# How Long Does It Take to Achieve Clinically Significant Outcomes After Isolated Biceps Tenodesis?

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**Background:** Clinically significant outcomes (CSOs) connect patient-reported outcome measures data to patient-perceived benefit. Although investigators have established threshold values for various CSOs, the timeline to achieve these outcomes after isolated biceps tenodesis (BT) has yet to be defined.

**Purpose:** To define the time-dependent nature of minimal clinically important difference (MCID), substantial clinical benefit (SCB), and Patient Acceptable Symptom State (PASS) achievement after isolated BT.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** The American Shoulder and Elbow Surgeons score (ASES), the Single Assessment Numeric Evaluation, and the Constant-Murley score (CMS) were administered preoperatively and at 6 and 12 months postoperatively to patients undergoing isolated BT between 2014 and 2018 at our institution. Cumulative probabilities for achieving MCID, SCB, and PASS were calculated using Kaplan-Meier survival analysis. Weibull parametric regression evaluated the hazard ratios (HRs) of achieving earlier MCID, SCB, and PASS.

**Results:** Overall cohort (N = 190) achievement rates ranged between 77.8% and 83.2% for MCID, between 42.2% and 80.2% for SCB, and between 59.7% and 62.9% for PASS. Median achievement time was 5.3 to 6.1 months for MCID, 5.9 to 6.4 months for SCB, and 6.07 to 6.1 months for PASS. Multivariate Weibull parametric regression identified older age, male sex, higher body mass index, preoperative thyroid disease, smoking history, and higher preoperative CMS as predictors of delayed CSO achievement (HR, 1.01-6.41), whereas normal tendon on arthroscopy, defined as absence of tenosynovitis or tendon tear on arthroscopy, predicted earlier CSO achievement (HR, 0.19-0.46). Location of tenodesis and worker compensation status did not significantly predict the time to achieve CSOs on multivariate analysis.

**Conclusion:** After isolated BT, patients can expect to attain CSO by 13 months postoperatively, with most patients achieving this between 5 and 8 months. Patients tend to take longer to achieve PASS than MCID and SCB.

**Keywords:** ASES; biceps tenodesis; clinically significant outcomes; minimum clinically important difference; timeline

Biceps tenodesis (BT) is a common procedure that can be used in the treatment of various shoulder pathologies, including lesions of the long head of the biceps tendon (LHBT), superior labral tears, and rotator cuff injuries.[11] A 2015 study by Werner et al[43] found that nearly 45,000 tenodesis procedures were performed from 2008 to 2011 and that the incidence of BT increased 1.7-fold over that time. Other investigations have corroborated this finding of increasing incidence over the past decade,[6,41,43] highlighting the need to define success of clinical intervention.

Patient-reported outcome (PRO) measures (PROMs) are objective tools commonly used for this purpose. However, it is imperative to understand that statistically significant improvements in a given measure may be inconsequential, as they are not always indicative of clinically significant and tangible benefit to patients.[14]

Several metrics exist to characterize clinically significant outcomes (CSOs) and aid in the interpretation of PROMs. These include the minimal clinically important difference (MCID), the substantial clinical benefit (SCB), and the Patient Acceptable Symptom State (PASS). The MCID quantifies the smallest postintervention improvement in an outcome measure that a patient perceives as beneficial,[13] while SCB describes the degree of change in a

given outcome measure necessary for patients to feel a more significant amount of improvement.[25] Finally, PASS describes whether or not patients feel their current clinical status is acceptable.[19]

While tenodesis is often used as an adjunctive procedure, it can also be effective as an isolated procedure independent of other reconstructive shoulder procedures.[12,20,30,44] Puzzitiello et al[32] defined CSO thresholds after isolated BT. However, no investigation to date has evaluated the postoperative timing for achieving these benchmarks. This concept has important implications for maximizing value-based care, which has become a point of emphasis across medical fields, including orthopaedic surgery.[10,26,31] Defining the postoperative period required to achieve CSOs after isolated BT can aid providers in setting appropriate follow-up timelines and patients' expectations, ultimately improving the decision-making process shared between physicians and patients.

The purpose of this investigation was to define the time frames needed to achieve CSOs in patients receiving isolated BT. We hypothesized that most patients would achieve MCID, SCB, and PASS within 1-year follow-up, and that earlier achievement of CSOs would be more common among patients without findings of tenosynovitis or tendon tear on arthroscopy.

