



Costs, Complications, and Reoperations Associated With Primary Arthroscopic Rotator Cuff Repair With or Without Acromioplasty and/or Biceps Tenodesis

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Purpose: To evaluate the reoperations, complications, and costs up to 5 years following arthroscopic rotator cuff repair (RCR) alone, with acromioplasty (acro), with biceps tenodesis (BT), or with both acro and BT. **Methods:** We queried the MarketScan database to identify patients who underwent RCR from 2007 to 2016. Patients were stratified into groups based on concomitant procedures (acro and/or BT) performed on the same day as index RCR. Reoperations, complications, and costs were followed for 5 years post-index procedure. Patients without laterality codes were excluded. A multivariate logistic regression analysis was used to control for confounding factors. **Results:** This study identified 147,838 patients (mean age, 53.1 years; standard deviation, 8.3 years) who underwent primary RCR. Patients were stratified into 4 groups: (1) RCR only, (2) RCR + acro, (3) RCR + BT, and (4) RCR + acro + BT. Patients in the RCR only group experienced the highest rate of unadjusted overall postoperative complications (17.2%) versus the other groups (RCR + acro 16.4%, RCR + BT 15.1%, RCR + acro + BT 16.2%, $P < .0161$). The RCR only group also experienced a significantly greater number of reoperations on the ipsilateral shoulder ($P < .0001$), whereas the RCR + acro + BT had the highest costs at all timepoints. In the regression analysis, there was no significant differences between complications and reoperations between any groups. After adjusting for covariates, the performance of a BT with an RCR and acromioplasty led to increased costs (odds ratio, 1.47, 1.37-1.59, $P < .001$). **Conclusions:** Concomitant biceps tenodesis does lead to higher total healthcare costs, both in the shorter and longer terms. When adjusting for confounding factors, the performance of concomitant biceps tenodesis with rotator cuff repair does not lead to a difference in postoperative complication rate or risk for revision surgery. **Level of Evidence: Level IV, economic analysis.**

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Rotator cuff tears (RCTs) are a common orthopaedic pathology that account for upwards of 4.5 million annual visits to physicians.¹ The incidence of RCTs increases with age, with an estimated 10% of individuals above the age of 60 and up to 50% of individuals older than age 80 having full-thickness tears of the RCT.² Rotator cuff repairs (RCRs) can be performed using both arthroscopic and open techniques, with both having comparable clinical outcomes and complication rates.³⁻⁶

Procedures such as acromioplasty (acro) and biceps tenodesis (BT) are frequently performed in conjunction with a RCR.⁷ Acromioplasties are used when the acromion is considered the culprit of the RCT and/or there may be clinically significant impingement.⁸⁻¹⁰ The clinical benefit of these additional procedures, however, remains unclear because previous reports have identified no functional benefit or reduction of revision risk with the concomitant use of an acro in RCR.¹¹⁻¹⁴

Tenotomy or tenodesis is often favored when long head of the biceps tendon pathology is noted during surgery, with all techniques having similar clinical outcomes.¹⁵⁻¹⁹ Lesions of the long head of the biceps tendon (LHBT) are also often associated with RCTs and may be managed nonoperatively, with a tenotomy, or a BT.²⁰⁻²³ Tenotomy and tenodesis have been shown to have similar outcomes, but tenotomy has been shown to have an increased rate of cramping and deformity.²¹ Biceps tenodesis techniques differ by approach (open vs arthroscopic), location (proximal, suprapectoral, subpectoral), and fixation type (soft tissue to soft tissue vs soft tissue to bone).²²⁻²⁶

Although functional and clinical outcomes following BT with or without RCR repair are favorable,^{24,27-29} concerns remain about the cost effectiveness of BT over the long-term. Arthroscopic BT has been shown to have increased costs when compared with open procedures,³⁰ but few data exist regarding the cost-effectiveness of arthroscopic BT alone or in combination with acro when examining total procedural and postoperative costs.

The purpose of this study was to evaluate the reoperations, complications, and costs up to 5 years following RCR alone, with acro, with BT, or with both acro and BT. We hypothesize that the concomitant use of a BT will lead to increase costs in the short-term, however through long-term follow-up, become financially equivalent with RCR by itself.

