Rates and Risk Factors for Revision Open and Arthroscopic Proximal Biceps Tenodesis

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Background: Biceps tenodesis may be performed for symptomatic tendinopathy or tearing of the long head of the biceps tendon. Biceps tenodesis is also commonly performed as an adjunctive procedure. However, the indications and prevalence of biceps tenodesis have expanded.

Purpose: To establish the incidence and risk factors for revision biceps tenodesis.

Study Design: Case-control study; Level of evidence, 2.

Methods: The PearlDiver database of Humana patient data was queried for patients undergoing arthroscopic or open biceps tenodesis (Current Procedural Terminology [CPT] 29828 and CPT 23430, respectively) from 2008 through the first quarter of 2017. Patients without a CPT laterality modifier were excluded from analysis. Revision biceps tenodesis was defined as patients who underwent subsequent ipsilateral open or arthroscopic biceps tenodesis. The financial impact of revision biceps tenodesis was also calculated. Multivariate binomial logistic regression was performed to identify risk factors for revision biceps tenodesis, such as patient demographics as well as concomitant procedures and diagnoses. Odds ratios (ORs) and 95% CIs were calculated, and all statistical comparisons with $P < .05$ were considered significant.

Results: There were 15,257 patients who underwent biceps tenodesis. Of these, 9274 patients (60.8%) underwent arthroscopic biceps tenodesis, while 5983 (39.2%) underwent open biceps tenodesis. A total of 171 patients (1.8%) and 111 patients (1.9%) required revision biceps tenodesis after arthroscopic and open biceps tenodesis, respectively ($P = .5$). Male sex (OR, 1.38 [95% CI, 1.04-1.85]; $P = .02$) was the only independent risk factor for revision biceps tenodesis after the index open biceps tenodesis. After arthroscopic biceps tenodesis, age >45 years (OR, 0.58 [95% CI, 0.39-0.89]; $P = .01$) and concomitant rotator cuff tear (OR, 0.58 [95% CI, 0.47-0.71]; $P < .001$) were independent protective factors for revision biceps tenodesis. The total cost of revision biceps tenodesis after open and arthroscopic biceps tenodesis was US$3427.95 and US$2174.33 per patient, respectively.

Conclusion: There was no significant difference in the revision rate between arthroscopic and open biceps tenodesis. Risk factors for revision surgery included male sex for open biceps tenodesis, while age >45 years and rotator cuff tears were protective factors for arthroscopic biceps tenodesis.

Keywords: arthroscopic biceps tenodesis; open biceps tenodesis; revision; risk factors

The long head of the biceps tendon (LHBT) may be affected by several abnormalities that result in anterior shoulder pain.[2,6] Tenodesis of the LHBT is a commonly performed procedure to address LHBT lesions, which are often associated with rotator cuff tears, superior labrum anterior posterior (SLAP) tears, and glenohumeral arthritis.[3] Tenodesis of the LHBT is usually performed via an arthroscopic suprapectoral approach or a mini-open subpectoral technique.[17] As indications for biceps tenodesis have expanded to include the management of SLAP tears, the popularity of this procedure has increased.[11,22] From 2008 to 2011, the incidence of biceps tenodesis increased 1.7-fold, with the arthroscopic approach increasing at a rate greater than that of the open approach.[20]

Regardless of the operative technique, indication, or concomitant procedures, outcomes after biceps tenodesis have generally been favorable.[9-12,21] Patients demonstrate significant improvements in functional and clinical outcomes as well as low rates of revision, postoperative pain, and deformity.[8,14,21] There is recent evidence to suggest that biceps tenodesis offers no additional clinical benefit compared with tenotomy, as some studies have shown no difference in postoperative pain relief and functional outcomes.[15] Furthermore, concomitant biceps tenodesis with rotator cuff repair

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has been shown to increase the rate of revision rotator cuff repair at 6 months and 1 year postoperatively.[7] In patients undergoing biceps tenodesis, the failure of tenodesis may result in pain or cosmetic deformity.[16] In a previous series of 1083 patients who underwent biceps tenodesis for various indications and concomitant procedures, revision biceps tenodesis was performed in only 0.4% of patients.[4] Although previous investigations have reported the incidence of revision biceps tenodesis, the generalizability of the results is restricted because of relative limitations in the sample size.