## METHODS

### Patients and Procedures

Institutional review board approval was obtained as part of the study registry protocol. A prospectively maintained institutional registry was queried for patients who underwent isolated BT without other concomitant shoulder surgery between January 2014 and January 2018. The inclusion criteria were receipt of a primary arthroscopic suprapectoral (ASPBT) or open subpectoral BT (OSPBT), with or without concurrent rotator cuff debridement, for the indication of tenosynovitis, superior labrum anterior to posterior tear, partial tearing, or biceps instability, as well as completion of 1-year follow-up. Exclusion criteria were patients with full-thickness rotator cuff tears, patients receiving concurrent rotator cuff repair or shoulder arthroplasty, and history of ipsilateral BT.

After appropriate exclusion, 190 patients were included in the analysis. Patients enrolled in the prospective registry completed shoulder-specific PROMs, including the American Shoulder and Elbow Surgeons score (ASES), the Single Assessment Numeric Evaluation (SANE), and the Constant-Murley score (CMS), preoperatively and at 6- and 12-month follow-up. BT was performed by the senior authors (N.N.V., B.J.C., B.F.) as previously described.[2,7] Demographics and preoperative variables that were collected included age, sex, worker compensation status, body mass index (BMI), and medical history (smoking, diabetes, hypertension, and thyroid disease). Intraoperative variables collected by trained research assistants at the time of operation (Y.L., A.A., O.L.G., B.H.P., A.B.) included the type of bicep pathology, approach (ASPBT vs. OSPBT), and fixation device (eg, screw or suture anchor).

### Surgical Technique

*Open Subpectoral BT.* The biceps tendon was released from the supraglenoid tubercle during diagnostic arthroscopy. A 3-cm longitudinal incision was made lateral to the axillary fold. The LHBT was identified within the bicipital tunnel. The remaining steps were dependent upon the type of fixation device used. If a SutureFix suture anchor (Smith & Nephew) was used, a 1.7- or 1.9-mm unicortical tunnel was created and the suture anchor was inserted into the socket. Sutures were passed through the biceps tendon at the musculotendinous junction in a Krackow configuration. Excess tendon was removed, and the biceps tendon was reapproximated in a normal position. In cases where a polyetheretherketone tenodesis screw (Arthrex) was used, the biceps tendon was prepared beginning at the musculotendinous junction with a Krackow configuration. A 6.5-, 7-, or 8-mm-diameter tunnel was drilled through the cortex of the bicipital tunnel 1.5 cm below the inferior border of the

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pectoralis major tendon. The tendon was inserted into the drill hole and fixated with the interference screw.

*Arthroscopic Suprapectoral BT.* The arthroscope was placed in the lateral portal. The LHBT was mobilized from any adhesions and the transverse humeral ligament. Through an accessory anterosuperolateral portal, a spinal needle was positioned perpendicular to the bicipital groove. The LHBT was removed from the subdeltoid space through an arthroscopic portal and prepared in a fashion similar to that of the open approach, described above. Final fixation occurred approximately 15 mm above the pectoralis major tendon within the bicipital groove with an interference screw or suture anchor.

### Statistical Analysis

The MCID, SCB, and PASS values used in our analysis were derived from a cohort from the same institution using a distribution-based approached for MCID and an anchor-based approached for SCB and PASS. Reference MCID, SCB, and PASS values, respectively, were as follows: ASES, 11.0, 16.8, 59.6; SANE, 3.5, 5.8, 65.5; and CMS, 3.8, 11.0, 19.5.[32]

Outcome measures were classified into 3 periods according to when the outcome measure was collected: 0 to 45 days before surgery (categorized as preoperative timepoint), 5 to 7 months postoperatively (categorized as 6-month postoperative timepoint), and 11 to 13 months postoperatively (categorized as 12-month postoperative timepoint). Statistical comparisons of absolute instrument scores were assessed via 1-way analysis of variance. Cumulative probabilities for achieving MCID, SCB, and PASS were calculated with Kaplan-Meier survival curve analysis and interval censoring among the 2 follow-up times (6 and 12 months). To investigate the demographic and clinical characteristics that influence time needed to achieve MCID, SCB, and PASS for each PRO score, a univariate analysis was used with Weibull parametric survival regression. Demographic, preoperative, and intraoperative variables found to be significant on univariate analysis were then included in a multivariate model to confirm hazard ratios (HRs) predictive of the time to CSO achievement. All statistical analysis was performed using RStudio software Version 1.0.143 (R Foundation for Statistical Computing).