Methods

Data Source

This study obtained a sample of the MarketScan Commercial Claims and Encounters database (Truven Health Analytics, Ann Arbor, MI) from January 1, 2007, to December 31, 2016. This database is a

collection of commercial inpatient, outpatient, and pharmaceutical claims of more than 75 million employees, retirees, and dependents representing a substantial portion of the US population covered by employer-sponsored insurance. MarketScan contains 53 million patient inpatient records, 40 million with employer-sponsored insurance, 3.7 million with Medicare Part B, and 6.8 million on Medicaid for a total of more than 28 billion patient records. The data are updated quarterly, with all new records becoming available within 15 months of service and 91% of claims available within 5 months. Because of MarketScan's sourcing from large employers, its data boast superior longitudinal tracking of patients. Truven Health Analytics MarketScan data sets are publicly available to researchers for a fee per year of data. The MarketScan database contains International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) and 10th revision, Clinical Modification, Current Procedural Terminology (CPT), Diagnosis Related Group codes, as well as National Drug Codes.

Inclusion Criteria

This study identified 147,838 patients who underwent primary RCR surgery (CPT 29827) between 2007 and 2016. Other procedures performed on the same day of index surgery were identified by the following CPT codes: Acromioplasty (CPT 29826) and Biceps Tenodesis (CPT 23430 or 29828). Only patients with confirmed laterality were included in this study. Individual demographic information and comorbidity status including history of diabetes, hyperlipidemia, arterial hypertension, obesity, osteoporosis, and tobacco use of each patient were gathered. Laterality of surgery was also noted (Fig 1).

Outcomes

The primary outcome measure of the study was 5-year costs after primary RCR, and we compared this for RCR alone versus with BT, acro, or both BT and acro. A secondary goal was to determine postoperative complication and revision surgery rates. The presence of a postoperative complication was defined as a complication occurring within 90 days of the index RCR surgery. These included infection (998.5-998.59, 730.0-730.91, 996.66, 996.67) capsulitis (726.0, 719.51), hematoma (998.1, 998.11, 998.12, 998.13), shoulder dislocation (831.00, 831.09, 718.31, 718.21), nerve injury (955.0-955.9, 907.4), or wound complications (998.3, 998.31, 998.32, 998.81, 998.83, 998.4, 101.40, 101.60, 101.80, deep vein thrombosis [451.0-453.9], and pulmonary embolism [415.1-415.19]). Thromboembolism was defined as presence of either a pulmonary embolism or deep vein thrombosis. A revision surgery was defined by the presence of the aforementioned RCR CPT codes for after the index surgery date and on the ipsilateral shoulder. This

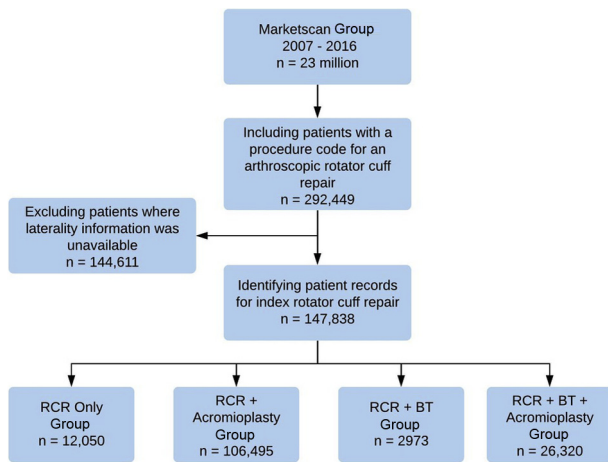


Fig 1. Group diagram

was measured at 90 days, 6 months, 1 year, and 2 years following index surgery. Health care utilization data were also collected. Immediate payments (same day of surgery) as well as payments through 9 months, 2 years, and 5 years were included. Procedure specific payments were also analyzed. This was defined as a payment on the same day of surgery directly attributed to the procedure (by the presence of an RCR CPT code in the service reimbursed).

