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A single-institution analysis of factors affecting costs in the arthroscopic treatment of glenohumeral instability

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Background: Although surgical shoulder stabilization is a substantial cost nationally within the United States, little information exists to analyze this cost. The purpose of this study was to identify factors associated with variation in direct costs with the arthroscopic treatment of glenohumeral instability.

Methods: This was a retrospective study of all patients who underwent arthroscopic treatment of glenohumeral instability between January 12, 2012 and July 11, 2017. Patient and procedure factors were collected. Direct perioperative costs were collected using a validated internal tool. Patient and procedure characteristics significantly associated with costs were identified using multivariate generalized linear models.

Results: The study included 302 patients, of whom 12% were undergoing revision and 32% were contact or collision athletes. Anterior instability was present in 73%, whereas 14% had posterior and 10% had multidirectional instability. Of the patients, 67% were recurrent dislocators and 33% were first-time dislocators or subluxators. Remplissage was performed in 13%; biceps tenodesis, 5%; and rotator cuff repair, 3%. An average of 4.0 ± 1.4 anchors were used. Of costs, 39% were operative facility utilization costs and 41% were implant costs. Factors associated with cost increase included an increased number of anchors ($P < .0001$), posterior vs. anterior instability ($P = .001$), recurrent instability vs. first-time dislocation ($P = .025$), remplissage ($P = .006$), rotator interval closure ($P = .021$), bicep tenodesis ($P = .020$), rotator cuff repair ($P < .0001$), an inpatient stay ($P = .003$), and repair of humeral avulsion of the glenohumeral ligaments ($P = .012$).

Conclusion: Most perioperative costs associated with the arthroscopic treatment of glenohumeral instability are facility utilization and implant costs. Nonmodifiable factors associated with increased cost included posterior direction of instability and recurrent instability. Modifiable factors included additional procedures and inpatient stay.

Over 20,000 surgical shoulder stabilizations are performed annually in the United States, and the incidence is increasing.[4] Each of these procedures is associated with an average cost of $23,199,[13] and thus, the annual cost of surgical shoulder stabilization in the United States exceeds $450 million. However, despite this substantial cost, no data are available as to factors associated with cost in shoulder stabilization. Potential sources of cost include personnel, implants, and operative time, which costs approximately $20/min-$60/min.[9,14] Without research to determine the source of these costs and the predictors of increased cost, no rational recommendations can be made to reduce costs.

Within our institution, an internal cost-analysis tool has been developed and validated that reports direct costs at a per-patient level[6] and thus allows the determination of patient and surgeon factors associated with costs.[18] This unique research resource allows the analysis of costs instead of charges, unlike prior cost-analysis research.[1,5] Although costs and charges must be related overall, assuming them to be equivalent at a per-patient level may obscure variation and may prevent the identification of cost predictors. The purpose of this study was to identify factors associated with variation in direct costs with the arthroscopic treatment of

This study was approved by the University of Utah Institutional Review Board (protocol no. 46622).

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glenohumeral instability. We hypothesized that most costs would be due to facility utilization and implant costs and that these costs would be directly related to concomitant pathology and instability severity, as measured by number of dislocations, concomitant procedures, and numbers of anchors implanted.

Materials and methods

This was a retrospective study of all patients who underwent arthroscopic treatment for glenohumeral instability between January 12, 2012 and July 11, 2017. Cost data were not available prior to January 12, 2012; thus, we excluded surgical procedures performed before this date. We did not conduct a power analysis as this was a retrospective analysis of a limited data set in which all available patients were included. We used the Current Procedural Terminology code 29806 to identify patients for inclusion. To address the question specifically regarding arthroscopic instability repair, we excluded patients who had undergone open surgery, patients in whom no anchors were used, and patients who had been treated at a facility within our system that did not reliably report cost data. Patients in whom no anchors were used were excluded because it was believed that these cases would not be comparable regarding costs. Aside from these exclusions, this was a consecutive series of patients. Informed consent was waived because this was an analysis of data available within the medical records.