As the indications and popularity of biceps tenodesis increase, it is useful to establish the rate of revision biceps tenodesis and factors that are associated with failure. The purpose of this investigation was to identify demographic variables, concomitant procedures, or concomitant diagnoses that contribute to revision procedures after arthroscopic biceps tenodesis and open biceps tenodesis. We hypothesized that (1) there is no inherent difference in the incidence of revision biceps tenodesis after the arthroscopic or open approach and (2) concomitant rotator cuff repair or SLAP repair is a risk factor for revision procedures, irrespective of the tenodesis technique.

TABLE 1
Patient Demographics[a]

Variable	Arthroscopic	Open	*P* Value
Male sex	5328 (57.5)	3760 (62.8)	**<.001**
Obesity (BMI >30 kg/m^2)	2997 (32.3)	1679 (28.1)	**<.001**
Age >45 y	8864 (95.6)	5565 (93.0)	**<.001**
Tobacco use	1672 (18.1)	1079 (18.0)	.99
Alcohol use	249 (2.7)	186 (3.1)	.12
Comorbidities			
Diabetes mellitus	3070 (33.1)	1688 (28.2)	**<.001**
Hyperlipidemia	7308 (78.9)	4338 (72.5)	**<.001**
Hypertension	7145 (77.0)	4222 (70.6)	**<.001**
Atherosclerosis	2215 (23.9)	1319 (22.0)	**.008**
Chronic lung disease	2644 (28.5)	1557 (26.0)	**<.001**
Chronic liver disease	1091 (11.8)	587 (9.8)	**<.001**
Concomitant diagnoses			
Biceps tendinitis	4220 (45.6)	2797 (46.7)	.13
Biceps tear	2635 (28.4)	1672 (27.9)	.53
SLAP tear	215 (2.3)	201 (3.4)	**<.001**
Rotator cuff tear	7478 (80.6)	4402 (73.6)	**<.001**
Concomitant procedures			
Rotator cuff repair	5939 (64.0)	3585 (43.2)	**<.001**
SLAP repair	82 (0.9)	54 (0.9)	.91

[a]Data are reported as n (%). Bolded *P* values indicate statistically significant difference between groups. BMI, body mass index; SLAP, superior labrum anterior posterior.

METHODS

Database

This was a retrospective review of Humana patient data within the PearlDiver database from 2008 through the first quarter of 2017 (2017q1). This database represents over 20 million patients in the United States, containing data regarding patient demographics, hospitalization details, diagnoses, procedures, and reimbursement. All data can be accessed with International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedural codes, International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) procedural codes, and Current Procedural Terminology (CPT) codes. The accessed data represent procedures and diagnoses that were billed to the insurance company by the provider during that period. All information in this database is deidentified and anonymous.

Study Cohort

This database was queried for patients who underwent arthroscopic biceps tenodesis (CPT 29828) or open biceps tenodesis (CPT 23430) from 2008 to 2017q1. The CPT code for arthroscopic biceps tenodesis began being recorded in this database from 2008. To ensure independent patient groups, data were collected from 2008 to 2017q1. Patients undergoing isolated biceps tenodesis or with concomitant SLAP repair or rotator cuff repair were included in the investigation. Patients were excluded if they did not have a CPT laterality modifier (left or right). This resulted in 15,257 patients who underwent biceps tenodesis during the specified time period, of whom 9274 patients (60.8%) underwent arthroscopic biceps tenodesis and 5983 patients (39.2%) underwent open biceps tenodesis. Baseline demographics for both groups are provided in Table 1.

Revision Surgery

Revision biceps tenodesis was defined as patients undergoing subsequent ipsilateral arthroscopic biceps tenodesis (CPT 29828) or subsequent ipsilateral open biceps tenodesis (CPT 23430) after the index procedure. The rate of revision biceps tenodesis was queried using CPT codes and modifiers for laterality to ensure that the secondary procedure was performed on the ipsilateral side. The time period for potential revision biceps tenodesis was dependent on

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Ethical approval was not sought for the present study.

