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# Biceps tenotomy vs. tenodesis in patients undergoing transtendinous repair of partial thickness rotator cuff tears

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A R T I C L E I N F O

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Partial-thickness tears
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*Level of evidence:* Level III; Retrospective Cohort Comparison; Treatment Study

**Background:** Patients with partial thickness rotator cuff tears (PTRCTs) often present with concurrent pathology of the long head of the biceps tendon (LHBT). To address both conditions simultaneously, long head of the biceps (LHB) tenotomy or tenodesis can be performed at the time of arthroscopic rotator cuff repair (RCR). This study aims to compare postoperative shoulder active range of motion (AROM) and complications following transtendinous RCR with concurrent LHB tenodesis or tenotomy.

**Methods:** A total of 90 patients with PTRCTs met inclusion criteria for this study. Patients who underwent tear-completion-and-repair, revision surgery, or open repair of the LHB tendon were excluded. Patients were stratified into tenotomy, arthroscopic suprapectoral tenodesis, or no biceps operation cohorts and were propensity matched 1:1:1 on age, sex, body mass index, and smoking status. Primary outcome measures included AROM in forward flexion, abduction, external rotation, and internal rotation at 6 weeks, 3 months, and 6 months postoperatively. The development of severe stiffness and rates of rotator cuff retear at final follow-up were recorded as secondary outcomes.

**Results:** When comparing the tenotomy and tenodesis cohorts, tenotomy patients were found to have increased AROM at 3 months in forward flexion (153.2° vs. 130.1°, $P = .004$), abduction (138.6° vs. 114.2°, $P = .019$), and external rotation (60.4° vs. 43.8°, $P = .014$), with differences in forward flexion remaining significant at 6 months (162.4° vs. 149.4°, $P = .009$). There were no significant differences in interval rates of recovery in any plane between cohorts. Additionally, there were no significant differences in rates of symptomatic retears between groups ($P = .458$). Rates of severe postoperative stiffness approached but did not achieve statistical significance between tenotomy (4.2%) and tenodesis (29.2%) cohorts ($P = .066$). Smoking status was a significant predictor of severe stiffness (odds ratio, 13.69; $P = .010$).

**Conclusion:** Despite significant differences in absolute AROM between cohorts, the decision to perform tenotomy or tenodesis was not found to differentially affect rates of AROM recovery for patients undergoing arthroscopic transtendinous RCR for PTRCT. Notably, however, transient stiffness complications were more commonly observed in smokers, and data trends suggested an increased risk of stiffness for patients undergoing LHB tenodesis. Overall, postoperative stiffness is

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likely multifactorial and attributable to both patient- and procedure-specific factors, and LHB tenotomy may be more appropriate for patients with risk factors for developing stiffness postoperatively.



Partial thickness rotator cuff tears (PTRCTs) are a common cause of shoulder pain and functional limitation.[15,36] Although nonoperative interventions remain first-line for management, the optimal method of surgical treatment for those who fail conservative measures remains contested.[32] Imaging and histologic studies have demonstrated that the healing potential of PTRCTs is limited and biomechanical models have found an increase in strain on neighboring, intact tendons when tears involve >50% of the tendon thickness.[15,16,31,35-37,48] As such, surgical options for rotator cuff repair (RCR) for PTRCTs include transtendinous repair or tear-completion-and-repair. While both techniques are effective in mitigating tear progression and preventing long-term complications, some studies have found transtendinous repair to have superior outcomes in terms of biomechanical integrity and rates of cuff retear.[19,40,41,45] However, transtendinous repairs have classically been associated with increased stiffness and a slower rate of recovery, especially in the early postoperative period.[23,45] While an accelerated physical therapy regimen may help obviate these early postoperative mobility complications, this phenomenon remains a problem that may be further compounded in the setting of concurrent arthroscopic procedures performed at the time of cuff repair.[30,38]

Symptomatic rotator cuff tears are often associated with concurrent biceps tendinopathy.[2] The concomitant presentation of biceps pathology is likely related to the anatomic course of the long head of the biceps tendon (LHBT), which originates intraarticularly at the supraglenoid tubercle, making it prone to injury in the setting of rotator cuff pathology.[13] For this reason, arthroscopic repair of PTRCTs often necessitates simultaneous biceps interventions, which commonly include long head of the biceps (LHB) tenotomy or tenodesis. While tenotomy and tenodesis are both effective in relieving pain arising from the LHBT, available literature has yet to establish a definitive preference for either procedure. In the absence of rotator cuff pathology and with the exception of certain patient populations for which the literature has specifically demonstrated improved outcomes with biceps tenodesis (e.g. patients <35 year old, contact/overhead athletes, and laborers),[9] isolated LHB tenotomy and tenodesis have been shown to yield similar clinical benefit and functional outcomes.[21,49]

Specifically in the setting of concomitant RCR, studies have found differences in functional outcomes between these biceps operations to be largely equivocal.[6,7,12,25,28,34] In a prospective randomized trial by Lee et al examining patients with rotator cuff tears and concurrent biceps tendinopathy, functional scores were similar between tenotomy and tenodesis groups but with higher incidence of Popeye deformity in tenotomy patients and greater forearm supination power in tenodesis patients.[28] In cohort studies performed by Fang et al and Kim et al, tenotomy and tenodesis patients had comparable functional outcomes without any additional functional benefit being afforded by LHB tenodesis.[12,25] Importantly, however, these studies did not specifically explore postoperative shoulder range of motion and are limited by their inclusion of patients with both full- and partial thickness rotator cuff tears.