Clinical data collection

The following data were collected for each patient based on preoperative documentation: sex, age, body mass index, smoking status, medical comorbidities such that the Charlson Comorbidity Index could be calculated,[3] operative side, whether the patient was a contact or collision athlete, direction of instability (reported by the surgeon at the time of the preoperative evaluation as either anterior, posterior, or multidirectional), number of dislocations (reported as either $\leq$1 or $\geq$2), whether the patient underwent any prior shoulder surgery on the operative side, and time between initial dislocation and surgery. For each patient, the following data were collected based on the intraoperative documentation: American Society of Anesthesiologists score, position (beach chair vs. lateral decubitus), whether an anterior labral repair was performed, whether a superior labral repair was performed, whether a posterior labral repair was performed, number of anchors implanted, whether the patient received postoperative regional neuromuscular blockade and whether this blockade included a catheter, whether the procedure was performed at our ambulatory surgical center or within the main operating room of the hospital, and whether the patient was admitted postoperatively. We also recorded whether any concomitant procedures were performed, such as remplissage, rotator interval closure, biceps tenodesis, distal clavicle excision, subacromial decompression, rotator cuff repair, or repair of humeral avulsion of the glenohumeral ligaments (HAGL).

Operative procedure

To best capture variations in surgical technique that may vary with cost, our study design was purposefully inclusive. Thus, we included procedures performed by all 6 members of the Division of Sports within the University of Utah. Whereas each had fellowship training in sports or shoulder surgery, the location of this training varied. There was thus heterogeneity as to the surgical indications, surgical philosophy, patient positioning, portal placement, labral preparation methodology, implants used, method of suture passage, method of knot tying, and postoperative protocol among surgeons and among patients.

Cost analysis

We conducted our cost analysis with 2 individuals with advanced training in both statistics and economics (R.N. and M.Y.). Inclusion of these individuals in all steps of our study, from study design to data collection to data analysis to manuscript preparation, ensures that our cost analysis is coherent and as free of bias as possible. A team of economists, bioinformatics specialists, and computer programmers at our institution (University of Utah) developed an internal program called the Value-Derived Outcomes (VDO) tool. This tool has been internally validated but has not been compared with other hospitals or hospital systems and reflects costs specific to our institution.[2,6] This program has been made available to faculty within the institution to encourage monitoring and reduction of costs. It is independent of both the billing and finance departments and is thus unrelated to errors or inaccuracies within those departments; as such, it is also not influenced by either coding or reimbursement. This program only reflects costs within our health care system.

To calculate cost, this program both directly measures actual supply use and allocates cost based on use of shared resources. For the former, pharmaceutical costs, implants, and other consumables are allocated based on hospital ledger costs. For the latter, shared costs, such as personnel salaries, are allocated based on time spent by the patient in each phase of care, which is recorded within the electronic medical record. Overhead costs such as maintenance, salaries, utilities, and equipment costs are allocated in this manner. As time spent by the patient within each phase of care differs, these costs differ among patients, unlike facility fees. The program reports total direct cost and also divides costs into the following groups: facility/utilization, supply, implant, laboratory, pharmacy, imaging, and other. These costs are then normalized within our study. One caveat of the program is that confidentiality of the negotiated supply and implant costs is protected and thus the actual dollar amounts cannot be published. These costs are available internally and were included within the analysis, but their specific dollar amounts are not published in this article. All costs were adjusted to 2017 US dollars using the Personal Consumption Expenditures price index for health care services. Professional fee costs for the surgeon were not included in this cost analysis as they are not part of the Value-Derived Outcomes (VDO) tool. However, the cost to the hospital of the surgeon, anesthesiologist, and all other staff involved is included. As discussed earlier, these costs are allocated based on personnel salaries and the time spent by the patient in each phase of care. However, these costs are not perfectly reflective of professional fees.

