sagittal oblique T1-weighted MRI sequence (n = 2), incomplete imaging study (n = 1), prior RCR (n = 6), pinpoint full-thickness tears of the supraspinatus tendon at the footprint, critical zone, or myotendinous junction of such tiny size precluding distinct shape characterization (n = 6). Therefore, 51 shoulders (50.1% of male; mean age, 56.1 ± 9.9 years; range, 37–84 years) were included in the study. We stratified our study population into three cohorts: (1) L-shaped tear of the posterosuperior RC, with involvement of the anterior leading edge of the supraspinatus tendon (n = 29); (2) U-shaped or crescent-shaped tear of the posterosuperior RC, without involvement of the anterior leading edge of the supraspinatus tendon and posterior fibers of the infraspinatus tendon (n = 9); and (3) complete tear of the entire posterosuperior RC (n = 13).

Magnetic resonance imaging

All shoulder MRI examinations were performed with a dedicated shoulder coil at 1.5 T (Magnetom Avanto/Espree/Aera, Siemens, Erlangen, Germany) or 3.0 T (Magnetom Trio Siemens, Erlangen, Germany) and included a two-dimensional (2D) sagittal oblique spin echo (SE) sequence with a slice thickness of 3 or 4 mm. Each shoulder MRI examination also contained additional 2D sequences for comparison, including either a short-tau inversion recovery or turbo spin echo T2-weighted fat saturation sequence in the sagittal oblique and coronal oblique planes, and proton-density sequences in the coronal oblique and axial planes.

Magnetic resonance image analysis

Two blinded orthopedic surgeons and one blinded orthopedic resident were given a DICOM image module created on a three-dimensional visualization system viewer (Aquarius iNtuition Edition, version 4.4; TeraRecon Inc., Foster City, California, USA). Each DICOM image module contained a single identical deidentified oblique sagittal T1-weighted