## RESULTS

### General Demographics

A total of 190 (121; 64% male) patients with average age of 46.9 ± 13.01 years and average follow-up of 11.8 ± 0.78 months were included. Diagnostic arthroscopy identified tenosynovitis in 143 (75.3%) patients, partial LHBT tears in 16 (8.4%) patients, complete LHBT tears in 13 (6.8%) patients, and absence of gross LHBT pathology in 18 (9.4%) patients. Of the tenodesis performed, 143 (77.9%) were OSPBT and 47 (22.1%) were ASPBT. Of the 190 patients, 6 (3.65%) underwent a subsequent procedure on the ipsilateral shoulder. Of these, 2 (1.05%)

underwent revision BT for rerupture of the BT, 3 (1.57%) underwent rotator cuff debridement and subacromial decompression for recurrent impingement syndrome, and 1 (0.5%) underwent capsular release for adhesive capsulitis. Complete patient demographics, comorbidities, and intraoperative characteristics are found in Table 1.

### PRO Measures

The mean preoperative and postoperative scores of patients included in the study are listed in Table 2. The cumulative probability of achieving the MCID, SCB, and PASS are listed in Table 3. Median and mean achievement in months suggested right-tailed distributions for MCID (median = 5.3-6.1 months; mean = 7.3-8.0 months), SCB (median = 5.9-6.4 months; mean = 7.3-8.1 months) and PASS (median = 6.07-6.1; mean = 7.4-7.7 months). On the contrary, by final follow-up, the fewest patients achieved the SCB on the ASES (64.1%), PASS on SANE (62.9%), and the SCB and PASS on the CMS (SCB, 42.2%; PASS, 59.7%).

### Subjective Assessment

Cumulative probability graphs comparing rates of MCID, SCB, and PASS achievement by PROM are displayed in Figure 1. For the ASES, median achievement of MCID and PASS occurred between 12 and 13 months postoperatively while achievement of SCB occurred at approximately 13 months postoperatively ($P = .45$) (Figure 1A). For the SANE, median achievement of MCID and SCB was at approximately 6 months postoperatively while achievement of PASS occurred between 6 and 7 months postoperatively ($P = .032$) (Figure 1B). For the CMS, median achievement of MCID occurred at 6 months postoperatively, median achievement of PASS between 6 and 7 months postoperatively, and median achievement of SCB at approximately 12 months postoperatively ($P = .0012$) (Figure 1C). At final follow-up, the highest proportion of patients had achieved the MCID and SCB on the SANE instrument (MCID, 83.2; SCB, 80.2) while the highest proportion of patients achieved PASS on the ASES score (70.8%) (Table 3).

### Characteristics Associated With Time to MCID, SCB, and PASS Achievement

*Overall CSO Achievement.* Overall, male sex, higher BMI, being a former or current smoker, and preoperative diagnosis of thyroid disease were consistently found to delay achievement of MCID, SCB, and/or PASS on multiple PROMs, while normal biceps tendon on arthroscopy was predictive of accelerated achievement. The approach (ASPBT vs OSBPT) and worker compensation status did not significantly predict the time to achieve CSOs on multivariate analysis.

