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Is residual tendon a predictor of outcome following arthroscopic rotator cuff repair? A preliminary outlook at short-term follow-up

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Background: Multiple factors including muscle atrophy, fatty infiltration, smoking, advanced patient age, and increasing tear size have been identified as risk factors for retear after rotator cuff repair. However, little is known about what effect the length of the residual rotator cuff tendon has on the success of repair and patient outcomes.

Methods: This study included 64 patients. Patients were stratified based on a residual tendon length of greater than 15 mm (group 1, residual tendon) or 15 mm or less (group 2, no residual tendon). Rotator cuff tendon integrity was then evaluated using ultrasound imaging at 6 months. Outcome measures included the Single Assessment Numeric Evaluation score, visual analog scale score, EQ5D Index score, Global Rating of Change score, and Penn Shoulder Score.

Results: No differences were found between groups regarding demographic data or repair configuration. Assessment of tendon healing demonstrated an increased rate of tendons that had ''not healed'' in group 2 (19.3% [n = 5] vs. 13.2% [n = 5]), but this difference was not statistically significant ($P = .55$). Functional outcome scores improved significantly from preoperatively to final follow-up in both groups and displayed no differences at 6-month follow-up.

Conclusion: A smaller residual tendon length was not a negative predictor of clinical outcomes following arthroscopic rotator cuff repair in patients with short-term follow-up. Although there was a trend toward a decreased rate of healing in patients with smaller residual tendons, this was not significant.

Level of evidence: Level II; Prospective Cohort Design; Treatment Study

Keywords: Rotator cuff tear; repair; retear rate; residual tendon length; risk factor; shoulder

Institutional Review Board approval was received from the Greenville Health System (file no. Pro00034149) prior to patient enrollment.

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Rotator cuff disease is a common reason patients seek medical attention.[7,11] For those requiring surgical repair, retears remain a major concern.[14,32] Many studies have shown that large to massive rotator cuff tears carry a high

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rate of retear.[15] Tear size has commonly been described regarding the degree of retraction, the anterior-to-posterior dimensions, or the medial-to-lateral dimensions. However, little is known about what effect residual rotator cuff tendon length has on the success of repair or patient outcomes.

The primary aim of this study was to investigate the role of residual tendon length on healing and repair integrity at short-term follow-up. A secondary aim was to determine the effect of residual tendon length on patient-reported outcomes. We hypothesized that patients with less residual tendon length would be at a greater risk of retear and would have decreased patient-reported outcomes compared with patients with greater residual tendon length.

Methods

Patients who presented with a rotator cuff tear and were deemed surgical candidates were prospectively enrolled from July 2014 to April 2017. Arthroscopic repair was performed by 1 of 4 sports medicine fellowship-trained surgeons. The inclusion criteria were patient age between 18 and 60 years and primary full-thickness supraspinatus or multi-tendon tears that had failed nonoperative management. The exclusion criteria included tears that were irreparable or partially repairable, revision rotator cuff tears, and repairs requiring patch augmentation or superior capsular reconstruction.

Patients were stratified intraoperatively based on a residual tendon length of greater than 15 mm (group 1, residual tendon) or 15 mm or less (group 2, no residual tendon). A probe with calibrated markings in 5-mm increments was used to measure the distance from the muscle belly to the lateral edge of the tear (Fig. 1). The length of the tendon was measured both from the smallest distance of the tear to the muscle belly and at the midpoint of the tear. The smallest distance of residual tendon was used for statistical analysis.

Patients were followed up prospectively, and outcome measures were obtained at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively. Demographic data included age, sex, race, smoking status, workers' compensation status, and acuity of injury. Preoperative magnetic resonance imaging (MRI) was used to assess and categorize fatty infiltration of each tendon according to the Goutallier classification.[12] Significant fatty infiltration was classified as Goutallier grade III or IV. Surgical technique and dimensions of the tendon tear were also collected. Outcome measures included the Single Assessment Numeric Evaluation (SANE) score, visual analog scale score, EQ5D Index score, Global Rating of Change (GRoC) score, and Penn Shoulder Score. The SANE score is a single response to the question, "What percentage of normal is your shoulder?" A rating is given on a scale from 0 to 100, with a higher score being better.[33] The SANE has been shown to be a reliable measure, providing similar scores to American Shoulder and Elbow Surgeons scores across a range of shoulder diagnoses.[6,13,31] The visual analog scale assesses the severity of pain from 0 to 10, with 0 defined as "no pain" and 10 defined as "severe pain." The EQ5D Index score is well-known and widely used, providing a simple, generic measure of health status from 0 to 100, with 0 defined as the worst imaginable health state and 100 defined as the best imaginable health state.[8] The GRoC is an assessment of well-being, with a single-item recall-based questionnaire compared with the initial treatment encounter.[10] It is a 15-point self-report scale (from −7 to 7) on which patients rate their shoulder well-being since the last visit. A score of 5 or greater has been identified as a potential important improvement that reflects continuing treatment.[29] The Penn Shoulder Score has been shown to be a reliable and valid measure for shoulder disorders, with 3 subscales assessing pain, satisfaction, and function on a 100-point scale.[13,20]