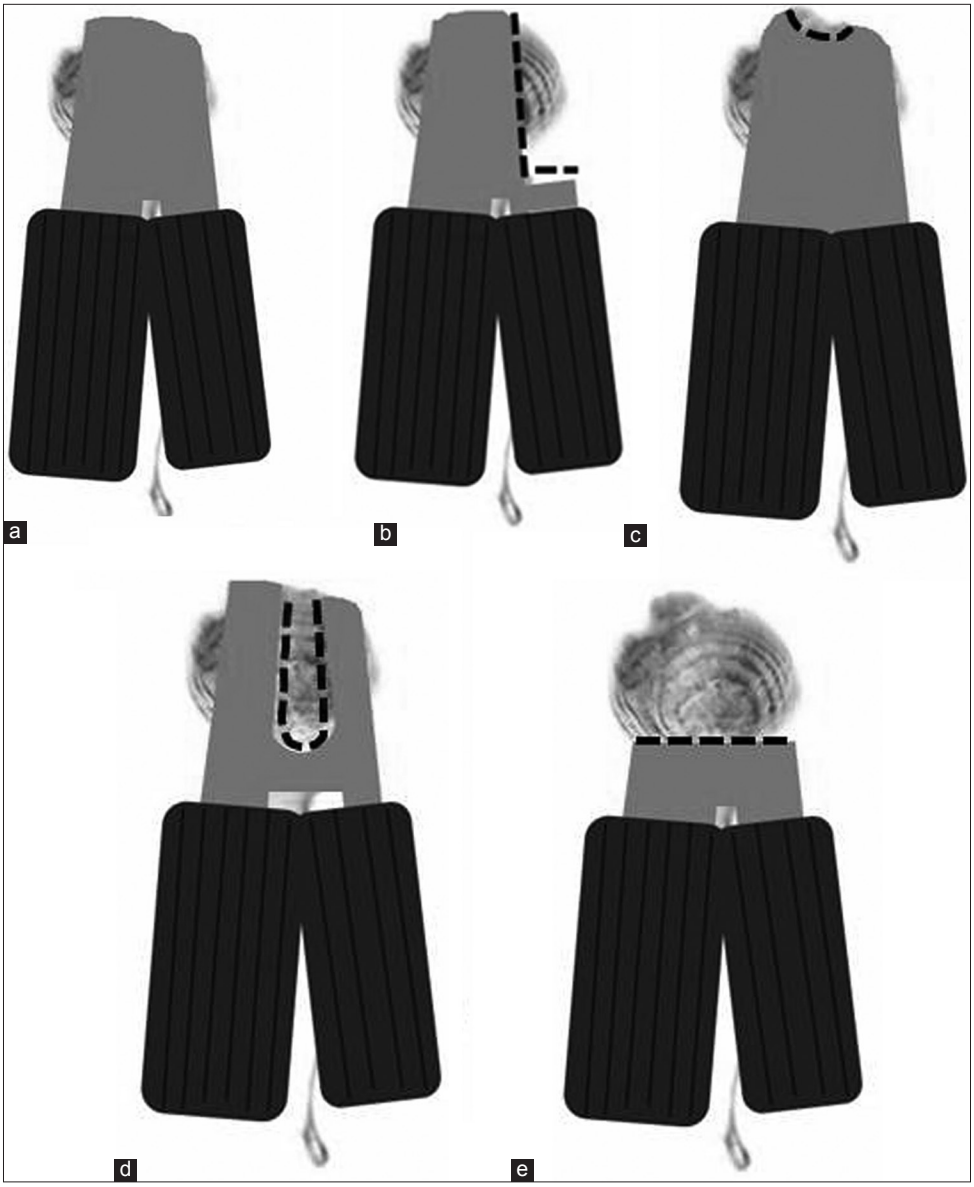

Figure 1: Illustrations demonstrating tear patterns of the posterosuperior rotator cuff, as viewed from above. (a) Intact rotator cuff. (b) L-shaped tear involving the supraspinatus tendon. (c) Crescent-shaped tear involving the supraspinatus and infraspinatus tendons. (d) U-shaped tear involving the supraspinatus and infraspinatus tendons. (e) Complete tear and retraction of the supraspinatus and infraspinatus tendons.

MRI corresponding to the Y-shaped view for each study subject included in the study.[12] Each blinded orthopedic surgeon or resident independently assigned a Goutallier grade for each supraspinatus muscle and infraspinatus muscle, based on the 5-point Goutallier classification scale: Grade 0, no fat; Grade 1, streaks of fat; Grade 2, muscle > fat; Grade 3, muscle = fat; and Grade 4, muscle < fat [Figure 2].[13] A single musculoskeletal radiologist reviewed each shoulder MRI in the study population to measure the mediolateral and anteroposterior size of each full-thickness posterosuperior RC tear and defined the shape of RC tear as defined by Davidson *et al*. for L-, U-, and crescent-shaped tears.[4,5] A complete tear was defined as a full-thickness tear involving the entirety of the supraspinatus and infraspinatus tendons.

Clinical evaluation

All clinical histories were provided by the authors' institutional PACS. A research assistant documented the available clinical history for each shoulder MRI examination in the PACS which accompanied the shoulder MRI pertaining to age, sex, documentation of trauma, and documentation of length of clinical symptoms pertaining to shoulder pain, weakness, instability, and/or decreased range of motion (4≤ weeks or >4 weeks).

Statistical analysis

Statistical analysis was performed using Stata Statistical Software Version 14 (Stata Corporation, College Station, Texas, USA). The Chi-square test was used to compare cohorts for mean age, % male, tear size, documented trauma, documented symptoms ≤4 weeks, supraspinatus mean Goutallier grade, and infraspinatus mean Goutallier grade.