Statistical analysis

Descriptive statistics including counts and percentages or means and standard deviations were used to describe clinical, demographic, and surgical characteristics of the patient cohort. A multivariate regression analysis was performed to identify predictors of total cost. A generalized linear model with log link and gamma functions was used to account for the skewed distribution of cost. Predictors included in the multivariate analysis were weeks from first dislocation to surgery, number of anchors, revision surgery, facility location, instability direction, first-time or recurrent instability, lateral or beach-chair position, anterior labral repair, superior labral repair, posterior labral repair, remplissage, rotator interval closure, biceps tenodesis, rotator cuff repair, HAGL repair, postoperative regional block, and postoperative inpatient admission, controlling for patient age, body mass index, Charlson Comorbidity Index, sex, tobacco use, year of procedure, and provider. Statistical significance of the multivariate analysis was set at $P \leq .05$.

Results

Study group

A total of 302 of 324 cases were included. We excluded 10 patients as no anchors were used, 3 because they underwent concomitant open humeral bone grafting, 1 as he underwent concomitant open glenoid bone grafting, 4 because they underwent a prior Latarjet procedure, and 5 as their procedures were performed at a facility that did not reliably report cost data during the study period. The included patients generally comprised a young, male, healthy cohort with largely anterior instability treated with anterior labral repair on an outpatient basis (Table I).

Cost analysis

Of operative costs, 39% were facility utilization costs, 7% were operative supply costs, 41% were implant costs, 8% were pharmacy costs, and 6% were costs of other services. Both year of procedure and procedure provider were significantly associated with total cost; thus, both were included as covariates. After correction for these 2 factors using multivariate analysis, factors associated with increased cost included number of anchors (11% ± 1% increase per anchor, $P < .0001$; Fig. 1), direction of instability (22% ± 6% increase for posterior instability vs. anterior instability, $P = .001$), number of prior dislocations (6% ± 2% increase for recurrent instability vs. ≤1 dislocations, $P = .025$), addition of a remplissage (8% ± 3% increase, $P = .007$), addition of rotator interval closure (13% ± 5% increase, $P = .021$), addition of a biceps tenodesis (10% ± 4% increase, $P = .020$), addition of a rotator cuff repair (31% ± 8% increase, $P < .0001$), and addition of HAGL repair (18% ± 7% increase, $P = .012$). Postoperative admission was associated with a 71% ± 19% increase in costs ($P = .003$), whereas a postoperative block was associated with an 11% ± 4% decrease in costs ($P = .003$, Table II).

Table I
Demographic characteristics

Variable	Mean or n	SD or %
Age, yr	26	9
BMI	27	6
CCI	0.2	0.5
Time from first dislocation to surgery, wk	49	66
No. of anchors	4	1.4
Revision surgery	37	12
Surgical center location	294	97
Female sex	75	25
Tobacco use	44	15
ASA score		
1	230	76
2	65	22
3	7	2
Contact or collision athlete	96	32
Direction of instability		
Anterior	220	73
Posterior	42	14
Multidirectional	29	10
Recurrent dislocator	203	67
Surgeon		
1	91	30
2	118	39
3	66	22
4	22	7
5	4	1
6	1	0
Lateral position	274	91
Anterior labral repair	257	85
Superior labral repair	28	9
Posterior labral repair	95	32
Remplissage	38	13
Rotator interval closure	6	2
Biceps tenodesis	16	5
Rotator cuff repair	10	3
HAGL repair	5	2
Postoperative regional block	263	87
Postoperative inpatient admission	6	2

SD, standard deviation; *BMI*, body mass index; *CCI*, Charlson Comorbidity Index; *ASA*, American Society of Anesthesiologists; *HAGL*, humeral avulsion of glenohumeral ligaments.
Discrete variables are presented as number and percentage, whereas continuous variables are presented as mean and SD.

Discussion

Although surgical shoulder stabilization is a substantial cost nationally within the United States, little information exists to analyze the source of operative costs or those factors associated with cost in shoulder stabilization. The purpose of this study was to identify the source of operative costs during arthroscopic shoulder stabilization and the factors associated with variation in direct costs with the arthroscopic treatment of glenohumeral instability. Within our study, most costs were due to facility utilization and implants. We identified multiple factors associated with increased cost, including posterior instability, recurrent instability, remplissage, rotator interval closure, biceps tenodesis, rotator cuff repair, HAGL repair, and an inpatient stay.

