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Patient, imaging, and surgical factors associated with supraspinatus re-tear pattern after rotator cuff repair

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Background: This study aimed to characterize patient, imaging, and surgical factors associated with re-tear patterns after rotator cuff repair, as well as to identify predictors of type 2 failure in a large patient cohort.

Methods: A retrospective case-control study was performed at a single urban academic institution. All patients who underwent an arthroscopic rotator cuff repair by 2 fellowship-trained shoulder and elbow surgeons between 2005 and 2022 and were subsequently found to have a symptomatic re-tear on magnetic resonance imaging were included. Patients were characterized as either a type 1 (failure at bone-tendon interface) or type 2 (failure medial to the bone-tendon junction) re-tear based on the Cho classification. Chart review was performed to collect demographic, imaging, and intraoperative surgical factors. Multivariable analysis was performed to determine patient and imaging factors associated with type 2 failure.

Results: Fifty-seven patients were included in the study. Overall, 33 (57.9%) patients were classified as a Cho 1 re-tear and 24 (42.1%) were classified as Cho 2 re-tear. No differences in preoperative tear characteristics (tear width, tear retraction, and tendon length) or fatty infiltration were found between Cho 1 and Cho 2 re-tears. Bivariate analysis comparing Cho 1 vs. Cho 2 found male sex was associated with a higher incidence of a Cho 2 re-tear (79.2% vs. 20.8%; $P = .033$). No significant differences in repair construct (single row vs. double row) ($P = .816$), biceps treatment ($P = .552$), concomitant subscapularis repair ($P = .306$), number of medial anchors ($P = .533$), or number of lateral anchors ($P = .776$) were noted between re-tear types. After controlling for potential confounding factors, multivariable regression analysis demonstrated that male sex was predictive of developing a Cho 2 re-tear (odds ratio 3.8; 95% confidence interval 1.1-13.3; $P = .039$). Repair construct was not found to be predictive of re-tear pattern ($P = .580$).

Conclusion: Repair construct used during rotator cuff repair does not appear to influence re-tear pattern. Male sex was associated with a higher rate of type 2 failure.

While rotator cuff repair in appropriately selected patients often results in high levels of satisfaction and improved functional outcomes, certain patients do experience re-tears after undergoing an arthroscopic repair. Previous studies have identified both biological as well as biomechanical factors that may influence the rates as well as types of re-tear.[14,20,27] While many of these factors are nonmodifiable (eg, tear size, age, fatty infiltration),[13,19] a growing interest in understanding modifiable risk factors (eg, technique-dependent factors) has developed.[6,11,21,25]

In 2010, Cho et al described a novel type of re-tear classification, with a type 1 failure defined as failure of the repair at the rotator cuff footprint (failure at bone-tendon interface) and a type 2 failure defined as failure at the myotendinous junction.[3] In this study, Cho et al reported a higher rate of type 2 failure among patients with a double-row repair (vs. single row).[3] Interestingly, several subsequent studies have demonstrated this same link between type 2 failure and a double-row construct.[1,2,10,12] As a result, it has largely become dogma that despite a biomechanically stronger repair, double-row constructs may be prone to this unique mode of failure and consequently more complex revision options.

This study was approved by the University of Utah Institutional Review Board as protocol 46622.

The work for this manuscript was performed at the University of Utah in Salt Lake City, Salt Lake City, UT, USA.

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However, many of these studies are limited by small sample sizes and variable techniques. Furthermore, our group has not noticed a higher rate of type 2 failures among patients with a double-row construct. As such, the purpose of this study was to better characterize patient, imaging, and surgical factors associated with various re-tear patterns after rotator cuff repair, as well as to identify predictors of type 2 failure in a large patient cohort. We hypothesized that single-row and double-row constructs would demonstrate similar rates of type 2 failure.