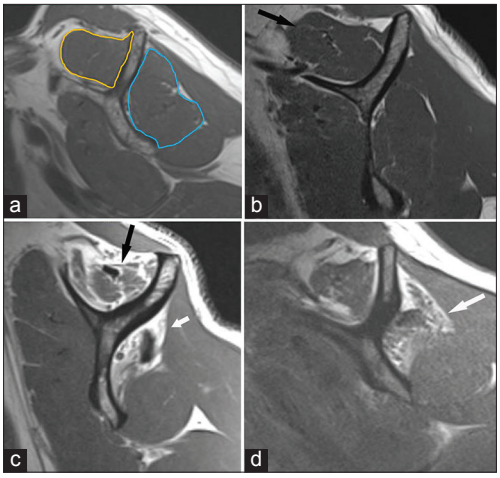

Figure 2: A 70-year-old woman with chronic shoulder pain. (a) Oblique sagittal magnetic resonance image shows Goutallier Grade 0 for the supraspinatus (gold outline) and infraspinatus (blue outline) muscles. A 53-year-old man unable to lift objects due to his shoulder. (b) Oblique sagittal magnetic resonance image shows Goutallier Grade 1 for the supraspinatus muscle (arrow). A 65-year-old man with shoulder dysfunction. (c) Oblique sagittal magnetic resonance image shows Goutallier Grade 2 for the supraspinatus muscle (black arrow) and Goutallier Grade 4 for the infraspinatus muscle (white arrow). A 53-year-old man with instability and shoulder pain. (d) Oblique sagittal magnetic resonance image shows Goutallier Grade 3 for the infraspinatus muscle (arrow).

The unpaired *t* test was used to compare supraspinatus and infraspinatus mean Goutallier grade for each cohort. Spearman rank order correlation (r_s) was used to assess for correlation between mean Goutallier grade for each respective cohort and age, % male, tear size, and documented trauma for the supraspinatus and infraspinatus. Inter-rater reliability was determined by calculating kappa. $P < 0.05$ was considered to indicate a statistically significant difference.

RESULTS

The characteristics of study subjects are presented in Table 1. There was a significant difference in tear size among the cohorts ($P < 0.001$). All full-thickness RC tears in the complete tear cohort were >3 cm, while there were no tears >3 cm in the L-shaped tear cohort. Most RC tears <1 cm were in the L-shaped tear cohort, while all RC tears ≥5 cm were in the complete tear cohort. There was also a significant difference among the cohorts for documented trauma ($P = 0.002$) with the largest number involving the complete tear cohort. There was no significant difference among cohorts for age, sex, or documented symptoms ≤4 weeks.

A significant difference was found among cohorts for mean infraspinatus Goutallier grade ($P = 0.024$), but not for mean supraspinatus Goutallier grade ($P = 0.370$). There was near statistically significant difference between supraspinatus and infraspinatus mean Goutallier grade for the complete tear cohort ($P = 0.055$), but no significant difference for the L-shaped tear ($P = 0.130$) and crescent-/U-shaped tear ($P = 0.513$) cohorts, although the infraspinatus had higher mean Goutallier grade in all three cohorts. The L-shaped tear cohort had the lowest mean Goutallier grade and the complete tear cohort had the highest mean Goutallier grade, for the supraspinatus and infraspinatus muscles.

Table 1: Characteristics of the study population by cohort.

	L-shaped tear (*n*=29)	Crescent-/U-shaped tear (*n*=9)	Complete tear (*n*=13)	*P*-value
Age, years	57.80±9.25[A]	54.67±11.42	53.07±9.97	0.748
Male, %	37.9%	55.5%	76.9%	0.062
Tear size				<0.001
<1 cm	11	3		
>1–<3 cm	18	3		
>3–<5 cm		3	9	
≥5 cm			4	
Documented trauma				0.002
Yes	6	5	10	
No	23	4	3	
Documented symptoms[B] ≤4 weeks				0.172
Yes	3	2	3	
No	26	7	10	
Goutallier grade, supraspinatus	0.99±0.68	1.07±1.12	1.54±0.89	0.370
Goutallier grade, infraspinatus	1.30±0.85	1.48±1.44	2.23±0.86	0.024

[A]Mean±standard deviation, [B]Shoulder pain, weakness, instability, and/or decreased range of motion

In the L-shaped tear cohort, there was a moderate to strong correlation ($P = 0.003$) between the percentage of male study subjects and infraspinatus mean Goutallier grade [Table 2]. A fair to moderate trend for correlation with borderline statistical significance existed between infraspinatus mean Goutallier grade with age ($P = 0.063$) and tear size ($P = 0.066$) and also between supraspinatus mean Goutallier grade and percentage of male study subjects ($P = 0.068$).

A strong correlation existed between age with mean supraspinatus Goutallier grade ($P = 0.031$) and mean infraspinatus Goutallier grade ($P = 0.029$) in the crescent-/U-shaped tear cohort [Table 3]. A strong correlation existed between tear size with mean supraspinatus Goutallier grade ($P = 0.001$) and mean infraspinatus Goutallier grade ($P = 0.001$) in the complete tear cohort [Table 4]. Moderate inter-rater reliability for Goutallier grade was identified for the supraspinatus muscle (kappa, 0.484) and infraspinatus muscle (kappa, 0.427).