Patient Groups and Statistical Analysis

Patients were stratified into surgical groups based on the concomitant procedures performed on the same day of index surgery: RCR only, RCR + acro, RCR + BT, or RCR + acro + BT. If patient records lacked the codes for acro and BT, there were classified as RCR only. Follow-up time was measured, and no significant differences were noted between the procedures. This allowed us to conclude that loss to follow-up was similar among the groups, and comparative analyses of the long-term outcomes would be fair. To minimize the effect of potential confounding on the direct comparison of patients undergoing the different RCR procedures, a multivariate multiple logistic regression analysis was conducted. This

methodology controlled for baseline covariates such as age, sex, and Charlson Comorbidity Index. Two sample *t* tests, rank-sum and χ^2 tests were used to assess significant differences in unadjusted demographic data, postoperative complications and reoperation rates, and payments among the groups. An alpha value of 0.05 was set as significant.

Results

Patient Group

A total of 147,838 patients met the inclusion criteria of this study, with each group being mutually exclusive (Table 1). RCR-only patients were significantly younger than the other 3 groups (49.6 years vs 53.2 vs 52.4 vs 54.3, $P < .0001$). RCR only (41.1%) and RCR + acro patients (44.2%) has a similar percentage of females, whereas patients who had a BT procedure had significantly fewer female proportions (RCR + BT: 31.1%, RCR + BT + acro 34.2%) ($P < .0001$). Rotator cuff repair + BT + acro patients had the highest rates of hypertension (47.4%, $P < .0001$) whereas RCR + acro patients had the highest rates of diabetes (17.3%, $P < .001$) and osteoporosis (6.7%, $P < .0001$).

Complications and Revision Surgery

In the unadjusted data, there is an increase in postoperative complications in the non-BT groups. Patients in the RCR-only group experienced the highest rate of postoperative complications (17.2%) compared with the other surgical approaches (RCR + acro 16.4%, RCR + BT 15.1%, RCR + acro + BT 16.2%, $P < .0161$). Patients undergoing RCR + BT had the highest rates of wound complication (0.27%, $P = .0016$), whereas patients undergoing RCR + acro had the highest rates of capsulitis (14.5%, $P < .0001$). Rates of thromboembolism, nerve injury, infection, and hematoma were similar among surgical approaches (Table 2). In multivariate regression, the performance of a BT does not lead to higher complications rates ($P > .05$).

Table 1. Demographics and Baseline Comorbidities

Variables	RCR Only (n = 12,050)	RCR + Acro (n = 106,496)	RCR + BT (n = 2,973)	RCR + Acro + BT (n = 26,320)	P Value
Age, mean	49.6	53.2	52.4	54.3	<.0001
Female	4,952 (41.1)	47,034 (44.2)*	924 (31.1)	9,006 (34.2)	<.0001
Hypertension	4,858 (40.3)	48,295 (45.4)	1,328 (44.7)	12,476 (47.4)*	<.0001
Obesity	1,512 (12.6)	13,787 (13.0)	403 (13.6)	3,425 (13.0)	.428
Diabetes	1,858 (15.4)	18,428 (17.3)*	445 (15.0)	4,465 (17.0)	<.0001
Tobacco use, N (%)	1,165 (9.7)	9,133 (8.6)*	286 (9.6)	2,464 (9.4)	<.0001
Osteoporosis, N (%)	607 (5.0)	7,079 (6.7)*	159 (5.4)	1,631 (6.2)	<.0001
Hyperlipidemia, N (%)	4,270 (35.4)*	44,216 (41.5)	1,234 (41.5)	11,658 (44.3)	<.0001
Rotator cuff, N (%)					<.0001
Left	4,503 (37.4)	38,889 (36.5)	1,035 (34.8)	9,126 (34.7)	
Right	7,547 (62.6)	67,606 (63.5)	1,938 (65.2)	17,194 (65.3)	
Follow-up in months, mean	31.2	29.6	30.3	31.8	.0581

NOTE. Boldface indicates statistical significance ($P < .05$).

*Driver of significance.