Typically, the method of addressing proximal biceps pathology is often selected through a shared decision-making process that factors in both surgeon and patient preference.[14,17,27] Proponents of biceps tenotomy often cite the ease of the procedure, shorter operative times, and preservation of the labral ring to support their decision to cut the LHBT at its origin.[9,46] Additionally, a body of evidence also suggests that tenotomy may be preferred in older patient populations due to faster pain relief and fewer activity restrictions early in the postoperative period.[8,9,12] However, tenotomy has been classically associated with a higher risk of residual cosmetic deformity (i.e., Popeye deformity) and the possible development of postoperative muscle cramping, soreness, and/or weakness.[6,9,24,28] Conversely, while technically more challenging, some studies have found tenodesis to provide greater forearm supination power and, in some instances, significantly higher Constant scores than tenotomy.[18,28] However, the functional advantages of tenodesis are not uniform across available meta-analyses, and controversy remains regarding the optimal treatment of the LHBT during concomitant RCR.[20,22,29,44]

To date, no studies have compared LHB tenotomy and tenodesis specifically in the setting of transtendinous RCR for PTRCTs, where stiffness remains a significant concern in the early postoperative period.[23,45] As such, the purpose of this study was to explore the effects of concomitant LHB tenotomy vs. arthroscopic suprapectoral tenodesis vs. no biceps operation on postoperative shoulder mobility and secondarily track complications related to postoperative stiffness and retears. We hypothesized that the type of concurrent biceps operation performed would not differentially affect absolute active range of motion (AROM), interval rates of improvement in AROM, or complications related to postoperative stiffness and retears.

## Methods

### *Study population and design*

This was a retrospective matched cohort study comparing postoperative shoulder AROM and complication rates among patients who underwent arthroscopic transtendinous RCR with either concurrent biceps tenotomy or tenodesis. These patients were also compared to a control cohort of patients who underwent arthroscopic transtendinous RCR without concurrent biceps intervention. Approval for this study was obtained from our institutional review board (Mass General Brigham IRB Protocol #2022P002878).

A total of 331 patients who underwent transtendinous RCR by the senior author between November 2008 and December 2021 were initially reviewed for inclusion in this study. The inclusion criteria were: presence of PTRCT involving more than 50% of the tendon thickness confirmed by magnetic resonance imaging (MRI), failure of minimum 3 months of conservative management, management with primary transtendinous RCR, and clinical follow-up with documented AROM values.[11] Patients were excluded from the analysis if they underwent revision shoulder surgery or had radiographic evidence of significant glenohumeral osteoarthritis (i.e., Samilson-Prieto Grade > II). In addition, operative notes were queried, which excluded patients with full-thickness tears identified arthroscopically, those who received RCR via the tear-completion-and-repair approach, and those who underwent open