*MCID Achievement.* Multivariate analysis identified the following characteristics as significantly predictive of earlier achievement of MCID (HR [95% CI]): male sex (SANE, 0.41 [0.32-0.61]), absence of gross tendon pathology on
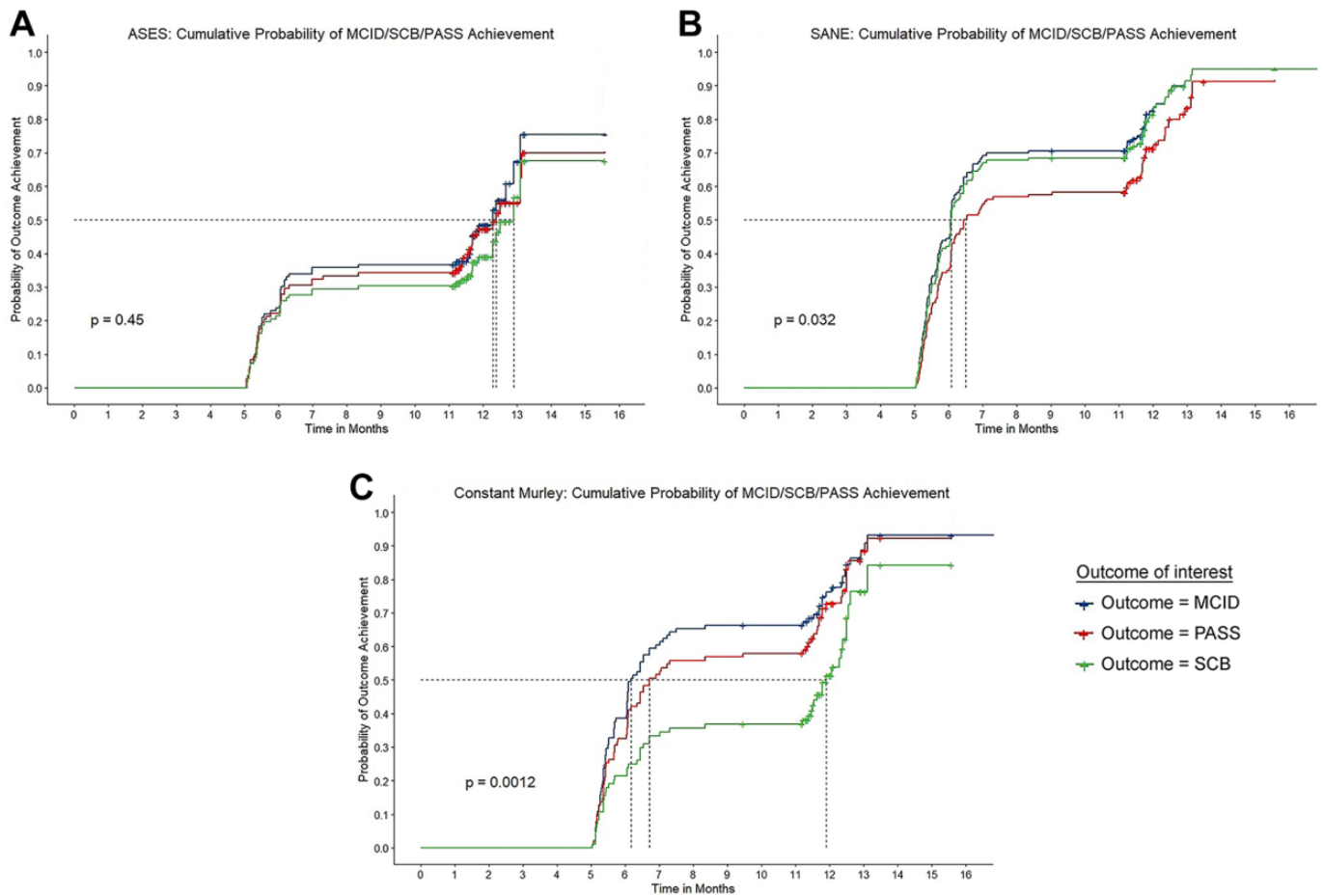
**Figure 1.** Cumulative probability for achieving MCID, SCB, and PASS on (A) ASES, (B) SANE, and (C) CMS. ASES, American Shoulder and Elbow Surgeons score; CMS, Constant-Murley score; MCID, minimal clinically important difference; PASS, Patient Acceptable Symptom State; SANE, Single Assessment Numeric Evaluation; SCB, substantial clinical benefit. Dashed lines indicate median time to achievement of MCID, SCB, or PASS.

arthroscopy (SANE, 0.19 [0.04-0.96]; CMS, 0.46 [0.20-0.83]), and preoperative scores (see Table 4). Characteristics predicting delayed achievement of MCID included being a former smoker (SANE, 2.48 [1.20-5.11]) or current smoker (SANE 3.82 [1.95-7.45]), preoperative diagnosis of thyroid disease (ASES, 3.73 [1.96-7.09]; SANE, 1.71 [1.02-2.81]; CMS, 2.18 [1.32-3.58]), tendon tear on arthroscopy (ASES, 1.81 [1.21-2.73]; SANE, 2.21 [1.41-3.46]), and older age (SANE, 1.01 [1.00-1.02]; CMS 1.01 [1.00-1.03]) (Table 4).