DISCUSSION

Our study suggests that shape and size of posterosuperior full-thickness RC tears are factors associated with FI. L-shaped, crescent-/U-shaped, and complete tear cohorts demonstrated differing scores of mean Goutallier grade at the posterosuperior RC. Age is strongly associated with mean Goutallier grade for crescent-/U-shaped full-thickness supraspinatus and infraspinatus tears, and tear size has a strong association with mean Goutallier grade for complete full-thickness tears of the posterosuperior RC.

RC tears present with non-uniform amounts of FI on imaging studies. Significant amounts of FI are predominantly associated with full-thickness RC tear, but not partial-thickness RC tear.[6,14] In addition, larger full-thickness RC tears commonly present with higher amounts of FI as compared to smaller tears.[6,8,15] In our study, there was a significant difference in tear size among cohorts, with the complete tear cohort presenting with the largest size and highest mean Goutallier grade for the posterosuperior RC, although only statistically significant for the infraspinatus. Tear size also showed strong correlation to supraspinatus and infraspinatus mean Goutallier grade for the complete tear cohort.

Several studies suggest that involvement of the anterior leading edge of the supraspinatus tendon in RC tears has association with higher amounts of FI in the supraspinatus muscle, as compared to RC tears which spare this region.[6,8,15] Investigators posit that tendon histology and function of the anterior portion of the supraspinatus tendon are distinct from the remainder of the RC.[16] Kim *et al.* suggested that all full-thickness RC tear sizes, including small tears, involving the anterior leading edge lead to more pronounced FI of the supraspinatus muscle than expected, while tears not involving the anterior aspect of the supraspinatus tendon have relatively less FI.[6] Crescent- and U-shaped RC tears, as opposed to tears involving the supraspinatus anterior leading edge, are theorized to mitigate detrimental biomechanical loads through intact anterior and posterior posterosuperior cuff fibers.[8] Namdari *et al.* compared shoulders with small and medium STTs with and without involvement of the anterior leading edge. RC tears associated with the anterior leading edge were larger and showed higher supraspinatus FI on ultrasound.[8] However, there were no significant differences found between groups for clinical parameters such as baseline pain and function or post-operative outcomes following arthroscopic RCR surgery. There also was a trend without statistical significance for higher infraspinatus FI on ultrasound in the anterior leading edge tear group.[8] Our

Table 2: Correlation of L-shaped tear cohort characteristics with supraspinatus and infraspinatus mean Goutallier grade.

	Supraspinatus		Infraspinatus	
	r_s	*P*	r_s	*P*
Age, years	0.267	0.161	0.349	0.063
Male, %	0.344	0.068	0.532	0.003
Tear size	0.206	0.283	0.346	0.066
Documented trauma	−0.285	0.134	−0.019	0.922

Table 3: Correlation of crescent-/U-shaped tear cohort characteristics with supraspinatus and infraspinatus mean Goutallier grade.

	Supraspinatus		Infraspinatus	
	r_s	*P*	r_s	*P*
Age, years	0.712	0.031	0.720	0.029
Male, %	0.498	0.173	0.545	0.129
Tear size	0.523	0.148	0.525	0.146
Documented trauma	0.429	0.250	0.518	0.154

Table 4: Correlation of posterosuperior complete tear cohort characteristics with supraspinatus and infraspinatus mean Goutallier grade.

	Supraspinatus		Infraspinatus	
	r_s	*P*	r_s	*P*
Age, years	0.272	0.368	0.229	0.452
Male, %	−0.100	0.746	−0.223	0.463
Tear size	0.796	0.001	0.793	0.001
Documented trauma	−0.101	0.743	−0.233	0.444

study sample failed to show the L-shaped tear cohort to have a higher mean Goutallier grade than crescent-/U-shaped tear cohort for the supraspinatus and infraspinatus, possibly because the L-shaped tear cohort, RC tears were on average smaller in size as compared to the other cohorts.