The surgical technique was standardized for all patients. The lateral decubitus position was used following administration of general anesthetic and interscalene block. A diagnostic arthroscopy was performed through standard posterior and anterior portals. If biceps pathology was encountered, either a tenodesis or tenotomy was performed based on patient age and activity level. The arthroscope was then oriented to the subacromial space, and a lateral portal was created. A subacromial decompression with acromioplasty, if warranted, was performed. The rotator cuff tear was evaluated for tear size and pattern, as well as cuff mobility. If the rotator cuff was deemed repairable, the dimensions of the tear from anterior to posterior were measured, along with the residual tendon length. The rotator cuff footprint on the greater tuberosity was prepared and the torn tendon was mobilized in standard fashion. Rotator cuff repair was performed with a single- or double-row construct at the discretion of the treating surgeon.

Postoperatively, patients were placed in an immobilizing shoulder abduction brace. Beginning on postoperative day 1, patients began wrist and elbow range-of-motion exercises along with scapular protraction and retraction exercises, during the "quiet"

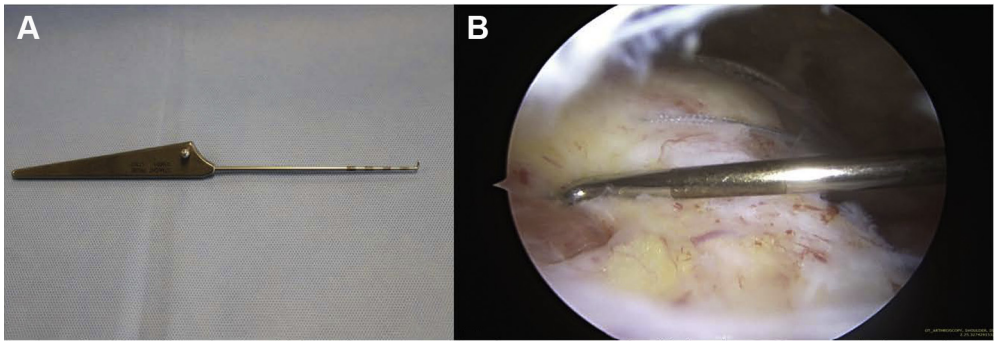

Figure 1 (**A, B**) Intraoperative images of measurement of residual tendon length using a calibrated probe with markings at 5-mm increments.

phase of rehabilitation. The usual physical therapy protocols were used based on tear size. Patients progressed to passive range-of-motion exercises in the second postoperative week if the tear was smaller than 3 cm or in postoperative week 4 or 5 if the tear was greater than 3 cm. Active-assisted range-of-motion exercises began in weeks 6 to 8, and strengthening was gradually added, for a total of 12 weeks of postoperative physical therapy.

At 6 months postoperatively, assessment of the healing rate and rotator cuff repair integrity was performed with ultrasound by 2 blinded reviewers. The healing rate and repair integrity were defined using the scale previously described by Sugaya et al[5,30]: type I, sufficient thickness with homogenously low intensity; type II, sufficient thickness with partial high intensity; type III, insufficient thickness without discontinuity; type IV, presence of minor discontinuity; and type V, presence of major discontinuity. Types I, II, and III were classified as "healed," whereas types IV and V were classified as "not healed."

Statistical analysis

To determine the sample size, the study was powered (a priori) with the assumptions associated with an analysis of covariance, analyzing for fixed effects, main effects, and interactions. The primary outcome measure was the healing rate and integrity of the rotator cuff tear. On the basis of previous comparative literature and estimates of the healing rate and integrity, a projected effect association of 0.40 between residual tendon length and healing rate was used. With an expected 80% power at 4 dedicated time points (2 weeks, 6 weeks, 3 months, and 6 months), 4 covariates (tear size, tear chronicity, patient age, and single- vs. double-row repair), and a standard error of probability of .05, it was estimated that a minimum sample size of 73 patients was needed to achieve statistical significance. A dropout rate of 20% from baseline was expected, resulting in a target of 87 patients required to meet the goals of the analyses.

Descriptive statistics of the sample were calculated and compared between tendons classified as healed vs. those classified as not healed using t and χ^2 tests (or the Fisher exact test when appropriate). We performed an analysis of covariance to assess the differences in residual tendon length between the healed and not healed groups while controlling for the operative and demographic covariates of tear size, tear chronicity, patient age, and single- vs. double-row repair. A P value of .05 was used for all analyses.