*SCB Achievement.* Male sex (SANE 0.42 [0.29=0.62]; CMS, 1.62 [1.17-2.21]), older age (CMS, 1.02 [1.01-1.03]), and higher BMI (ASES, 1.07 [1.04-1.091]; SANE, 1.03 [1.07-1.11]; CMS, 1.01 [0.99-1.03]) predicted delayed achievement of SCB. Absence of gross LHBT pathology on arthroscopy was predictive of early achievement of SCB on multiple PROMs (SANE, 0.20, [0.04-0.98]; CMS, 0.39 [0.13-1.19]) (Table 5).

*PASS Achievement.* Male sex (CMS, 1.69 [1.24-2.42]), higher BMI (ASES, 1.04 [1.01-1.06]), being a former (SANE, 1.09 [0.78-1.54]) and current smoker (SANE, 1.65

[1.21-2.26]), preoperative thyroid disease (ASES, 6.41 [3.33-12.2]; SANE, 3.01 [1.72-5.13]; CMS, 2.24 [1.12-4.31]), and higher preoperative CMS score (CMS, 1.06 [1.04-1.11]) were found to predict delayed achievement of PASS (Table 6).

## DISCUSSION

In this investigation, we determined the general timeline for patients to achieve CSOs after isolated BT for 3 different PRO instruments. For the PROMs examined, most patients can reasonably be expected to achieve MCID/SCB/PASS by 13 months postoperatively, with the highest likelihood of outcome achievement observed between 5 and 8 months; this is consistent with the hypothesis of the present study. MCID and SCB were the most achievable on the SANE score and PASS was the most achievable on the ASES score. Upon evaluation of the ASES, which is a measure recommended by the American Academy of Orthopaedic Surgeons for shoulder pathology and generally considered

TABLE 1
Demographic and Clinical Characteristics of the Study Population (N = 190)[a]

| Characteristic | Value |
|---|---|
| Age, y, mean ± SD | 46.9 ± 13.01 |
| Male sex, n (%) | 121 (64) |
| Worker compensation, n (%) | 54 (28) |
| BMI, kg/m², mean ± SD | 28.71 ± 5.95 |
| Positive smoking history, n (%) | 46 (24) |
| Current smoker, n | 26 |
| Former smoker, n | 20 |
| Diabetes, n (%) | 12 (6.3) |
| Hypertension, n (%) | 31 (16.4) |
| Thyroid, n (%) | 12 (6.3) |
| Preoperative diagnosis, n | |
| Rotator cuff tendinopathy | 56 |
| Biceps-labral complex | 112 |
| Miscellaneous[b] | 24 |
| Bicep pathology on arthroscopy, n (%) | |
| No gross pathology | 18 (9.4) |
| Complete tear | 13 (6.8) |
| Partial tear | 16 (8.4) |
| Tenosynovitis | 143 (75.3) |
| Tenodesis technique, n (%) | |
| Arthroscopic suprapectoral | 47 (22.1) |
| Open subpectoral | 143 (77.9) |
| Fixation device, n (%) | |
| Tenodesis screw | 57 (30.0) |
| Suture anchor | 133 (70.0) |

[a]BMI, body mass index.
[b]Subacromial impingement, acromioclavicular arthropathy, or capsulitis.

TABLE 2
Mean Patient-Reported Outcome Scores at Baseline and Follow-up Time Points[a]

| PROM | Baseline | 6 Months | 12 Months | $P$[b] |
|---|---|---|---|---|
| ASES | 47.4 ± 19.0 | 70.7 ± 20.9 | 72.3 ± 23.7 | <.01 |
| SANE | 33.4 ± 22.5 | 64.4 ± 25.4 | 65.9 ± 29.7 | <.01 |
| CMS | 12.5 ± 6.9 | 20.3 ± 8.7 | 21.3 ± 9.7 | <.01 |

[a]ASES, American Shoulder and Elbow Surgeons score; CMS, Constant-Murley score; PROM, patient-reported outcome measure; SANE, Single Assessment Numeric Evaluation.
[b]$P$ value at $\alpha$ = .01 for 1-way analysis of variance across baseline and postoperative time points.