Methods

Study design

A retrospective case-control study was performed at an urban academic institution. All patients who underwent an arthroscopic rotator cuff repair between 2005 and 2022 by 2 fellowship-trained shoulder and elbow surgeons and were subsequently found to have a symptomatic re-tear of their prior repair on magnetic resonance imaging (MRI) were included. Both double-row and single-row constructs were used. A double-row construct was preferred if the tendon was able to cover the footprint without excessive tension. All double-row constructs used medial-row knot tying. In cases with excessive tension noted intraoperatively, a single-row construct was used. Single-row medialized constructs used simple sutures with knots tied from triple-loaded anchors. All patients were managed with 6 weeks of sling immobilization, 6 weeks of progressive range of motion, and strengthening staring at 3 months. Patients were characterized as either a type 1 (failure at bone-tendon interface) or type 2 (failure medial to the bone-tendon junction) re-tear based on the Cho classification. Chart review was performed to collect demographic, imaging, and intraoperative factors. Time to re-tear was defined as date of clinic note where re-tear was first suspected, date of trauma leading to re-tear, or date of MRI demonstrating re-tear if the first 2 reasons listed were not applicable. The patients who experienced re-tear included both symptomatic and asymptomatic patients who obtained follow-up imaging as part of a previous study. All imaging measurements were performed by 2 fellowship-trained shoulder and elbow surgeons who were not the surgeons who performed the repairs.

Imaging analysis

Preoperative and postoperative (demonstrating re-tear) MRIs were analyzed for tear characteristics. Tear width was measured on a sagittal T2 slice at the level of the supraspinatus footprint. Tear retraction was measured on a coronal T2 slice at the level of the re-tear and was measured as the gap from the remaining lateral tendon stump. Intraclass coefficient for tear width was 0.906 and 0.790 for tear retraction. Fatty infiltration was measured using the Goutallier classification system and was collected on the most lateral sagittal-oblique imaging where the acromion, coracoid, and scapular body are all visible (scapular Y view).[4,24] Additional measurements included the length of tendon attached to the footprint as well as the length of the tendon attached to the muscle belly. The length of tendon attached to the footprint was measured as the length in mm of visible tendon that extended from the rotator cuff footprint (Fig. 1). The residual tendon length on the muscle was measured as the length in mm from the myotendinous junction to the end of the tendon (Fig. 2). There was a subset of patients that ruptured mid-tendinous (6) instead of at the musculotendinous junction and these patients were classified as Cho 2. Inter-rater reliability analysis was performed for both length of the tendon attached to the muscle belly and length of the tendon attached to the footprint and was found to have an intraclass correlation coefficient of 0.673 and 0.865, respectively.

Figure 1 Image demonstrating measurement of tendon length on footprint on coronal T2 right shoulder MRI. *MRI*, magnetic resonance imaging.

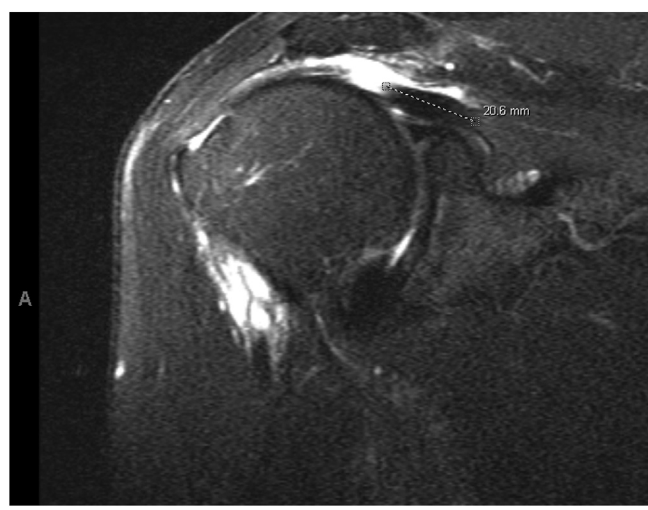

Figure 2 Image demonstrating measurement of residual tendon length on muscle on coronal T2 right shoulder MRI. *MRI*, magnetic resonance imaging.

Re-tear pattern classification

We characterized re-tears based on Cho's original paper, with a type 1 failure defined as detachment of the tendon from the rotator cuff footprint and type 2 failure as medial to the footprint, most typically at the muscle-tendon junction.[3]

Table I
Characteristics of the study population.