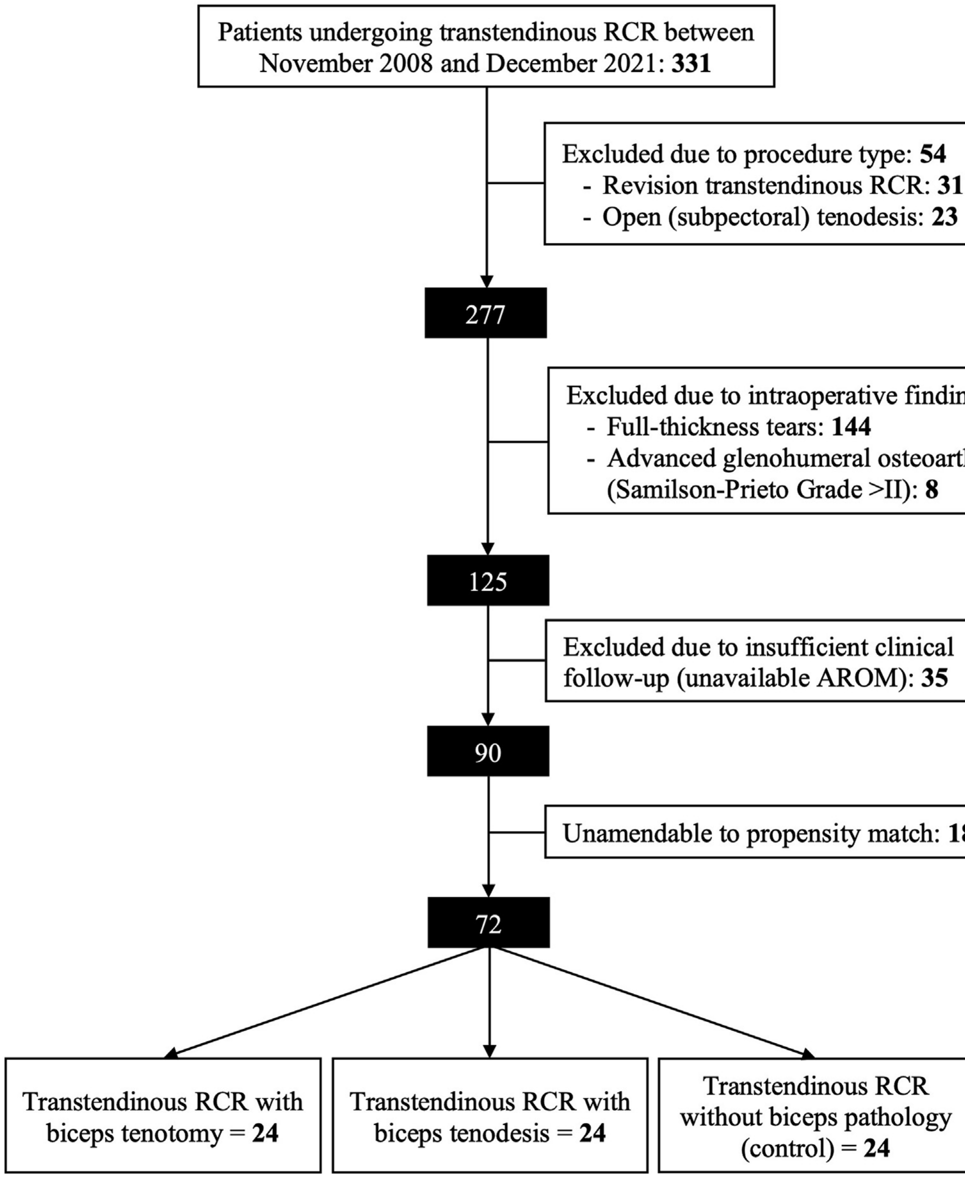


**Figure 1** Patient flowchart detailing exclusion criteria. *RCR*, rotator cuff repair; *AROM*, active range of motion.

tenodesis. Finally, patients with preoperative indications for biceps tenodesis were excluded from this study. This included patients <35 year old, contact/overhead athletes, and individuals with high physical demand occupations (e.g., manual laborers), as current literature largely supports tenodesis for these patient populations in the setting of concomitant RCR (Fig. 1).[9]

Following the application of inclusion and exclusion criteria, a total of 90 patients met eligibility for analysis. These patients were stratified into three cohorts based on whether they received long head of the biceps (LHB) tenotomy, tenodesis, or no biceps operation. To minimize the impact of any residual confounding factors, patients in each cohort were propensity score matched without replacement in a 1:1:1 fashion for age, sex, body mass index, and smoking status.[42] 18 patients could not be matched and were excluded from the analysis, resulting in a final study sample of 72 patients, with 24 patients in each cohort. To ensure homogeneity among cohorts, medical charts were queried for arthroscopic findings, including specific tendons requiring repair, the presence of concomitant labral tears, and isolated high-grade chondral lesions necessitating microfracture.

Data were retrospectively reviewed from our institution's electronic medical record by two of the authors (T.J.M. and K.A.T.). The primary outcome of this study was postoperative shoulder AROM, evaluated with standard goniometry. These data were collected in degrees for forward flexion, abduction, external rotation, and as vertebral levels for internal rotation at 6 weeks, 3 months, and 6 months postoperatively. Secondary outcomes included the rates of symptomatic (i.e., pain or weakness) rotator cuff retear based on clinical assessment by the senior author at final postoperative follow-up and the number of patients that developed severe postoperative stiffness. Per Brislin et al, severe stiffness was defined as AROM in forward flexion $\leq 100°$ or external rotation $\leq 10°$ at 3 months or later postoperatively (i.e., at the 3-month or 6-month timepoints in this study).[5] Patients with deficits and/or clinical signs concerning for cuff retear underwent repeat MRIs to confirm or exclude this diagnosis.

*Abbreviated surgical technique*

The operative shoulder was prepped and draped in the usual sterile manner using aseptic technique, and the patient was placed in the beach-chair position. The arthroscope was inserted through the standard posterior viewing portal, and additional portals were created under direct arthroscopic visualization. Anterior and anterosuperior portals were established to facilitate repair of the partial cuff tears and to address the LHBT. First, a diagnostic arthroscopy was performed to visualize the glenohumeral articular surfaces, labrum, rotator cuff, and LHBT. Individual rotator cuff tendons were systematically identified and examined arthroscopically to confirm the severity of the tear seen on MRI. Using the anterosuperior portal, areas of torn tendon or regions with poor tissue quality were lightly débrided with a 4.5-mm arthroscopic shaver. The area of the torn rotator cuff tendon was tagged with a polydioxanone suture (PDS). The arthroscope was then inserted into the subacromial space from the posterior portal, and bursectomy was carried out to better visualize the bursal side of the cuff and localize the area of the articular tear tagged with PDS. After inspection, if no evidence of full-thickness defects was identified, the senior author proceeded with transtendinous RCR and subacromial decompression was performed as indicated.

The anterosuperior portal was utilized for placement of a 4.75-mm bio-composite SwiveLock anchor at the dead man's angle of 45 degrees to ensure good bone purchase. The arthroscope was then placed back into the glenohumeral joint for anchor placement and suture passage. Number 2 fiber wire sutures were shuttled through the cuff using an 18-gauge spinal needle and a Chia suture shuttle relay. Additionally, use of the anterior portal with a 7-mm cannula enabled the proper separation and subsequent shuttling of suture. Sutures were passed through the area of the cuff cable, making a horizontal mattress pattern. The scope was then switched to the subacromial space, and a 7-mm cannula was placed through the lateral portal. Suture pairs were retrieved and brought out through the lateral portal. Sutures were secured with a Weston sliding knot followed by multiple half hitches. Once all sutures were retrieved and tied, a transosseous equivalent repair was completed by placing a second row using a 5.5-mm SwiveLock anchor(s) in the greater tuberosity for a tension-free repair. The repair was examined both on the subacromial and articular sides to ensure reapproximation of the cuff to the footprint and good stability of the repair throughout dynamic ROM testing.[38]

Next, the LHBT was examined with applied traction with a blunt probe bringing the biceps tendon into the joint. Care was taken to evaluate the biceps tendon as it coursed through the intertubercular groove. Intraoperative indications for biceps tenotomy or tenodesis were based upon 1) quality of the tissue (e.g., fraying, tearing, erythema, vascular injection, hypertrophy, etc.), 2) anatomic tracking of the tendon through the bicipital groove to the glenohumeral joint, 3) presence of concomitant SLAP tears or instability of the biceps anchor, and/or 4) disruption of the medial sling (subscapularis tearing ± biceps tendon subluxation or dislocation).