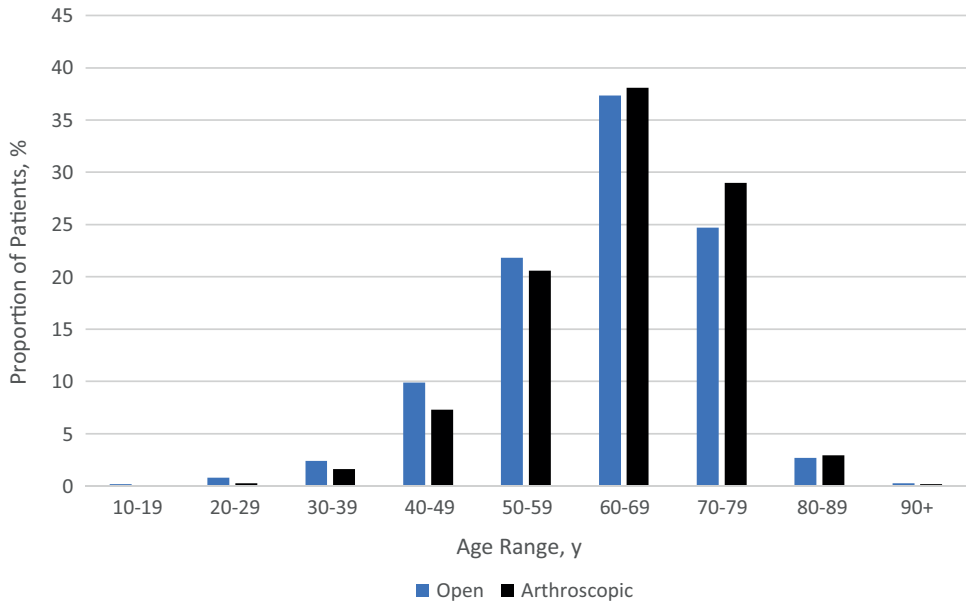

Figure 1. Distribution of arthroscopic and open biceps tenodesis procedures.

when the index procedure was performed. The PearlDiver database allows for a revision period of a maximum of 9 years (ie, outcomes of patients who underwent index biceps tenodesis in 2008 can be tracked for 9 years).

Cost Analysis

The annual overall and per-patient reimbursements for arthroscopic and open biceps tenodesis (in US dollars) were calculated utilizing their diagnosis-related group (DRG). The DRG is inclusive of all costs associated with the event of care. For patients undergoing revision biceps tenodesis, the overall and per-patient reimbursements were also calculated using the DRG.

Statistical Analysis

A multivariate binomial logistic regression model was used to identify demographics and comorbidities (sex, age, diabetes, smoking) as well as concomitant diagnoses (SLAP tear, rotator cuff tear, biceps tendinitis, biceps tear) or procedures (SLAP repair, rotator cuff repair) at the time of the index procedure as risk factors for revision biceps tenodesis. Odds ratios (ORs) and 95% CIs were calculated, and $P < .05$ was considered statistically significant. Multivariate binomial logistic regression was performed using RStudio software (version 1.0.143).

RESULTS

There was no statistical difference in the number of patients who underwent subsequent ipsilateral biceps tenodesis after arthroscopic or open biceps tenodesis (1.8% vs 1.9%, respectively; $P = .5$). The distribution of patients undergoing primary biceps tenodesis based on age is provided in Figure 1.

Several independent risk factors for revision biceps tenodesis were identified (Table 2). Male sex (OR, 1.38; $P = .02$) was the only independent risk factor for revision biceps tenodesis after the index open biceps tenodesis. After arthroscopic biceps tenodesis, age >45 years (OR, 0.58; $P = .01$) and concomitant rotator cuff tear (OR, 0.58; $P < .001$) were independent protective factors for a revision procedure.