Parameter	All patients	Study group		P
		Cho 1	Cho 2	
Total†	57/57 (100%)	33/57 (57.9%)	24/57 (42.1%)	
Age* (y)	61.5 ± 9.1	61.6 ± 9.1	61.4 ± 9.2	.722
Sex†				
Female	21/57 (36.8%)	16/33 (48.5%)	5/24 (20.8%)	**.033**
Male	36/57 (63.2%)	17/33 (51.5%)	19/24 (79.2%)	
BMI*	29.9 ± 6.2	30.2 ± 5.6	29.5 ± 7.0	.452
ASA†				
≤2	27/39 (69.2%)	16/24 (66.7%)	11/15 (73.3%)	.734
≥3	12/39 (30.8%)	8/24 (33.3%)	4/15 (26.7%)	
CCI†				
≤3	53/57 (93.0%)	31/33 (93.9%)	22/24 (91.7%)	1.000
≥4	4/57 (7.0%)	2/33 (6.1%)	2/24 (8.3%)	
Occupation†				
Nonmanual labor	31/53 (58.5%)	19/31 (61.3%)	12/22 (54.5%)	.623
Manual labor	22/53 (41.5%)	12/31 (38.7%)	10/22 (45.5%)	
Smoking Status†				
Never	38/55 (69.0%)	22/32 (68.8%)	16/23 (69.6%)	.470
Former	11/55 (20.0%)	8/32 (25.0%)	3/23 (13.0%)	
Current	6/55 (11.0%)	2/32 (6.2%)	4/23 (17.4%)	
Prior Physical Therapy†				
No	27/51 (53.0%)	17/31 (54.8%)	10/20 (50.0%)	.735
Yes	24/51 (47.0%)	14/31 (45.2%)	10/20 (50.0%)	
Prior Shoulder Injection†				
No	28/52 (53.8%)	15/32 (46.9%)	13/20 (65.0%)	.202
Yes	24/52 (46.2%)	17/32 (53.1%)	7/20 (35.0%)	
Prior Rotator Cuff Repair†				
No	51/56 (91.1%)	29/32 (90.6%)	22/24 (91.7%)	1.000
Yes	5/56 (8.9%)	3/32 (9.4%)	2/24 (8.3%)	
Traumatic Tear†				
No	21/53 (39.6%)	13/31 (41.9%)	8/22 (36.4%)	.683
Yes	32/53 (60.4%)	18/31 (58.1%)	14/22 (63.6%)	

ASA, American Society of Anesthesiologists; *CCI*, Charlson Comorbidity Index; *BMI*, body mass index.
Bolded values are statistically significant with significance of alpha <.05.
*The values are given as the mean and the standard deviation.
†The values are given as the number of patients, with the percentage in parentheses.

Statistical analysis

Descriptive statistics were calculated. Continuous variables were compared between tear pattern groups using a 1-way analysis of variance test or student's *t*-test. Categorical variables were compared between groups using chi-squared or Fisher's exact test. Statistical significance was considered at 0.05. Multivariable regression was performed to assess for risk factors for re-tear. The reverse fragility index (RFI) was calculated for repair construct as previously reported.[18] All analyses were conducted using Excel 16 (Microsoft Corp., Redmond, WA, USA) and SPSS 29 (IBM Corp., Armonk, NY, USA).

Results

A total of 57 patients were included in the study. During the study period, 853 rotator cuff repairs were performed by the senior authors. Demographics of our cohort can be found in Table I. Overall, 33 (57.9%) patients were classified as a Cho 1 re-tear and 24 (42.1%) were classified as Cho 2 re-tear (Table I). Of the Cho 1 re-tears, 4 (12%) had anchor pullout. Time to re-tear was 15.1 ± 22.0 months (range 0-142 months). Bivariate analysis comparing Cho 1 vs. Cho 2 found no statistical difference when comparing age, body mass index, American Society of Anesthesiologists Classification, Charleston Comorbidity Index, occupation, smoking status, prior physical therapy, prior shoulder injection, prior rotator cuff repair, or traumatic tear (vs. nontraumatic). However, male sex was associated with a higher incidence of a Cho 2 re-tear (79.2% vs. 20.8%; $P = .033$) (Table I).

No differences in preoperative tear characteristics (tear width, tear retraction, and tendon length) or fatty infiltration were found between Cho 1 and Cho 2 re-tears. Furthermore, no differences in intraoperative surgical technique were noted between re-tear types. Specifically, no significant differences in repair construct (single-row medialized, single-row lateral, and double row) ($P = .816$), biceps treatment ($P = .552$), concomitant subscapularis repair ($P = .306$), number of medial anchors ($P = .533$), or number of lateral anchors ($P = .776$) were noted between re-tear types (Table II).