*Tenotomy*

A 4.5-mm arthroscopic shaver was used to mobilize the tendon by removing loose debris, lysing adhesions/scarred tissue near the bicipital sheath within the bicipital groove. A straight duckbill basket punch was utilized to release the LHBT at the biceps-labral junction near the superior aspect of the glenoid labrum. Next the remnant tendon was contoured to a stable, retracted position distally toward the bicipital groove. Hemostasis was ensured using a thermal wand with high flow to maintain ambient temperatures.

*Arthroscopic suprapectoral tenodesis*

The bicipital groove was decompressed using a 4.5-mm arthroscopic shaver, and a knife rasp was used to débride the bicipital groove bed in preparation for the tenodesis. In all cases, the tenodesis site was within the bicipital groove. After debriding with a 4.5-mm arthroscopic shaver, a double-loaded 4.75-mm SwiveLock anchor was then seated at the level of the tenodesis site within the groove. The suture limbs were then shuttled through the biceps tendon using a Chia suture shuttle relay and retrieved on the dorsal surface of the tendon. Large horizontal mattresses were tied down using modified Weston knots with multiple half-hitches, and care was taken to optimize the tension distributed to the proximal portion of the tendon. As described above, tenotomy was then carried out in a similar fashion and remnant tendon proximal to the attachment site was débrided.

*Postoperative rehabilitation*

A standard postoperative rehabilitation protocol was employed by the senior author following all RCRs performed before March 2015. After anecdotally observing that transtendinous patients, in particular, tended to exhibit substantial postoperative stiffness, the senior surgeon transitioned to an accelerated physical therapy (PT) protocol for all of his patients undergoing transtendinous repair from March 2015 onward.[38] Assignment to standard or accelerated PT was based solely on the patient's surgery date, with no patient factors governing this decision.

The protocol for standard PT was uniform across all three cohorts. Standard PT consisted of obligate sling wear for the first 6 weeks postoperatively and progression from purely passive ROM initially after surgery to active-assisted ROM after 6 weeks and ultimately to AROM with strengthening at 3-6 months, as is commonly cited in the literature.[40]

Accelerated PT was uniform across the tenotomy and control cohorts but was modified slightly for the tenodesis cohort. All accelerated PT patients were allowed active-assisted ROM at 2-4 weeks, AROM as early as 4-6 weeks, and strengthening exercises commencing at 6-8 weeks. Tenotomy and control patients also had early liberation from obligate sling wear, with patients being allowed to sleep without the sling using pain as their guide starting at 2-4 weeks and with no formal restrictions on sleeping position. For tenodesis patients undergoing accelerated PT, however, the sling was worn for 6 weeks during the daytime, with discontinuance during sleep permitted at 3 weeks. Patients' clinical progress was assessed via physical examination, and the decision to advance PT was made by the senior author when the patient was within the appropriate postoperative timeframe.[38]

*Power calculation and statistical analysis*

An *a priori* power analysis was performed based on a minimal clinically important difference in forward flexion of 11.7 degrees and demonstrated that at least 16 patients were required in each group to achieve at least 80% power.[39] The threshold for statistical significance was set to $P = .05$. Patients who met the inclusion criteria were propensity score matched 1:1:1 without replacement.[42] Descriptive statistics (i.e., means, standard deviations, ranges, and proportions) were calculated and reported, as appropriate. Forward flexion, abduction, and external rotation were recorded in degrees. Internal rotation was converted from vertebral levels to the Constant Shoulder