The RC cable forms an important structural complex with the anterior leading edge of the supraspinatus tendon, which is posited to facilitate transmission of force from the supraspinatus myotendinous unit to the proximal humerus.[6,15,16] Burkhart *et al*. suggested that load bearing by an intact RC cable provides stress shielding for the crescent of posterosuperior RC.[9] Full-thickness RC tears of the RC cable-anterior supraspinatus complex are hypothesized to be associated with greater propagation of RC dysfunction as compared to RC tears with a preserved supraspinatus tendon anterior leading edge.[6,15] Mesiha *et al.* in a cadaveric study suggested that integrity of the RC cable-anterior supraspinatus complex is the principal structure for normal distribution of biomechanical load from the scapula to the proximal humerus.[16] These investigators showed that full-thickness RC tears involving the anterior leading edge of the supraspinatus are associated with greater tendon tear displacement and regional strains, as compared to similar sized RC tears of the crescent, and also speculated that RC tears of the RC cable-anterior supraspinatus complex may be associated with worse clinical symptoms, such as pain and muscle dysfunction, and greater propensity for continued tear propagation.[16]

Debate exists as to where tears of the posterosuperior RC begin, with competing theories that RC tears begin at the center of the crescent versus the anterior leading edge of the supraspinatus tendon.[6,8] Investigators have theorized that age-related factors play a role for load bearing transmission from the scapula to the humerus through the RC cable-anterior supraspinatus complex. Burkhart *et al.* in a cadaveric study posited that two different age-related patterns existed: (1) Younger patients who do not require stress shielding from the RC cable due to the presence of thick and robust RC crescent (a.k.a, crescent-dominant pattern) and (2) older patients, who have thin and weak RC crescents from age-related tendon degeneration, require the RC cable for mechanical loading (a.k.a., RC cable-dominant pattern).[9] There is also the hypothesis that the RC cable hypertrophies as an adaptation to age-related RC crescent thinning, with non-traumatic crescent tears representing advanced age-related degeneration of the central RC cuff at its insertion site.[9] Our study supports these theories by showing a strong correlation of age to supraspinatus and infraspinatus mean Goutallier grade in the crescent-/U-shaped tear cohort. RC tears involving the RC cable are theorized to be more consequential in RC cable-dominant shoulders in older patients since the critical load-bearing function of the RC cable-anterior supraspinatus complex is lost.[9]

Infraspinatus FI out of proportion to the observed visible size of infraspinatus tendon full-thickness tear on MRI is often encountered. Mochizuki *et al*. in a cadaveric study suggested that the footprint of the infraspinatus tendon has a more anterior insertion onto the greater tuberosity of the humerus at the superior facet than was previously believed and also that the portion of the posterosuperior RC cuff inserting onto the greater tuberosity superior facet of the humerus representing solely the supraspinatus tendon was much smaller than previously thought.[7] In our study, mean Goutallier grade was higher for infraspinatus as compared to the supraspinatus, although showing only a strong trend for the complete tear cohort.

The pattern of RC tear on pre-operative shoulder MRI influences surgical planning. Most RCR surgeries are performed arthroscopically in current clinical practice. Crescent-shaped tears are repaired typically by a direct tendon-to-bone technique at the greater tuberosity of the humerus, while U-shaped tears and smaller L-shaped tears receive a marginal convergence/side-to-side tendon repair technique preceding direct anchoring of the tendon to bone.[4] Larger L-shaped tears and complete tears of both supraspinatus and infraspinatus may not be amenable to surgical restoration of the entire native footprint of the posterosuperior RC. These more challenging tear patterns may require extensive soft tissue releases, including a rotator interval slide, to mobilize the cuff before fixation. At times, a more medialized repair may be utilized to affect a tension-free repair. Furthermore, RC tears with poor tendon quality may require allograft augmentation or even a superior capsular reconstruction. In general, chronic massive RC tears with FI have a worse prognosis for long-term shoulder outcomes compared to acute small RC tears without FI.[4]

Our study was not without limitations. The study design was retrospective and occurred at one-time point. Only clinical information that was associated with the shoulder MRI on the institution's PACS was available. The hand dominance and shoulder range of motion for the study subjects were unknown. Our results may not be generalizable to RC tear

patterns not included in the study. The lack of surgical correlation is also a limitation for vetting RC tear pattern found on MRI or determining if the anterior portion of the RC cable was actually torn for RC tears in the L-shaped tear cohort. The study also was performed without histologic correlation for RC muscle intramuscular FI. The number of study subjects was relatively small. A larger study is needed to verify the results and assess whether or not additional statistically significant differences and correlations exist for differing patterns of full-thickness RC tears. Future studies also will be necessary to determine the relationship among differing RC tear patterns, FI, and post-surgical outcomes.