There were significant differences in tear width (27.7 mm ± 11.3 vs. 20.8 ± 10.8; $P = .021$), remaining tendon length on muscle (23.2 ± 6.6 vs. 17.1 ± 4.6; $P < .001$), and length of residual tendon stump attached to the rotator cuff footprint (0.3 ± 1.7 vs. 19.7 ± 7.0; $P < .001$) between Cho 1 and Cho 2 re-tears. No differences in tear retraction or fatty infiltration were noted between groups (Table III).

After controlling for potential confounding factors, multivariable regression analysis demonstrated that male sex was predictive of developing a Cho 2 re-tear (odds ratio [OR] 3.8; 95% confidence interval [CI] 1.1-13.3; $P = .039$). Repair construct was not found to be predictive of re-tear pattern (double row; OR 1.5; 95% CI 0.4-6.4; $P = .580$) (single-row medial; OR 1.2; 95% CI 0.2-7.1; $P = .820$) (single-row lateral; Reference) (Table IV). The RFI was calculated for double-row repair to have a significantly higher rate of type 2 failure and was found to be 13 patients.

Discussion

The purpose of this study was to better understand patient, imaging, and surgical characteristics associated with various re-

Table II
Preoperative MRI findings and intraoperative repair construct (Cho 1 vs. Cho 2).

Parameter	All patients	Study group		P
		Cho 1	Cho 2	
Preoperative MRI Findings*				
Tear Width (mm)	25.2 ± 11.8	23.9 ± 10.8	26.8 ± 13.1	.358
Tear Retraction (mm)	23.1 ± 11.8	22.5 ± 10.7	24.0 ± 13.3	.646
Tendon Length (mm)	26.3 ± 6.4	25.7 ± 6.3	27.1 ± 6.7	.426
Preoperative Goutallier†				
Supraspinatus				
0-2	37/54 (68.5%)	22/31 (71.0%)	15/23 (65.2%)	.653
3-4	17/54 (31.5%)	9/31 (29.0%)	8/23 (34.8%)	
Infraspinatus				
0-2	47/54 (87.0%)	26/31 (83.9%)	21/23 (91.3%)	.685
3-4	7/54 (13.0%)	5/31 (16.1%)	2/23 (8.7%)	
Subscapularis				
0-2	38/54 (70.4%)	20/31 (64.5%)	18/23 (78.3%)	.274
3-4	16/54 (29.6%)	11/31 (35.5%)	5/23 (21.7%)	
Teres Minor				
0-2	53/54 (98.1%)	30/31 (96.8%)	23/23 (100.0%)	1.000
3-4	1/54 (1.9%)	1/31 (3.2%)	0/23 (0.0%)	
Repair Construct†				
Single-Row Medial‡	12/57 (21.1%)	6/33 (18.2%)	6/24 (25.0%)	.816
Single-Row Lateral§	12/57 (21.1%)	7/33 (21.2%)	5/24 (20.8%)	
Double Row	33/57 (57.8%)	20/33 (60.6%)	13/24 (54.2%)	
Biceps Treatment†				
None	10/57 (17.5%)	5/33 (15.2%)	5/24 (20.8%)	.552
Tenodesis	42/57 (73.7%)	26/33 (78.8%)	16/24 (66.7%)	
Tenotomy	5/57 (8.8%)	2/33 (6.1%)	3/24 (12.5%)	
Concomitant Subscapularis Repair†				
No	36/57 (63.2%)	19/33 (57.6%)	17/24 (70.8%)	.306
Yes	21/57 (36.8%)	14/33 (42.4%)	7/24 (29.2%)	
Number of Anchors†				
Medial Anchors				
≤2	45/57 (78.9%)	27/33 (81.8%)	18/24 (75.0%)	.533
≥3	12/57 (12.1%)	6/33 (18.2%)	6/24 (25.0%)	
Lateral Anchors				
<2	32/57 (56.1%)	18/33 (54.5%)	14/24 (58.3%)	.776
≥2	25/57 (43.9%)	15/33 (45.5%)	10/24 (41.7%)	

MRI, magnetic resonance imaging.
*The values are given as the mean and the standard deviation.
†The values are given as the number of patients, with the percentage in parentheses.
‡Medialized single-row repair at the edge of the articular surface.
§Single-row repair with anchors at the center of the tendon footprint.

tear patterns after rotator cuff repair, as well as to identify risk factors for type 2 failure in a large patient cohort. The results of our study suggest that repair construct used during rotator cuff repair (eg, double vs. single row) does not appear to associate with re-tear pattern. Furthermore, male sex was found to be associated with a higher rate of type 2 failure.