**Table I**
Baseline demographic data and surgical parameters for propensity-matched cohorts.

| | Tenotomy ($n = 24$) | Tenodesis ($n = 24$) | Control ($n = 24$) | *P* value |
|---|---|---|---|---|
| Age, mean years (SD) | 58.7 (8.9) | 54.8 (11.4) | 56.3 (11.1) | .442 |
| Sex, n (%) | | | | .651 |
| Male | 16 (66.7%) | 17 (70.8%) | 14 (58.3%) | |
| Female | 8 (33.3%) | 7 (29.2%) | 10 (41.7%) | |
| BMI, mean kg/m$^2$ (SD) | 28.5 (5.1) | 27.3 (3.5) | 28.5 (4.2) | .492 |
| Smoking status, n (%) | | | | >.999 |
| Never | 16 (66.7%) | 17 (70.8%) | 16 (66.7%) | |
| Former | 6 (25%) | 6 (25%) | 7 (29.2%) | |
| Current | 2 (8.3%) | 1 (4.2%) | 1 (4.2%) | |
| Mean follow-up for ROM evaluation, mean months (SD) | 10.4 (12.8) | 10.1 (8.9) | 12.7 (23.7) | .833 |
| Partial tear grade, n (%) | | | | .717 |
| Low grade partial | 1 (4.2%) | 1 (4.2%) | 0 (0%) | |
| Intermediate grade partial | 9 (37.5%) | 6 (25%) | 6 (25%) | |
| High grade partial | 14 (58.3%) | 17 (70.8%) | 18 (75%) | |
| Full thickness tear, n (%) | 0 (0%) | 0 (0%) | 0 (0%) | >.999 |
| Labral repair, n (%) | 8 (33.3%) | 14 (58.3%) | 8 (33.3%) | .128 |
| Supraspinatus repair, n (%) | 24 (100%) | 23 (95.8%) | 23 (95.8%) | >.999 |
| Infraspinatus repair, n (%) | 7 (29.2%) | 11 (45.8%) | 9 (37.5%) | .491 |
| Subscapularis repair, n (%) | 10 (41.7%) | 11 (45.8%) | 7 (29.2%) | .461 |
| Subacromial decompression, n (%) | 23 (95.8%) | 24 (100%) | 23 (95.8%) | >.999 |
| Outerbridge grade: humeral head, n (%) | | | | .849 |
| 0 | 0 (0%) | 2 (8.3%) | 2 (8.3%) | |
| 1 | 16 (66.7%) | 13 (54.2%) | 15 (62.5%) | |
| 2 | 6 (25%) | 7 (29.2%) | 6 (25%) | |
| 3 | 2 (8.3%) | 2 (8.3%) | 1 (4.2%) | |
| Outerbridge grade: glenoid, n (%) | | | | .348 |
| 0 | 0 (0%) | 1 (4.2%) | 2 (8.3%) | |
| 1 | 10 (41.7%) | 6 (25%) | 10 (41.7%) | |
| 2 | 6 (25%) | 12 (50%) | 8 (33.3%) | |
| 3 | 6 (25%) | 5 (20.8%) | 4 (16.7%) | |
| 4 | 2 (8.3%) | 0 (0%) | 0 (0%) | |
| Chondral lesion microfracture, n (%) | | | | >.999 |
| Humeral head | 0 (0%) | 0 (0%) | 0 (0%) | |
| Glenoid | 0 (0%) | 0 (0%) | 0 (0%) | |
| Indication for LHBT management, n (%) | | | | |
| SLAP tear | 8 (33.3%) | 14 (58.3%) | 8 (33.3%) | |
| Degeneration/tear | | | | |
| Biceps subluxation | | | | |
| Rehabilitation protocol, n (%) | | | | .111 |
| Standard physical therapy | 9 (37.5%) | 14 (58.3%) | 16 (66.7%) | |
| Accelerated physical therapy | 15 (62.5%) | 10 (41.7%) | 8 (33.3%) | |

*SD*, standard deviation; *BMI*, body mass index; ROM, range of motion; *LHBT*, long head of the biceps tendon; *SLAP*, superior labrum anterior posterior.

Score's numerical ten-point scale for analysis. The Shapiro-Wilk test was performed to confirm that continuous variables followed a normal distribution. The F-test was performed to confirm that continuous data demonstrated equal variances. A one-way analysis of variance test with Tukey post hoc analysis was used to compare normally distributed continuous data between groups. Univariate logistic regression analyses were used to analyze the relationship between demographic variables of interest, LHB procedure, and rehabilitation protocol on the probability of developing severe stiffness postoperatively. Chi-Square and Fisher's Exact tests were utilized to compare proportions of categorical variables between groups, as appropriate. Statistical analyses were performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and SPSS statistical software (version 28.0.0; IBM Corp., Armonk, NY, USA).

## Results

Following 1:1:1 propensity score matching, 72 patients remained and were included in our analyses, with 24 patients in each of the tenotomy, tenodesis, and control cohorts (Fig. 1). Baseline patient demographics were not significantly different between cohorts. Furthermore, there were no significant differences with respect to tear severity, chondral wear of the humeral head/glenoid (i.e., Outerbridge grade), postoperative rehabilitation regimens, or surgical parameters between cohorts. Duration of follow-up was also similar between groups (Table I).

### *Aggregate*

While no significant differences were observed between cohorts in AROM at 6-week follow-up, notable differences emerged at 3 and 6 months. In aggregate, the tenotomy, tenodesis, and control groups differed in forward flexion (153.2° vs. 130.1° vs. 137.3, respectively, $P = .004$), abduction (138.6° vs. 114.2° vs. 130.0, $P = .023$), and external rotation (60.4° vs. 43.8° vs. 46.3°, $P = .011$) at 3 months postoperatively. The only difference remaining at the 6-month timepoint was in forward flexion (162.4° vs. 149.4° vs. 149.5°, $P = .004$. However, differences also approached significance for abduction (160.3° vs. 148.8° vs. 151.6°, $P = .052$). The three cohorts did not have any significant differences in internal rotation AROM at any recorded timepoint (Table II).

### *Tenodesis vs. controls*

Post hoc comparisons between cohorts showed no significant differences between the tenodesis and control patients at any timepoint included in this study.