Table 2. Postoperative Complications

Variables	RCR Only (n = 12,050)	RCR + Acro (n = 106,496)	RCR + BT (n = 2,973)	RCR + Acro + BT (n = 26,320)	P Value
Any complication	2,072 (17.2)*	17,447 (16.4)	449 (15.1)	4,253 (16.2)	.0161
Infection	30 (0.3)	243 (0.2)	11 (0.4)	71 (0.3)	.2923
Wound complication	14 (0.12)	78 (0.07)	8 (0.27)*	25 (0.1)	.0016
Hematoma	9 (0.1)	100 (0.1)	4 (0.1)	28 (0.1)	.7103
Capsulitis	1,499 (12.5)	15,545 (14.5)*	321 (10.0)	3,698 (14.1)	<.0001
Dislocation	549 (4.6)*	1,492 (1.4)	119 (4.0)	449 (1.7)	<.0001
Nerve injury	7 (0.1)	52 (0.1)	4 (0.1)	15 (0.1)	.2379
Thromboembolism	50 (0.4)	410 (0.4)	17 (0.6)	106 (0.4)	.4261

NOTE. Boldface indicates statistical significance ($P < .05$).

*Driver of significance.

In the unadjusted data, the RCR-only group had an increased reoperation rate at all time points following surgery ($P < .0001$) (Table 3). Within 90 days, the RCR-only patients had a 1.4% revision surgery rate compared with 1.3% in the BT groups. This difference remained through 2 years of follow-up, with RCR-only patients having a 2.9% revision rate, whereas RCR + BT had a 2.8% and RCR + BT + acro had a 2.4% revision rate ($P < .0001$) (Table 3). In multivariate regression analysis, RCR + BT and RCR + BT + acro did not lead to higher rates of revision surgery ($P > .05$) (Table 4).

Healthcare Utilization

Rotator cuff repair with acromioplasty and biceps tenodesis had the highest immediate costs (Table 5). Procedure specific payments ranged from RCR only being the least expensive (\$3,364) to RCR + acro + BT costing \$6,787. When comparing different BT techniques, open BT had a median cost of \$5,406, whereas median arthroscopic BT cost was \$5,803. Although the difference between the total health care utilization decreased over time, RCR + BT + acro remained the most expensive through 5 years of follow-up (\$28,434, $P < .0001$) (Table 6). This was confirmed in a regression analysis as well, as the performance of a BT alongside RCR + Acro led to increased odds of greater than average costs (odds ratio 1.47, 1.37-1.59, $P < .001$). (Table 4).

Discussion

After adjusting for confounding variables, the performance of a BT did lead to higher costs both

immediately and through 5 years of follow-up but had similar rates of overall complications and revision surgeries.

This study used a large national billing and claims dataset to conduct a comparative analysis of patients undergoing RCR with and without acromioplasties and BT from 2007 through 2016, and discusses the cost-effectiveness related to the concomitant use of BT during RCR. The performance of BT led to an increase in immediate costs. This is to be expected, as the concomitant use of BT not only increases the operative time, but also the technical complexity of the surgery. Interestingly, the elevation of BT related costs remained in long-term follow-up at 5 years. Rotator cuff repair resource utilization is a concern because data indicate payments associated with them increased 144% from 2001 through 2009, whereas hospital payments only increased 85%.³¹ Significant efforts need to be made to optimize patient selection for concomitant RCR procedures to mitigate the increasing burden on the health care system.

The cost-effectiveness of RCRs have been of significant interest in the orthopedic community. Adla et al.³² argued that arthroscopic RCR (ARCR) may be less cost-effective than open cuff repair because the arthroscopic portion led to higher payments but no difference in clinical metrics such as inpatient time, amount of analgesia, number of outpatient visits, or physiotherapy use. This finding was corroborated Kose et al.,³³ finding similar clinical results between ARCR and mini-open RCR but higher payments associated with ARCR.