The percentage increase in the mean per-patient cost of arthroscopic biceps tenodesis was 8.1%: $1369.48 in 2008 versus $1481.00 in 2016. The mean per-patient cost of open biceps tenodesis increased 38.1%, from $1180.74 in 2008 to $1630.24 in 2016. The cost of revision biceps tenodesis after the index open biceps tenodesis averaged $3427.95 per patient. The cost of revision biceps tenodesis after the index arthroscopic biceps tenodesis averaged $2174.33 per patient.

DISCUSSION

The first portion of the hypothesis was correct, as an analysis of Humana patient data within the PearlDiver database demonstrated similar rates of revision after arthroscopic and open biceps tenodesis (1.8% and 1.9%, respectively; $P = .5$). Patients who underwent arthroscopic biceps tenodesis were more likely to have medical comorbidities. The only risk factor for revision surgery that was identified was male sex for open biceps tenodesis. However, the second portion of our hypothesis was proven incorrect, as concomitant rotator cuff tears and age >45 years were found to be protective against revision surgery for patients undergoing arthroscopic biceps tenodesis. Concomitant procedures such as rotator cuff repair or SLAP repair were not significant risk factors for either technique of biceps

TABLE 2
Risk Factors for Failed Biceps Tenodesis Requiring Revision Surgery[a]

	Arthroscopic		Open	
Variable	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Male sex	1.17 (0.95-1.44)	.14	**1.38 (1.04-1.85)**	**.02**
Obesity (BMI >30 kg/m^2)	0.53 (0.32-0.84)	.22	0.91 (0.65-1.24)	.55
Tobacco use	1.06 (0.82-1.37)	.63	1.33 (0.94-1.83)	.09
Age >45 y	**0.58 (0.39-0.89)**	**.01**	1.16 (0.67-2.14)	.62
Concomitant diagnoses				
Biceps tendinitis	0.90 (0.73-1.12)	.32	1.08 (0.83-1.40)	.59
Biceps tear	0.82 (0.65-1.03)	.09	0.81 (0.59-1.10)	.18
SLAP tear	0.33 (0.08-0.90)	.06	0.58 (1.39-1.63)	.37
Rotator cuff tear	**0.58 (0.47-0.71)**	**<.001**	0.81 (0.59-1.10)	.18
Concomitant procedures				
Rotator cuff repair	0.99 (0.74-1.34)	.94	1.11 (0.75-1.74)	.60
SLAP repair	1.09 (0.18-3.71)	.90	2.14 (0.33-7.71)	.32

[a]Bolded values indicate statistically significant difference between groups. BMI, body mass index; OR, odds ratio; SLAP, superior labrum anterior posterior.

tenodesis. The cost and incidence of biceps tenodesis have increased substantially over the past 9 years, and the cost of revision biceps tenodesis far exceeds that of a primary procedure. This finding highlights the necessity for surgeons to be aware of appropriate indications as well as risk factors for revision biceps tenodesis.

Biceps tenodesis is a common procedure that provides favorable outcomes for a range of LHBT abnormalities.[16] The most common complications associated with biceps tenodesis include residual groove pain, pain or soreness in the biceps muscle belly, strength deficits in supination or elbow flexion, and cosmetic deformity.[5,18] While it has been shown that biceps tenodesis is a risk factor for revision rotator cuff repair,[7] very few studies have reported on revision biceps tenodesis. Brady et al[4] reported only 4 cases of revision biceps tenodesis (0.4%) after an open subpectoral technique, whereas Schrock et al[14] reported only 2 cases of revision biceps tenodesis (2%) for an arthroscopic technique. While there is no clearly established indication for performing revision biceps tenodesis, indications in these previous studies included recurrent biceps-specific pain and symptomatic biceps ruptures.[4,14] The low number of revisions reported in these previous studies further emphasizes the necessity of a larger sample size to elucidate clinically significant and meaningful findings about revision biceps tenodesis. The present study consists of the largest cohort of biceps tenodesis procedures analyzed, and the results confirm the findings from previous studies that both open and arthroscopic biceps tenodesis are associated with a very low rate of revision surgery.