**Table II**
Active range of motion, stiffness, and retear data for all cohorts.

| | Tenotomy (n = 24) | Tenodesis (n = 24) | Control (n = 24) | *P* value | Post hoc comparisons | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tenotomy vs. tenodesis | Control vs. tenotomy | Control vs. tenodesis |
| 6 Weeks, mean (SD) | | | | | | | |
| Flexion | 120.0 (24.6) | 106.7 (32.8) | 115.5 (34.5) | .327 | 0.307 | 0.888 | 0.618 |
| Abduction | 106.0 (22.8) | 88.2 (28.8) | 108.2 (37.6) | .054 | 0.109 | 0.972 | 0.083 |
| IR | 6.2 (2.3) | 5.6 (3.0) | 6.1 (2.7) | .741 | 0.749 | 0.992 | 0.829 |
| ER | 38.0 (16.1) | 31.0 (18.2) | 43.7 (18.2) | .065 | 0.363 | 0.557 | 0.053 |
| 3 mo, mean (SD) | | | | | | | |
| Flexion | 153.2 (18.9) | 130.1 (27.1) | 137.3 (25.1) | .004* | 0.004* | 0.062 | 0.553 |
| Abduction | 138.6 (30.4) | 114.2 (33.1) | 130.0 (27.9) | .023* | 0.019* | 0.592 | 0.178 |
| IR | 7.4 (1.7) | 7.1 (1.9) | 6.9 (2.5) | .685 | 0.905 | 0.659 | 0.891 |
| ER | 60.4 (21.5) | 43.8 (18.3) | 46.3 (19.1) | .011* | 0.014* | 0.042* | 0.899 |
| 6 mo, mean (SD) | | | | | | | |
| Flexion | 162.4 (6.8) | 149.4 (14.0) | 149.5 (20.8) | .004* | 0.009* | 0.012* | >0.999 |
| Abduction | 160.3 (13.9) | 148.8 (15.5) | 151.6 (20.3) | .052 | 0.051 | 0.191 | 0.832 |
| IR | 7.9 (1.9) | 8.2 (1.6) | 8.3 (2.2) | .698 | 0.769 | 0.721 | 0.995 |
| ER | 67.8 (19) | 57.7 (17.9) | 62.0 (21.4) | .207 | 0.180 | 0.582 | 0.731 |
| Severe stiffness, n (%) | 1 (4.2%) | 7 (29.2%) | 3 (12.5%) | .066 | | | |
| Retear, n (%) | 2 (8.3%) | 4 (16.6%) | 5 (20.8%) | .458 | | | |
| Atraumatic | 0 (0%) | 3 (12.5%) | 2 (8.3%) | | | | |
| Traumatic | 2 (8.3%) | 1 (4.2%) | 3 (12.5%) | | | | |

*IR*, internal rotation; *ER*, external rotation; *SD*, standard deviation.
*Statistically significant ($\alpha = .05$).

**Table III**
Improvement in active range of motion over time.

| | Tenotomy (n = 24) | Tenodesis (n = 24) | Control (n = 24) | *P* value | Post hoc comparisons | | |
|---|---|---|---|---|---|---|---|
| | | | | | Tenotomy vs. tenodesis | Control vs. tenotomy | Control vs. tenodesis |
| 6 Weeks-3 mo, mean (SD) | | | | | | | |
| Flexion | 33.4 (22.7) | 23.4 (33.4) | 24.7 (26.5) | .432 | 0.447 | 0.583 | 0.987 |
| Abduction | 34.3 (30.1) | 26 (29.9) | 26.3 (29.5) | .575 | 0.609 | 0.668 | 0.999 |
| IR | 1.3 (2.2) | 1.5 (3.3) | 1.2 (2.6) | .960 | 0.988 | 0.989 | 0.956 |
| ER | 23 (23.1) | 12.8 (18.6) | 5.7 (16.7) | .023* | 0.192 | 0.019* | 0.480 |
| 3 mo-6 mo, mean (SD) | | | | | | | |
| Flexion | 9.2 (15.8) | 19.3 (26.5) | 13 (32.2) | .385 | 0.358 | 0.871 | 0.676 |
| Abduction | 21.6 (24.8) | 33.8 (31.3) | 22 (34.4) | .301 | 0.353 | 0.999 | 0.395 |
| IR | 0.6 (1.9) | 1.1 (1.7) | 1.6 (3.1) | .334 | 0.691 | 0.302 | 0.763 |
| ER | 8.1 (23) | 14 (18.9) | 15.5 (19.1) | .446 | 0.593 | 0.456 | 0.967 |
| 6 Weeks-6 mo, mean (SD) | | | | | | | |
| Flexion | 42.5 (23.5) | 42.8 (36.3) | 40.3 (44.2) | .972 | >0.999 | 0.978 | 0.973 |
| Abduction | 54.2 (24.5) | 59.7 (32) | 48.2 (46.8) | .574 | 0.848 | 0.849 | 0.545 |
| IR | 1.8 (2.8) | 2.6 (3.1) | 2.3 (4) | .686 | 0.664 | 0.868 | 0.950 |
| ER | 31.5 (28) | 26.8 (17.8) | 23.8 (24.3) | .579 | 0.770 | 0.564 | 0.915 |

*mo*, months; *IR*, internal rotation; *ER*, external rotation; *SD*, standard deviation.
*Statistically significant ($\alpha = .05$).

### *Tenotomy vs. controls*

Between the tenotomy and control cohorts, there were no significant differences at 6 weeks. However, tenotomy patients were found to have greater AROM than controls in external rotation (60.4° vs. 46.3°, $P = .042$) at 3 months postoperatively. At 6 months, tenotomy patients exhibited greater AROM than controls in forward flexion (162.4° vs. 149.5°, $P = .012$).