The primary finding of our study was that repair construct was not found to be associated with re-tear pattern in our patient cohort. Cho et al in their 2010 paper introduced the concept that repair construct may influence re-tear pattern after rotator cuff repair, as they demonstrated a higher rate of type 2 failure (failure at the myotendinous junction) among patients with a double-row construct, when compared to those who underwent a single-row repair.[3] Several subsequent studies have supported this finding by reporting similar results.[1,2,12] Despite the dogma that has developed suggesting a link between double-row constructs and type 2 failure, studies supporting this thought are few and are limited by small sample sizes and methodological concerns.[2,12,17] For example, the largest available study (65 patients) assessing this question, by Kim et al, did not find a link between repair construct and re-tear pattern when considering 3 repair constructs together (single row, suture bridge, and knotless suture bridge), but required a subgroup analysis to elicit statistical significance between a traditional suture bridge construct and a single-row repair.[10] Furthermore, a systematic review found only 4 comparative studies assessing re-tear types among various repair constructs.[1] However, when including a combination of 10 additional studies reporting a single technique and pooling the data of multiple retrospective studies, they did report a higher rate of type 2 failure among double-row and suture-bridge constructs when compared to single-row repairs.[1]

One factor that may play a role in the development of type 2 failure is tension of the repair.[9] While overtensioning a repair with a double-row construct may lead to an increased likelihood of failing at the myotendinous junction,[8] in our sample, patients who demonstrated increased tension during repair underwent a single-row medialized repair rather than double-row repair. As such, our study's results may differ from prior results in part due to careful consideration to not overtension our repairs. Therefore, given our study's large sample size, technical improvements, and P values that do not approach statistical significance (repair construct bivariate P value = .816, multivariable P value for double-row repair = .580, RFI = 13), our results indicate that in appropriately selected patients, repair construct may not play as large of a role in re-tear pattern as previously thought.

Cho 2 failure remains an incompletely understood phenomenon. As it accounted for 42% of re-tears within our group, better understanding the mechanism for this failure type could provide surgeons with better strategies to avoid these failures. One potential explanation for this failure type is that the suture cuts through

Table III
MRI findings after re-tear (Cho 1 vs. Cho 2).

Parameter	All patients	Study group		*P*
		Cho 1	Cho 2	
Re-Tear MRI Findings*				
Tear Width (mm)	24.8 ± 11.3	27.7 ± 11.0	20.8 ± 10.8	**.021**
Tear Retraction (mm)	35.0 ± 9.6	34.3 ± 11.3	35.9 ± 6.7	.545
Tendon Length on Muscle (mm)	20.6 ± 6.5	23.2 ± 6.6	17.1 ± 4.6	**<.001**
Tendon Length on Footprint (mm)	8.5 ± 10.7	0.3 ± 1.7	19.7 ± 7.0	**<.001**
Re-Tear Goutallier†				
Supraspinatus				
0-2	15/55 (27.3%)	8/31 (25.8%)	7/24 (29.2%)	.781
3-4	40/55 (72.7%)	23/31 (74.2%)	17/24 (70.8%)	
Infraspinatus				
0-2	36/55 (65.5%)	20/31 (64.5%)	16/24 (66.7%)	.868
3-4	19/55 (34.5%)	11/31 (35.5%)	8/24 (33.3%)	
Subscapularis				
0-2	48/55 (87.3%)	29/31 (93.5%)	19/24 (79.2%)	.220
3-4	7/55 (12.7%)	2/31 (6.5%)	5/24 (20.8%)	
Teres Minor				
0-2	52/55 (94.5%)	29/31 (93.5%)	23/24 (95.8%)	1.000
3-4	3/55 (5.5%)	2/31 (6.5%)	1/24 (4.2%)	

MRI, magnetic resonance imaging.
Bolded values are statistically significant with significance of alpha <.05.
*The values are given as the mean and the standard deviation.
†The values are given as the number of patients, with the percentage in parentheses.

Table IV
Predictors of Cho type 2 tear.