Table 3. Revision Surgery

Variables	RCR Only (n = 12,018)	RCR + Acro (n = 106,191)	RCR + BT (n = 2,968)	RCR + Acro + BT (n = 26,320)	P Value
Within 30 days	151 (1.3)*	838 (0.8)	37 (1.3)	326 (1.2)	<.0001
Within 90 days	163 (1.4)*	965 (0.9)	39 (1.3)	346 (1.3)	<.0001
Within 6 months	225 (1.9)*	1,338 (1.2)	57 (1.9)	447 (1.7)	<.0001
Within 1 year	296 (2.5)*	1,819 (1.7)	74 (2.5)	568 (2.2)	<.0001
Within 2 year	346 (2.9)*	2,126 (2.0)	83 (2.8)	623 (2.4)	<.0001

NOTE. Boldface indicates statistical significance ($P < .05$).

*Driver of significance in post hoc analysis.

Table 4. Multivariate Regression to Determine Independent Association of Approach Type with Outcomes

Variables	Any Complication			Any Reoperation			Greater than Average Costs		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Rotator cuff repair only	1.03	0.97-1.09	.3181	1	0.93-1.07	.991	0.31	0.29-0.32	<.0001
RCR + acromioplasty	0.99	0.96-1.0	.7992	1	0.95-1.05	.978	0.42	0.41-0.43	<.0001
RCR + biceps tenodesis	0.91	0.82-1.0	.0925	1.1	0.96-1.28	.1503	0.68	0.63-0.73	<.0001
Rotator cuff repair + biceps tenodesis + acromioplasty	1	0.97-1.0	.7992	1	0.95-1.05	.988	1.47	1.37-1.59	<.0001

NOTE. Boldface indicates statistical significance ($P < .05$).
CI, confidence interval; OR, odds ratio.

Churchill et al.³⁴ built upon these data and identified decreased operating room times and significantly reduced costs with mini-open compared to ARCR. Although the financial consequences of acromioplasties have also been investigated, and in cases of shoulder impingement syndrome, 1 study showed no clinical benefit but significantly increased costs, a more recent study has shown better long-term outcomes of isolated acromioplasty in comparison to PT alone for impingement syndrome.^{35,36}

This study also identified differing rates of adverse events between the procedures. The postoperative complication rate was the highest in the RCR only group, which also had a mean age significantly younger than the other procedure groups. This is to be expected because younger patients are typically more active and therefore have higher chances of shoulder dislocations and subsequent pathology.³⁷⁻⁴⁰ Patients undergoing BT had higher rates of wound complications than the other patients. This is consistent with Nho et al.'s⁴¹ study that identified a rate of 0.28% of patients developing wound infections necessitating irrigate and debridement. This can be explained by the increased operative time needed in arthroscopic BT or the necessity for an additional incision in an open BT.⁴²⁻⁴⁴

The surgical management of RCTs typically includes subacromial decompression in conjunction with the repair of the damaged tendons.⁴⁵ The role of subacromial impingement of the rotator cuff was initially described by Neer at al.⁴⁶ in 1972, with a recommendation of partial resection of the acromion to reduce friction and damage of the tendons in contact. Although outcomes following RCR with concomitant

acromioplasty are favorable,^{11,47,48} a concern remains regarding the effectiveness of acromioplasty. Interestingly, in this study, 89.8% of the patients undergoing RCR had a concomitant acromioplasty, indicating its prevalence in use. Several randomized controlled trials have described little to no difference in the clinical and functional outcomes in the performance of RCR with or without acromioplasties.^{11,49,50} However, 1 investigation was able to identify a reduction in revision risk following RCR with acromioplasty compared with RCR alone and indicate that acromioplasty may be indicated in rotator cuff disease with a type III acromion.^{11,45}

Lesions of the biceps tendon are often identified during RCR, but are also associated with superior labrum anterior posterior tears and glenohumeral arthritis.⁵¹⁻⁵³ Pathology of LHBT is often associated with anterior shoulder pain, with surgical intervention being indicated in situations of biceps instability, tenosynovitis, tendinosis, or acute or degenerative tearing.⁵⁴ Surgical options include biceps tenotomy or tenodesis; however, considerable debate remains regarding the optimal surgical strategy.^{19,30,55,56} Both strategies provide strong clinical outcomes, however, tenotomy has less associated surgical morbidity and tenodesis may provide better maintenance of supination strength.⁵⁶ In the context of rotator cuff repairs, biceps tenotomy or tenodesis may further relieve pain and increase shoulder function.²⁷ The severity of RCT and LHBT has been suggested to be directly proportional, with 16% to 75% of RCT having some concomitant LHBT pathology.⁵³ Previous studies have determined that patients who undergo RCR with any concomitant biceps tendon surgery (biceps tenodesis