### *Tenotomy vs. tenodesis*

When comparing the biceps operation cohorts, there were no significant differences in AROM between the tenotomy and tenodesis patients at 6 weeks. At 3 months, forward flexion (153.2° vs. 130.1°, $P = .004$), abduction (138.6° vs. 114.2°, $P = .019$), and external rotation (60.4° vs. 43.8°, $P = .014$) were all significantly greater in the tenotomy cohort than the tenodesis cohort, with the difference in forward flexion also remaining significant at the 6-month timepoint (162.4° vs. 149.4°, $P = .009$). Ultimately, no statistically significant differences between the tenotomy and tenodesis cohorts were found in the interval improvements of AROM between any timepoints (Table III). Between the 6-week and 3-month follow-ups, tenotomy and tenodesis patients displayed similarly improved AROM in forward flexion (33.4° vs. 23.4°, $P = .447$) and abduction (34.3° vs. 26.0°, $P = .609$). Additionally, over the entire study period (6 weeks to 6 months), the total change in AROM was not found to be significantly different between tenotomy and tenodesis patients in any plane.

### *Secondary outcomes*

With respect to the secondary outcomes of this study, no significant difference in retear rates were found between the tenotomy (8.3%; $n = 2$), tenodesis (16.7%; $n = 4$), or control (20.8%; $n = 5$) groups ($P = .458$; Table II). Differences in rates of severe stiffness trended toward but ultimately did not achieve statistical

**Table IV**
Adjusted analysis evaluating postoperative stiffness based upon baseline demographics and arthroscopic procedures performed

| Parameter | Odds ratio (95% CI) | *P* value* |
|---|---|---|
| Age, years | 1.01 (0.93-1.09) | .808 |
| Sex | | |
| Female vs. male | 1.42 (0.23-8.62) | .702 |
| BMI (kg/m$^2$) | 1.00 (0.82-1.23) | .975 |
| Smoking status‡ | | |
| Current/former vs. never | 13.69 (1.89-99.37) | .010† |
| LHB procedure performed§ | | |
| Tenotomy vs. control | 0.58 (0.04-8.16) | .688 |
| Tenodesis vs. control | 8.30 (0.94-73.55) | .057 |
| Rehabilitation protocol | | |
| Accelerated vs. standard PT | 0.10 (0.01-1.22) | .072 |

*CI*, confidence interval; *BMI*, body mass index; *kg*, kilogram; *m*, meters; *LHB*, long head of the biceps; *PT*, physical therapy.
*All *P* values adjusted for age, sex, BMI, smoking status, rehabilitation protocol, and LHB, procedure performed.
†Statistically significant ($\alpha = 0.05$).
‡Reference: Never Smoked.
§Reference: Control Cohort (No Biceps Procedure).

significance, with a rate of 4.2% ($n = 1$; adjusted residual $= -1.9$) among tenotomy patients, 29.2% ($n = 7$; adjusted residual $= 2.3$) in tenodesis patients, and 12.5% ($n = 3$; adjusted residual $= -0.5$) in controls ($P = .066$). All cases of severe stiffness were found to have resolved by the final postoperative follow-up, including one case of adhesive capsulitis in the tenodesis cohort which required lysis of adhesions. A logistic regression was performed to assess the effects of age, sex, body mass index, smoking status, LHB procedure performed, and rehabilitation protocol on the likelihood of developing severe stiffness. Smoking status was found to be a significant predictor of severe stiffness, with current and former smokers having 13.69 greater odds of developing severe stiffness (95% CI: 1.89-99.37; $P = .010$) (Table IV). However, collectively, the predictors included yielded a statistically significant model for assessing severe postoperative stiffness, ($\chi^2$ (7) $= 23.212$, $P = .002$) and correctly classified 86% of cases of severe stiffness.

### *Sensitivity analysis*

A sensitivity analysis was conducted to assess differences in AROM within each cohort between patients who underwent a standard versus accelerated postoperative rehabilitation protocol, as accelerated PT has been associated with superior postoperative AROM in the setting of transtendinous RCR.[38] Consistent with the findings of McBroom et al, no significant differences were observed within tenotomy or tenodesis cohorts at 6 weeks postoperatively, or for any timepoint within the control group. However, tenotomy patients who underwent an accelerated PT exhibited greater AROM in external rotation at 3 months (69.4° vs. 46.4°, $P = .009$) and 6 months (73.7° vs. 57.8°, $P = .044$) postoperatively. Those who underwent accelerated PT in the tenodesis cohort displayed significantly greater AROM in abduction at 3 months (133.5° vs. 100.4°, $P = .012$) and forward flexion at both 3 (145.7° vs. 118.9°, $P = .013$) and 6 months postoperatively (157.0° vs. 144.0°, $P = .021$) (Supplementary Table S1).

## Discussion

The ideal method for addressing pathologies of the LHBT remains debated in the current literature. To our knowledge, no previous studies have directly assessed how LHBT management influences shoulder AROM and rates of secondary complications exclusively in the setting of concurrent transtendinous RCR for PTRCTs. While fewer incidences of Popeye deformities are an established advantage of biceps tenodesis, available meta-analyses indicate that patient satisfaction, functional outcomes, failure rates, and pain relief do not vary to a clinically significant degree.[4,20,22,29,44] Despite isolated AROM deficits for tenodesis at 3-month follow-up, the present study largely supports this notion, as patients undergoing tenotomy and tenodesis were found to have similar rates of improvement in AROM over the first 6 months postoperatively. The occurrence of retears and postoperative stiffness between these patients were also predictably similar. However, our results indicate that current or former smokers have a greater risk of postoperative stiffness, and although this aligns with previous literature, the etiopathogenesis for this association is currently unknown.[47]