Predictor	Odds ratio (95% CI)	*P*
Sex		
Male (reference: female)	3.8 (1.1, 13.3)	**.039**
Repair Construct (reference: single-row lateral)		
Single-Row Lateral	Reference	
Single-Row Medial	1.2 (0.2, 7.1)	.820
Double Row	1.5 (0.4, 6.4)	.580

CI, confidence interval.
Bold value is statistically significant with significance of alpha <.05.

the tendon, resulting in a re-tear at the site of the medial suture line. This theory has led some surgeons to reinforce their sutures with dermal allograft pledgets to avoid suture cut-out. Another potential explanation is that the suture constricts the tendon and reduces its vascularity, resulting in a re-tear through tissue necrosis. This theory has led some surgeons to use suture tapes instead of traditional round sutures. Within our study, those patients within the Cho 2 group had 17 mm of remaining tendon length on the muscle and 20 mm of remaining tendon length on the bone, for a combined tendon length of 37 mm. However, those patients in the Cho 1 group had 23 mm of remaining tendon length on the muscle and essentially no tendon length on the bone. So within our study, patients in the Cho 2 group had longer tendons than those in the Cho 1 group. These data do not fit with either of the above proposed mechanisms for Cho 2 failure. One potential alternative explanation for this discrepancy is that patients with Cho 2 failure experience tendon lengthening and failure in continuity[16] prior to experiencing a frank re-tear. This might also explain why Cho type did not associate with repair construct in our paper, because failure in continuity occurs independently of repair construct.

Regarding patient demographics, we found that male sex is predictive of a Cho type 2 re-tear. Specifically, the absolute proportion of males with a type 2 re-tear (79.2%) was much larger than the proportion of females with a type 2 re-tear (20.8%) indicating that this finding likely is not only statistically significant but also clinically relevant. While the exact reason for this finding is unclear, we can speculate that it may be due to differences in tendon and bone quality between genders. Specifically, women may be more prone to fail at the bone-tendon interface (type 1 failure) due to postmenopausal osteoporosis,[7,27] whereas males, who on average have higher bone density, may be prone to fail medially.[8] These differences suggest that differential strategies may be necessary between genders to reduce failure rates. In women, a bone-based strategy may be necessary, whereas in men, a tendon-based strategy may be necessary.

Furthermore, the connection between sex and type 2 failure could be due to hormonal influences on tendon strength and healing. Although a recent meta-analysis did not find that sex was a risk factor for re-tear, there have been multiple studies that highlight hormone deficiency as being associated with rotator cuff disease.[15,26,27] Tashjian et al reported in an animal model that estrogen supplementation after repair improves the histologic quality of the tendon enthesis and testosterone supplementation improves animal activity.[22] A necessary hormonal balance likely also needs to be achieved as other studies have shown an increased risk of rotator cuff tears, repairs, and revisions in patients on testosterone replacement therapy.[23] Testosterone has been shown to increase tendon stiffness which can increase tendon quality but is also linked to reduced responsiveness to relaxin which can influence rotator cuff tear.[5] As such, further investigation regarding the influence of sex on re-tear pattern should be considered moving forward.

Our study is not without limitations. First, this study is a retrospective study, indicating that it cannot prove causation but can only demonstrate associations. Second, it should be noted that the time to re-tear indicates that both chronic and traumatic tears were included, which is also demonstrated by the increased postoperative Goutallier atrophy which could lead to some bias in choice of repair construct. However, due to the relatively small patient cohort, it was not felt that a subgroup analysis between early and late failure was appropriate, but subsequent studies should address the issue of time to failure. Third, it should be noted that the decision to perform a single-row or double-row repair was subjective and based on the clinical judgment of the 2 senior surgeons intraoperatively. Furthermore, there was no objective measure of tension intraoperatively, and thus the authors have only their subjective sense for what is excessive tension to guide the decisions that were made as to repair constructs. It is therefore possible that our results are not generalizable to all surgeons. Fourth, the tendon length measurement demonstrated low intraclass correlation suggesting that there needs to be increased standardization of measurement protocols. Fifth, despite the large size of our cohort compared to prior studies, our relatively small cohort may be prone to type II errors. However, it is unlikely that this is the case in regards to the influence of repair construct on re-tear pattern given the fact that our *P* value on both bivariate and multivariable analyses does not closely approach statistical significance.

Conclusion

Repair construct used during rotator cuff repair does not appear to influence re-tear pattern. Male sex was associated with a higher rate of type 2 failure.

Disclaimers:

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