Green et al[8] demonstrated in a sample of 49 patients who underwent either open subpectoral biceps tenodesis or arthroscopic suprapectoral biceps tenodesis that there was no difference in patient-reported outcomes, pain, or satisfaction at an average of 4.5 years' follow-up. No failures were reported, perhaps secondary to the relatively small sample size. In a recent systematic review comparing arthroscopic and open biceps tenodesis, it was concluded that both provided satisfactory outcomes, without any identifiable differences between the procedures.[1] The present study further supports this conclusion by highlighting a nonsignificant difference in the revision rate ($P = .5$) between arthroscopic and open biceps tenodesis. It should be noted that patients undergoing arthroscopic biceps tenodesis were more likely to be female, be obese, be older than 45 years, and have more medical comorbidities. It is possible that physicians may elect to perform arthroscopic biceps tenodesis in patients who are obese or have medical comorbidities because of concerns of wound complications. It has previously been shown that open subpectoral biceps tenodesis is associated with an increased incidence of wound complications because of the location of the incision within the axillae.[7] Although there were statistical differences in these preoperative factors, it is unlikely that these differences negatively affected the results of this investigation, as all variables were controlled during multivariate analysis.

This study also elucidates risk factors for revision biceps tenodesis. To our knowledge, no other study has identified prognostic variables associated with biceps tenodesis complications or failures. The influence of age on the complication rate after biceps tenodesis was recently studied by Voss et al,[19] who found that patients older than 65 years did not have an increased risk of complications after biceps tenodesis. The present study supports this finding for both arthroscopic and open biceps tenodesis in older populations. Our study also suggests that rotator cuff tears were protective against revision surgery for arthroscopic biceps tenodesis but not open biceps tenodesis. The reason for this could be that a rotator cuff tear requires more extensive debridement at the time of arthroscopic biceps tenodesis, including release of the biceps sheath, which has been shown to decrease the rate of revision surgery after biceps tenodesis.[13] Our findings did suggest, however, that a risk factor for revision surgery after open biceps tenodesis was male sex. We contend that a large proportion of surgeons performing arthroscopic biceps tenodesis during the time

frame in which these data were collected (2008-2017q1) incorporated a tenotomized biceps into rotator cuff repair. This technique may have carried a higher failure rate than securing the biceps at a separate fixation point. The rationale for male sex having an impact on the failure rate after open biceps tenodesis remains unclear, although the reasoning is likely multifactorial. A possible explanation is that male patients performing strenuous labor may have been more likely to sustain an injury or tendinitis of the proximal biceps tendon and undergo open biceps tenodesis, and returning to their strenuous occupation or sport may have resulted in increased failures. Furthermore, with increasing age, activity levels typically decrease, likely resulting in decreased failure rates. Unfortunately, this theory cannot be tested in this data set, as variables such as occupation, work intensity, or sports participation are not recorded in the PearlDiver database.

We acknowledge that this study is not without limitations. This study utilized a national database of a single insurer, the quality and accuracy of which rely on procedural coding by physicians. Any miscoding, or noncoding, by providers is a potential source of error in these data. Additionally, patients with failed tenodesis who did not require revision surgery would be missed in this investigation. Furthermore, this database only encompasses a 9-year time span for this population, which excludes any revision surgery that fell outside this period. Thus, our reported revision rates may be an underestimation. Because of baseline differences in patient demographics, selection bias may be introduced into the results. For example, male patients may be more likely to hold higher intensity occupations. Thus, the failure of biceps tenodesis in their dominant arm may necessitate revision biceps tenodesis. Patient factors that may explain revision biceps tenodesis, such as workers' compensation status, level of occupational intensity, or baseline activity level, are unknown and may be confounding factors in this investigation. Knowledge regarding the indications for revision surgery, such as persistent groove tenderness or ruptures of the remnant tendon, is unavailable. Therefore, we were unable to identify specific clinical factors that contribute to revision biceps tenodesis. Specific operative techniques were unidentifiable within the database. Technical factors that may contribute to the need of revision biceps tenodesis were unable to be analyzed in this investigation.

CONCLUSION

We observed no significant difference in the revision rate between arthroscopic and open biceps tenodesis. Risk factors for revision surgery included male sex for open biceps tenodesis, while age over 45 years and rotator cuff tears were protective factors for arthroscopic biceps tenodesis.

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