TABLE 3
Cumulative Probability of Achieving CSOs at Follow-up[a]

| | 6 Months | | | 12 Months | | |
|---|---|---|---|---|---|---|
| PROM | MCID, % | SCB, % | PASS, % | MCID, % | SCB, % | PASS, % |
| ASES | 71.3 | 59.4 | 69.5 | 77.8 | 64.1 | 70.8 |
| SANE | 83.1 | 80 | 61.2 | 83.2 | 80.2 | 62.9 |
| CMS | 76.4 | 35.9 | 58.3 | 78.7 | 42.2 | 59.7 |

[a]ASES, American Shoulder and Elbow Surgeons Score; CMS, Constant-Murley score; CSO, Clinically Significant Outcome; MCID, minimal clinically important difference; PASS, Patient Acceptable Symptom State; PROM, patient-reported outcome measure; SANE, Single Assessment Numeric Evaluation; SCB, substantial clinical benefit.

the gold standard, patients were found to achieve MCID and PASS earlier while more time was required to achieve SCB. In addition, most patients achieved CSOs on the ASES by 13 months. The present investigation highlighted the following demographic and intraoperative variables as predictors of delayed CSO achievement: male sex, higher BMI, being a former or current smoker, and preoperative diagnosis of thyroid disease, whereas normal bicep tendon on arthroscopy was found to be predictive of early CSO achievement. Although univariate analysis found suprapectoral approach to be predictive of delayed MCID achievement, this finding did not maintain significance on multivariate analysis.

While there has been emerging interest in determining the timeline to CSO for orthopaedic procedures, such data for shoulder procedures remain elusive.[25] Clinicians have established a robust body of evidence for the efficacy of both ASPBT and OSPBT, and attempts should be made to establish the expected time for clinical improvement as well as a consensus protocol for postoperative follow-up.

Werner et al[44] compared the ASPBT and OSPBT approaches and found that all patients experienced significant functional improvements as well as significant clinical improvements on PROMs, including the ASES and CMS, by 2-year follow-up. Similarly, the average length of follow-up for most outcome studies on BT in the literature is 2 years.[9,15,21,23,40] However, other studies have suggested that significant clinical improvements can be achieved by anywhere from 12 months to as early as 3 months.[12,16,17,38,42] In a study by Hufeland et al[12] that evaluated a small cohort of patients undergoing ASPBT at 3, 6, 12, and 24 months postoperatively, the authors found no significant improvements in elbow flexion strength beyond the first 3 months of the postoperative period. The investigators also found that patients were able to achieve significant improvements in scores on the ASES, CMS, and Simple Shoulder Test by 3 months. However, CSO information was unavailable to contextualize the initial numerical improvement.[12]

Schoch et al[37] examined clinical outcomes at 6, 52, and 104 weeks after ASPBT and noted a significant improvement in the pain component of the CMS within the first 6 weeks of the postoperative period. The authors did not examine differences in other instruments, nor did they assess interval changes in PRO scores at each follow-up visit.. The study is also limited by the lack of data between 6 weeks and 52 weeks, which may have prevented the documentation of additional clinical improvements.[37] A case series by Vitali et al[42] observed significant increase on the CMS score by 12 months, with the most improvement coming during the first 3 months. Despite the utilization of PROMs in measuring clinical outcomes in these studies, information on the timeline to CSO achievement remains sparse. As the first study to our knowledge to assess clinical

TABLE 4
Characteristics Predictive of Time to Achieve MCID[a]

| | HR (95% CI) for Time to Achieve MCID | | |
| --- | --- | --- | --- |
| | ASES | SANE | CMS |
| Single-year age increase | NS | 1.01 (1.00-1.02) | 1.01 (1.00-1.03) |
| Male sex | NS | 0.41 (0.32-0.61) | NS |
| BMI | 1.03 (1.0-1.1) | 1.01 (1.01-1.02) | NS |
| Preoperative thyroid disease | **3.73 (1.96-7.09)** | **1.71 (1.02-2.81)** | **2.18 (1.32-3.58)** |
| Smoking history, former smoker | NS | **2.48 (1.20-5.11)** | NS |
| Smoking history, current smoker | NS | 3.82 (1.95-7.45) | NS |
| Tendon tear on arthroscopy | 1.81 (1.21-2.73) | 2.21 (1.41-3.46) | NS |
| Absence of gross tendon pathology on arthroscopy | NS | 0.19 (0.04-0.96) | **0.46 (0.20-0.83)** |
| Arthroscopic suprapectoral tenodesis | NS | NS | 1.66 (1.1-2.5) |
| Preoperative ASES | NS | 1.03 (1.02-1.04) | 1.04 (1.02-1.1) |
| Preoperative SANE | NS | 1.02 (1.01-1.03) | NS |
| Preoperative CMS | NS | 1.12 (1.08-1.2) | 0.97 (0.95-0.99) |