Results

A total of 90 patients were initially enrolled, of whom 64 were available at final follow-up. Of these patients, 38 had a residual tendon length of greater than 15 mm (group 1, residual tendon) and 26 had a residual tendon length of 15 mm or less (group 2, no residual tendon). Demographic data demonstrated no difference in age ($P = .09$), sex ($P = .08$), smoking status ($P = .98$), workers' compensation status ($P =$

Table I Descriptive baseline statistics

Variable	Group 1: tendon length $>$ 15 mm (n = 38)	Group 2: tendon length $\leq$ 15 mm (n = 26)	P value
Sex, n			
Male	23	10	.08
Female	15	16	
Age, mean (SD), yr	58.52 (9.05)	62.31 (8.56)	.09
Race, n			
White	28	25	.02*
African American	10	1	
Days to surgery, mean (SD)	64.6 (59.8)	52.5 (51.71)	.41
Workers' compensation status, n			
Yes	8	4	.57
No	30	22	
Smoking status, n			
Yes	5	3	.98
Former	7	5	
Never	26	18	
Single row vs. double row, n			
Single	15	11	.82
Double	23	15	
Anterior-to-posterior dimension (mm), mean (SD)	25.01 (9.25)	26.07 (7.31)	.63
Significant fatty infiltration (Goutallier grade III or IV), n (%)			
Subscapularis	1 (2.8)	2 (10)	.25
Supraspinatus	0 (0)	0 (0)	—
Infraspinatus	3 (8.3)	1 (5)	.64
Teres minor	1	0	.45

SD, standard deviation.
* Statistically significant ($P < .05$).

Table II Preoperative baseline outcomes

Variable	Group 1: tendon length > 15 mm (n = 38), mean (SD)	Group 2: tendon length ≤ 15 mm (n = 26), mean (SD)	*P* value
SANE score	47.0 (21.41)	31.52 (23.09)	<.01*
VAS score	6.74 (3.04)	7.08 (2.91)	.67
EQ5D score	66.18 (26.64)	76.0 (18.59)	.64
Penn Shoulder Score	42.42 (16.2)	39.78 (16.19)	.53

SD, standard deviation; *SANE*, Single Assessment Numeric Evaluation; *VAS*, visual analog scale.
* Statistically significant ($P < .05$).

Table III Analysis of tendon healing

Blinded ultrasound evaluation of healing rate at 6 mo	Group 1: tendon length > 15 mm (n = 38), n	Group 2: tendon length ≤ 15 mm (n = 26), n	*P* value
Healed	33	21	.55
Not healed	5	5	

.57), or tear acuity ($P = .41$). However, a significantly higher proportion of white patients to African American patients was found in group 2 (Table I).

RoRotator cuff tear size and repair configuration (single vs. double row) did not differ significantly between groups ($P = .63$ and $P = .82$, respectively). Preoperative MRI did not demonstrate any significant difference in fatty infiltration of any tendon between groups (Table I). Baseline outcome scores were similar between groups except for the SANE score, with group 2 having a significantly worse baseline SANE score (47.0 vs. 31.5, $P < .01$) (Table II).

Assessment of tendon healing demonstrated an increased rate of tendons that had not healed in group 2 (19.3% [n = 5] vs. 13.2% [n = 5]), but this difference was not statistically significant ($P = .55$) (Table III). All outcome measures showed improvements from baseline values, with the GRoC score, SANE score, and Penn Shoulder Score demonstrating statistically significant improvements ($P = .04$, $P < .01$, and $P < .01$, respectively) at final follow-up. Comparison between groups 1 and 2 did not demonstrate any differences in outcome scores (Table IV).

Discussion

The results of this study did not prove our hypothesis as a smaller residual tendon length was not found to have a negative effect on healing rates and functional outcomes compared with a larger residual cuff length at short-term follow-up. Although an increased rate of repairs that had not healed was noted in patients with a smaller residual tendon length, this was not statistically significant.

The primary goal of any rotator cuff repair is to restore the anatomic footprint with a sufficient bone-tendon interface, maximizing the ultimate load to failure of the repair construct while not placing undue tension on the tendon.[1,3,21] With this in mind, several studies have noted superior biomechanical characteristics of double-row repairs compared with single-row repairs.[4,17,22,28] However, to maximize tendon compression over the footprint, it is often necessary to pass sutures anywhere from 10 to 15 mm medial to the lateral edge of the tendon tear.[2,27] Intuitively, it would be reasonable to assume that a reduced residual tendon length could affect outcomes of rotator cuff repair. With decreasing tendon area, passage of sutures closer to the musculotendinous junction creates increased vulnerability to medial cuff failure near the musculotendinous junction, often referred to as a ''type 2'' failure, which has occurred secondarily to a previous rotator cuff repair.[2,26]