CONCLUSION

Our study suggests that RC tear pattern is associated with different presentations of FI at the posterosuperior RC and that FI in the setting of full-thickness RC crescent- and U-shaped tears is associated with age. Our study also suggests that RC tear size is associated FI. Larger future studies will be necessary to confirm these associations.

Declaration of patient consent

The authors certify that the study was approved by an institutional review board and complied with the Health Insurance Portability and Accountability Act guidelines. The requirement for patient informed consent was waived for this retrospective study by the authors' institutional review board.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Jain NB, Higgins LD, Losina E, Collins J, Blazar PE, Katz JN, *et al.* Epidemiology of musculoskeletal upper extremity ambulatory surgery in the united states. BMC Musculoskelet Disord 2014;15:4.
2. Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. J Bone Joint Surg Am 2012;94:227-33.
3. Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elbow Surg 1999;8:296-9.
4. Davidson JF, Burkhart SS, Richards DP, Campbell SE. Use of preoperative magnetic resonance imaging to predict rotator cuff tear pattern and method of repair. Arthroscopy 2005;21:1428.
5. Davidson J, Burkhart SS. The geometric classification of rotator cuff tears: A system linking tear pattern to treatment and prognosis. Arthroscopy 2010;26:417-24.
6. Kim HM, Dahiya N, Teefey SA, Keener JD, Galatz LM, Yamaguchi K, *et al.* Relationship of tear size and location to fatty degeneration of the rotator cuff. J Bone Joint Surg Am 2010;92:829-39.
7. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, *et al.* Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. Surgical technique. J Bone Joint Surg Am 2009;91 Suppl 2 Pt 1:1-7.
8. Namdari S, Donegan RP, Dahiya N, Galatz LM, Yamaguchi K, Keener JD, *et al.* Characteristics of small to medium-sized rotator cuff tears with and without disruption of the anterior supraspinatus tendon. J Shoulder Elbow Surg 2014;23:20-7.
9. Burkhart SS, Esch JC, Jolson RS. The rotator crescent and rotator cable: An anatomic description of the shoulder's "suspension bridge". Arthroscopy 1993;9:611-6.
10. Melis B, Nemoz C, Walch G. Muscle fatty infiltration in rotator cuff tears: Descriptive analysis of 1688 cases. Orthop Traumatol Surg Res 2009;95:319-24.
11. Lädermann A, Burkhart SS, Hoffmeyer P, Neyton L, Collin P, Yates E, *et al.* Classification of full-thickness rotator cuff lesions: A review. EFORT Open Rev 2016;1:420-30.
12. Yoo JC, Ahn JH, Yang JH, Koh KH, Choi SH, Yoon YC, *et al.* Correlation of arthroscopic repairability of large to massive rotator cuff tears with preoperative magnetic resonance imaging scans. Arthroscopy 2009;25:573-82.
13. Mellado JM, Calmet J, Olona M, Esteve C, Camins A, Pérez Del Palomar L, *et al.* Surgically repaired massive rotator cuff tears: MRI of tendon integrity, muscle fatty degeneration, and muscle atrophy correlated with intraoperative and clinical findings. AJR Am J Roentgenol 2005;184:1456-63.
14. Lee S, Lucas RM, Lansdown DA, Nardo L, Lai A, Link TM, *et al.* Magnetic resonance rotator cuff fat fraction and its relationship with tendon tear severity and subject characteristics. J Shoulder Elbow Surg 2015;24:1442-51.
15. Updegrove GF, Armstrong AD, Mosher TJ, Kim HM. Posterior displacement of supraspinatus central tendon observed on magnetic resonance imaging: A useful preoperative indicator of rotator cuff tear characteristics. Arthroscopy 2015;31:2089-98.
16. Mesiha MM, Derwin KA, Sibole SC, Erdemir A, McCarron JA. The biomechanical relevance of anterior rotator cuff cable tears in a cadaveric shoulder model. J Bone Joint Surg Am 2013;95:1817-24.

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