[a]Bolded values denote variables that maintained significance after multivariate Weibull parametric regression. The following variables were found to be nonsignificant predictors on univariate testing: worker compensation status, diabetes, hypertension, bicep tenosynovitis on arthroscopy, arthroscopic versus open tenodesis, and type of fixation device. ASES, American Shoulder and Elbow Surgeons score; BMI, body mass index; CMS, Constant-Murley score; HR, hazard ratio; MCID, minimal clinically important difference; NS, nonsignificant; SANE, Single Assessment Numeric Evaluation.

TABLE 5
Characteristics Predictive of Time to Achieve SCB[a]

| | HR (95% CI) for Time to Achieve MCID | | |
| --- | --- | --- | --- |
| | ASES | SANE | CMS |
| Older age | NS | NS | **1.02 (1.01-1.03)** |
| Male sex | NS | 0.42 (0.29-0.62) | **1.62 (1.17-2.21)** |
| BMI | **1.07 (1.04-1.09)** | **1.03 (1.07-1.11)** | **1.01 (0.99-1.03)** |
| Smoking history, current smoker | NS | 1.65 (1.21-2.26) | NS |
| Preoperative thyroid disease | NS | 1.91 (1.32-3.04) | NS |
| Tendon tear on arthroscopy | 1.71 (1.14-2.62) | 2.18 (1.42-3.42) | 1.65 (1.14-2.37) |
| Absence of gross tendon pathology on arthroscopy | NS | **0.20 (0.04-0.98)** | **0.39 (0.13-1.19)** |
| Preoperative ASES | NS | 1.03 (1.02-1.04) | NS |

[a]Bolded values denote variables that maintained significance after multivariate Weibull parametric regression. The following variables were found to be insignificant predictors on univariate testing: worker compensation status, being a former smoker, diabetes, hypertension, bicep tenosynovitis on arthroscopy, arthroscopic versus open tenodesis, type of fixation device, and preoperative SANE and CMS scores. ASES, American Shoulder and Elbow Surgeons score; BMI, body mass index; CMS, Constant-Murley score; HR, hazard ratio; MCID, minimal clinically important difference; NS, nonsignificant; SANE, Single Assessment Numeric Evaluation; SCB, substantial clinical benefit.

improvements after isolated BT in this context, our study identified the highest likelihood of CSO achievement within the first 5 to 8 months during the postoperative period, with potential for additional improvement up to 13 months.

Multivariate analysis identified the following demographic and intraoperative factors to predict delayed CSO achievement: male gender, higher BMI, smoking history, and preoperative thyroid disease. Puzzitiello et al[32] implicated male sex as a negative predictor of CSO achievement after isolated BT. BMI has also been associated with increased time to resumption of work in patients after arthroscopic subacromial decompression, further corroborating its impact on the time-dependence of postoperative clinical improvement.[22] Similarly, there is extensive

evidence for the negative influence of increased BMI and tobacco consumption on both clinical and surgical outcomes after shoulder and elbow surgery.[24,29,33,35]

Although there is a paucity of evidence on the impact of preoperative thyroid comorbidities on the outcomes of BT, sufficient evidence has demonstrated the deleterious effect of abnormal thyroid hormone levels on both collagen metabolism and tenocyte turnover.[18,27] There has also been a long-speculated association between thyroid disease and shoulder pain in patients with frozen shoulder.[4,36] In a case report describing a spontaneous biceps tendon rupture in a patient with hypothyroid, investigators contended that collagen degeneration and tenocyte apoptosis from thyroid hormone deficiency led to subclinical tendon damage and ultimately rupture.[28] Abnormal thyroid levels can be a