As the chronicity of a rotator cuff tear increases, the muscle undergoes atrophy and fatty degeneration; these, in turn, lead to decreased muscle elasticity and ultimately increased difficulty in obtaining a successful repair.[12,16] Musculotendinous retraction is often the most important pathophysiological consequence when considering the feasibility of a repair. It is important to note that it is not just the muscle that retracts; rather, the tendon itself has been shown to have the potential for shortening in animal models.[9,24]

Recently, the role of tendon shortening as it relates to rotator cuff tears in humans has been investigated. In a prospective evaluation of patients with full-thickness tears, Kim et al[18] found that tendon length decreased significantly with increasing cuff tear size in both the anterior-to-posterior and medial-to-lateral dimensions when measured intraoperatively. Furthermore, Meyer et al[23] noted that the residual tendon stump did not have the length of the original tendon and may in fact shorten over time. To our knowledge, only 2 studies have examined residual tendon length as a predictor of postoperative outcomes. In a small series of full-thickness supraspinatus tears, the combination of Goutallier grading and tendon length was found to be a predictor of reparability.[25] If the tendon had a Goutallier grade of II to III and a residual tendon length of less than 15 mm, the failure rate was 92%, as opposed to only 33% if the tendon length was greater than 15 mm. Kim et al[19] in a larger series examined single- vs. double-row repair as it related to remnant tendon lengths. It is interesting to note that a significant increase was found in the retear rate in double-row repairs if the residual tendon length was less than 10 mm. Kim et al concluded that consideration of single-row repair should be made in patients with a residual tendon length of less than 10 mm.

Although the results of our study did not demonstrate residual tendon to be a definitive predictor of outcomes

Table IV Patient-reported outcomes compared over time and between groups

Variable	6 wk, mean (SD)	3 mo, mean (SD)	6 mo, mean (SD)	*P* value	
				PROM over time	PROM between groups
GRoC score					
Group 1	2.82 (2.46)	3.30 (2.93)	4.83 (1.82)	.04*	.5
Group 2	3.57 (1.83)	4.00 (3.07)	4.32 (2.16)		
SANE score					
Group 1	37.54 (25.02)	70.32 (20.93)	77.88 (18.48)	<.01*	.6
Group 2	38.15 (26.78)	66.65 (22.79)	77.66 (23.82)		
VAS score					
Group 1	4.58 (3.30)	3.50 (3.03)	2.69 (2.91)	.58	.52
Group 2	4.84 (2.67)	3.31 (3.24)	2.11 (3.05)		
EQ5D score					
Group 1	64.24 (26.12)	76.16 (18.05)	75.76 (19.71)	.11	.8
Group 2	69.27 (22.14)	77.39 (17.15)	79.72 (19.28)		
Penn Shoulder Score					
Group 1	28.65 (20.35)	45.11 (30.81)	68.58 (32.51)	<.01*	.51
Group 2	36.32 (23.55)	53.77 (27.74)	68.33 (30.63)		

SD, standard deviation; *PROM*, patient-reported outcome measure; *GRoC*, Global Rating of Change; *SANE*, Single Assessment Numeric Evaluation; *VAS*, visual analog scale.
The analysis was controlled for race, baseline SANE score, anterior-to-posterior difference, and baseline value of the designated variable.
* Statistically significant ($P < .05$).

following rotator cuff repair, it stands to reason that residual tendon length may in fact still be a factor to consider. It is imperative to provide an environment in which the repaired tendon is under low tension while maximizing footprint coverage with a biomechanically sound construct.[32] If there is little residual tendon, the potential for an over-tensioned repair or suture passage too closely to the musculotendinous junction increases; this can lead to medial cuff failure.

Certainly, some of the limitations of this study may have played a role in the results found to date. Perhaps the most significant limitation of this study is the length of follow-up to date. With only 6 months' follow-up, there was a noted trend toward an increase rate of repairs that had not healed in the smaller residual tendon group, and with further follow-up, this may have become statistically significant. The measurement itself has some limitations as it uses a straight calibrated probe whereas the tendon itself can have an element of curvature. In addition, the reliability of this measurement technique was not tested. Repair integrity was classified using the Sugaya classification, which is MRI based. Although a previous study has described using ultrasound with the Sugaya classification,[5] this has not been validated and should be taken into consideration. Furthermore, concomitant procedures or objective strength measurements were not collected in this study. Finally, although the technique of single- or double-row repair was documented, decision making for repair technique was surgeon based, which naturally lends itself to potential for bias.

Conclusion

A smaller residual tendon length was not a negative predictor of clinical outcomes following arthroscopic rotator cuff repair in patients with short-term follow-up. Although there was a trend toward a decreased rate of healing in patients with smaller residual tendons, this was not significant. Longer follow-up is needed to assess the role a smaller residual tendon has in rotator cuff repair.

Disclaimer

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