Significant differences in the absolute values of AROM for forward flexion, abduction, and external rotation were found between biceps tenotomy and tenodesis cohorts. While a single study has associated decreased shoulder flexion with arthroscopic tenodesis,[10] the finding of the present study was largely unexpected and may be better attributed to variations in baseline functional status among our cohorts. In the present study, baseline ROM was unable to be accurately assessed, as a majority of patients' preoperative examinations were limited due to pain, and AROM metrics for the contralateral shoulder were not available as a surrogate measure for analysis. Alternatively, these differences could be explained in part by the complex relationship between the LHBT and the biomechanics of the shoulder joint. Kuhn et al demonstrated that the LHBT serves as a dynamic restraint to external rotation in the abducted position.[26] However, whether or not the biceps contributes to the functional range of motion in the shoulder is less clear. According to Ahrens and Boileau, the biceps functions as a weak abductor of the shoulder to supply about 7%-10% of the power for this plane of motion.[1] Hence, concurrent biceps operations at the time of arthroscopic RCR subtly alter the biomechanics of the shoulder, which may help explain the difference in AROM values in early postoperative follow-up visits.

While transtendinous repairs have been independently linked to stiffness early in the postoperative course, the present study suggests that LHB tenotomy or tenodesis does not significantly increase the risk of developing postoperative stiffness in the setting of transtendinous RCR. No significant differences were observed between groups in the development of severe stiffness, and LHB procedure was not a significant predictor of stiffness in our logistic regression model.[23,45] Additionally, while tenodesis patients displayed significantly less AROM in the early postoperative period relative to the tenotomy cohort, no differences were seen at any timepoint relative to the control. Nevertheless, data supporting an increased risk of postoperative stiffness in the setting of LHB tenodesis approached statistical significance, a finding that should be further explored. While LHB tenodesis may not independently increase the rate of postoperative stiffness, it appears to be one of several factors contributing to an increased risk profile. Compared to tenotomy, previous studies have cited that tenodesis inherently requires more soft-tissue manipulation/dissection to free the LHBT and appropriately reanchor the tendon. Additionally, arthroscopic methods of tenodesis have been associated with an increased risk for adhesion formation in the subdeltoid region, fluid extravasation, bleeding in the region of the biceps sheath, and possible overtensioning of the LHBT.[4,21,47] Furthermore, given that arthroscopic tenodesis is suprapectoral, the proximal anchoring point may necessitate the retention of more pathologic LHB tissue and further incite inflammation of the adjacent biceps tenosynovium.[9,10,33,47] Indeed, histologic analyses have found that the proximal portion of the LHBT and adjacent vascular bed have a high concentration of autonomic neuropeptides like calcitonin gene-related peptide and substance P.[3,43] This suggests that suprapectoral tenodesis may generate more inflammatory mediators in the shoulder postoperatively. Ultimately, the postoperative stiffness observed in the present study for tenodesis patients is likely multifactorial and attributable to both patient- and procedure-specific factors. Our data suggest that LHB tenotomy may be preferred in patients with significant risk factors for postoperative stiffness (i.e., older age, a history of smoking, or an inability to participate in accelerated PT).

Despite the strengths of this study, including following one of the largest reported cohorts of PTRCT patients, there are some notable limitations that should be considered. First, this study is a retrospective design with limitations commensurate with other observational studies. The choice of tenotomy and tenodesis procedures was not randomized and may be unduly influenced by potential confounders. Further, the present study did not assess the baseline mobility of patients with preoperative range of motion testing. It is possible that the differences in absolute AROM postoperatively could be partially attributable to lower baseline ROM for patients in the tenodesis cohort. Second, the study's follow-up period was limited to six months; a longer follow-up period could yield greater insights into the durability of improvements in AROM and potentially capture additional instances of postoperative stiffness and retear. Another important limitation is that the physical therapy protocols utilized for patients in this study were not uniform. Patients who underwent surgery in 2015 or later underwent an accelerated physical therapy regimen postoperatively. Although there was no significant difference in the overall utilization of accelerated physical therapy between the cohorts ($P = .111$), tenodesis patients who underwent this protocol had a longer duration of daytime obligate sling wear compared to tenotomy patients, which may have contributed to increased stiffness in the tenodesis group. Further, the decision to advance to subsequent phases of the physical therapy regimen was made by the senior author, which was an individualized determination based on evaluation of clinical progress at follow-up. Finally, data on cuff retear rates was based on physical exam and clinical assessment at the patients' final postoperative visit. MRI was reserved for patients presenting with an exam concerning for retear. Thus, the true incidence of cuff retear may have been higher than reported if there were subclinical tears, but this would not differentially affect any cohort relative to the others. Reassuringly, within these limitations there were no statistically significant differences in rotator cuff retear rates between the cohorts which did not vary between those undergoing standard vs accelerated PT.

## Conclusion

Despite significant differences in absolute AROM between cohorts, the decision to perform tenotomy or tenodesis was not found to differentially affect rates of AROM recovery in patients undergoing arthroscopic transtendinous RCR for PTRCT. Notably, however, transient stiffness complications were more commonly observed in smokers, and data trends suggested an increased risk of stiffness for patients undergoing LHB tenodesis. Overall, postoperative stiffness is likely multifactorial and attributable to both patient- and procedure-specific factors, and LHB tenotomy may be more appropriate for patients with risk factors for developing stiffness postoperatively.

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## Supplementary Data

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