TABLE 6
Characteristics Predictive of Time to Achieve PASS[a]

| | HR (95% CI) for Time to Achieve MCID | | |
| --- | --- | --- | --- |
| | ASES | SANE | CMS |
| Male sex | 1.92 (1.31-2.81) | NS | **1.69 (1.24-2.42)** |
| Preoperative thyroid disease | **6.41 (3.33-12.2)** | **3.01 (1.72-5.13)** | **2.24 (1.12-4.31)** |
| BMI | **1.04 (1.01-1.06)** | NS | NS |
| Worker compensation status | 0.05 (0.01-0.36) | NS | NS |
| Smoking history, former smoker | NS | **1.09 (0.78-1.54)** | NS |
| Smoking history, current smoker | NS | **1.65 (1.21-2.26)** | NS |
| Diabetes | NS | 0.15 (0.04-0.57) | NS |
| Tendon tear on arthroscopy | 2.27 (1.61-3.28) | NS | NS |
| Absence of gross tendon pathology on arthroscopy | 0.27 (0.05-0.95) | 0.33 (0.14-0.75) | NS |
| Preoperative ASES | 1.02 (1.01-1.04) | 1.02 (1.01-1.03) | 1.01 (0.99-1.02) |
| Preoperative CMS | 1.09 (1.07-1.15) | 1.08 (1.05-1.12) | **1.06 (1.04-1.11)** |

[a]Bolded values denote variables that maintained significance after multivariate Weibull parametric regression. The following variables were found to be insignificant predictors on univariate testing: age, hypertension, bicep tenosynovitis on arthroscopy, arthroscopic versus open tenodesis, type of fixation device, and preoperative SANE scores. ASES, American Shoulder and Elbow Surgeons score; BMI, body mass index; CMS, Constant-Murley score; HR, hazard ratio; MCID, minimal clinically important difference; NS, nonsignificant; PASS, Patient Acceptable Symptom State; SANE, Single Assessment Numeric Evaluation.

hallmark of autoimmunity, metabolic deficiencies, or systemic hormonal dysregulation.[1] Endocrinopathies have a negative effect on the integrity of connective tissues,[3,39] which may affect outcomes in patients undergoing BT. This is an important consideration for risk stratification of surgical candidates with similar comorbidities. Patients with diabetes did not demonstrate increased duration to achieve CSOs. It has been demonstrated previously that patients with diabetes have a higher risk of postoperative complications and lower outcome metrics after rotator cuff repair.[5,8] Despite this, the results of this investigation suggest that for patients with diabetes who have lower outcome metrics, these may not be clinically significant. Finally, absence of tenosynovitis or tendon tear on arthroscopy for patients who are clinically symptomatic suggests the presence of microscopic pathology not grossly evident and/or pathology of the tendon not visualized during arthroscopy.[34] However, arthroscopic visualization of other structures within the shoulder joint would be necessary to better elucidate these relationships. Indeed, while routine biceps treatment during shoulder arthroscopy remains controversial and is not the standard within our practice, there remains the possibility that patients with normal-appearing tendons could have symptoms attributable primarily to an impingement process, and biceps treatment in this population may not be efficacious. The resulting differences in time to CSO achievement is novel information that can be used in counseling these patients to expect accelerated improvement after surgery compared with those with intrinsic biceps pathology.

These findings represent valuable information from a homogeneous cohort that can serve to inform both patients' expectation and clinicians' management during the shared decision-making process. Patient education on an accurate timeline to achieve CSOs can improve satisfaction in the postoperative period, especially for those with demographic or intraoperative variables that delay achievement, and clinicians may reconsider the utility of follow-up beyond this timeline to optimize resource management in the delivery of value-based care.

## Limitations

The following limitations should be taken into consideration when interpreting the findings of our study. Most importantly, while we were unable to identify any significant influences exerted by preoperative diagnosis on time to CSO achievement, findings on diagnostic arthroscopy were limited to the biceps tendon and it is possible that intra-articular visualization of other structures could highlight more nuanced associations between these factors. Second, patient compliance decreased at postoperative time points with respect to the completion of anchor questions and PROM data. In addition, our follow-up time points were limited to 6 months and 1 year and, as such, we were unable to delineate the timeline of CSO achievement with more granularity. Thus, these results are to be used to establish general trends of achievement time. Finally, these findings came from a high-volume academic orthopaedic institution, and thus interpretation and application to smaller, community-based hospitals must be done with consideration of the population differences that exist.

## CONCLUSION

Patients undergoing BT have the highest likelihood of achieving MCID, SCB, and PASS 5 to 8 months into the postoperative period, and most patients can reasonably expect achievement of CSOs by 13 months. Male sex, higher BMI, smoking history, and preoperative diagnosis of thyroid disease were found to predict delayed

achievement of CSOs, whereas absence of tenosynovitis or tendon tear on arthroscopy predicted accelerated achievement. These results offer valuable insights that can help clinicians optimize resource allocation while educating patients on reasonable postoperative expectations.

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