Table 5. Costs Outcomes

Variables	RCR Only (n = 12,018)	RCR + Acro (n = 106,191)	RCR + BT (n = 2,968)	RCR + Acro + BT (n = 26,320)	P Value
Immediate payments	\$10,079	\$11,545	\$13,284	\$15,157	<.0001
Total payments					
9 months	\$15,766	\$17,277	\$19,217	\$21,236	<.0001
2 years	\$20,085	\$21,600	\$23,298	\$25,313	<.0001
5 years	\$24,033	\$25,644	\$25,914	\$28,434	<.0001

NOTE. Boldface indicates statistical significance ($P < .05$).

*Driver of significance in post hoc analysis.

Table 6. Procedural Costs

Variables	Median	25th Percentile	75th Percentile
RCR only	\$3,364	\$1,957	\$5,462
RCR and acromioplasty	\$4,867	\$3,258	\$7,122
RCR and biceps tenodesis (open)	\$5,406	\$3,680	\$8,176
RCR and biceps tenodesis (scope)	\$5,803	\$3,844	\$8,612
RCR and acromioplasty and any biceps tenodesis	\$6,787	\$4,609	\$10,191

or biceps tenotomy) present with lower baseline functional status (indicating more severe pathology) but have greater improvements in patient-reported outcomes when compared with those who underwent isolated RCR.²⁷ Meraner et al.⁵⁷ analyzed 53 patients undergoing RCR with concomitant biceps tenodesis or tenotomy procedures and found no difference in patient satisfaction or functional outcome scores. Zhang et al. further corroborated these findings in a study of 151 patients, but also noted there was no increased rate of Popeye deformity in the biceps tenodesis group. Erickson et al. conducted the first large-scale study investigating the risk for revision surgery following RCR and biceps tenodesis. In a study of 29,827 patients derived from an administrative database, they identified an increase rate of reoperation at 6 months and 1 year following concomitant BT and RCR, when compared with isolated RCR.²⁹ This is in contrast to the data of this study, which after adjusting for confounding variables, found no increased risk for reoperation following BT. One reason for the discrepancy may be in the nature of the administrative coding; in this study, confirmed laterality was required to consider a follow-up procedure as a revision; a criterion the previous study did not use that may have led to underestimate of revision risk in this study or overestimation of risk in theirs.

Limitations

As with all large database studies, interpretations of this study are limited by the retrospective and administrative nature of these data. Because patients, procedures, and clinical outcomes were queried using ICD-9-CM and CPT codes, it is not possible to assess the underlying validity of the collected records. Our analysis is limited by the accuracy and completeness of the codes. There may be underestimations regarding postoperative complications if the administrators did not appropriately code them. Using a large dataset such as MarketScan provides for powerful analyses but has an inherent level of selection bias and lacks clinical details, specifically shoulder functional status, radiographic findings, detailed physical examinations, clinical outcomes, and more detailed

long-term follow-up. The lack of data regarding the size and chronicity of RCT particularly affected our ability to stratify the group by severity of disease. In addition, the location of where the biceps tenodesis was performed was also unavailable. Furthermore, the data provided from MarketScan do not provide us with a specific indication for surgery. Preoperative morbidity may have served as a confound in that patients with increased morbidity were selected to not receive a biceps tenodesis. Also, patients frequently switch health plans, so it is possible that our longer term costs and complication data are less robust versus early follow-up data. We conducted a comparative cost analysis of the use of concomitant procedures in RCR and may provide useful insight into to the complications, costs, and revision rate of RCRs with and without concomitant procedures.

Conclusions

Concomitant biceps tenodesis does lead to higher total health care costs, both in the short and longer terms. When adjusting for confounding factors, the performance of concomitant biceps tenodesis with RCR does not lead to a difference in postoperative complication rate or risk for revision surgery.

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