Within our study, 80% of costs were due to facility utilization and implant costs. Future cost-reduction efforts should focus on reducing facility utilization by reducing operative times and reducing implant costs by using less expensive implants, using operative techniques that do not require implants (ie, open instability repair with bone tunnels), or negotiating lower implant costs with industry partners. As additional anchors could theoretically reduce the risk of recurrence, surgeons must balance the cost of each addition anchor against the likelihood that it will mitigate the risk of recurrence. Milne and Gartsman[12] conducted an internal analysis in 1994 and determined that the average cost for an open Bankart repair in that year was $8675, with a range from $6542 to $11,528. A similar analysis in 2018 determined that the average cost for an arthroscopic Bankart repair was $23,199.[13] Several comparative cost-effectiveness analyses have been conducted comparing arthroscopic Bankart repair with the open Latarjet procedure,[13] comparing the open Latarjet procedure with the arthroscopic Latarjet procedure,[15] and comparing revision arthroscopic repair vs. revision to a Latarjet procedure after a failed arthroscopic repair.[10] However, none of these studies have analyzed the source of costs associated with arthroscopic surgical stabilization or the factors associated with increased cost with arthroscopic surgical stabilization.

We identified several nonmodifiable factors associated with increased cost, including posterior instability and recurrent instability. Posterior instability is less common than anterior instability among highly active patient populations.[7] It may be more difficult to diagnose and may have worse outcomes regarding both patient-reported outcomes and return to play, although overall outcomes are good.[1,3,6] Our analysis suggests that it also tends to be more expensive intraoperatively, in part because it requires more anchors often extending to the anterior or superior labrum and a longer operative time. Within our analysis, posterior instability required 4.3 ± 1.7 anchors vs. 3.9 ± 1.3 anchors for cases without posterior instability ($P = .0382$). Several recent studies have

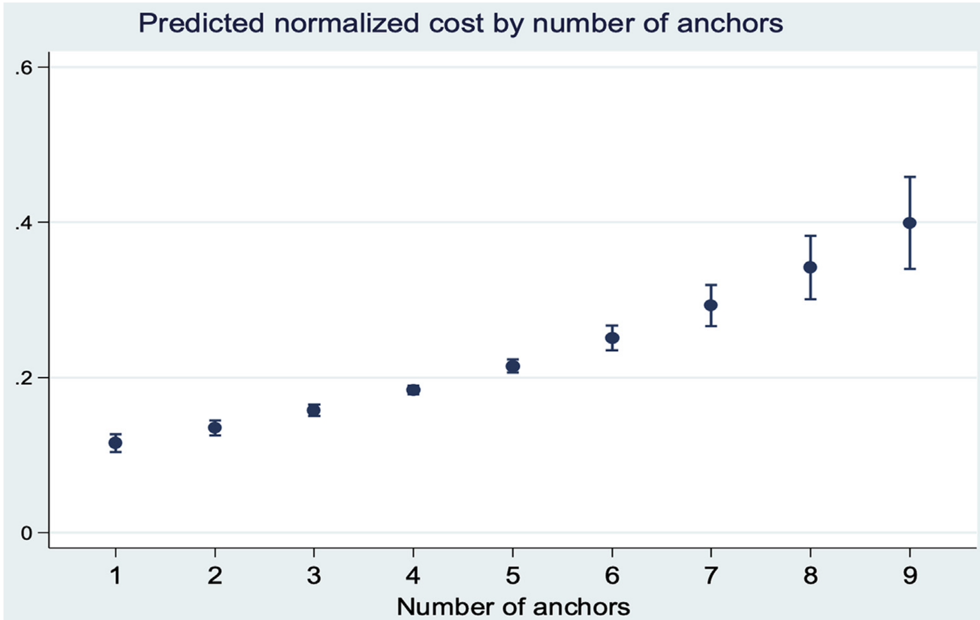

Figure 1 Predicted normalized cost compared with number of anchors. *Error bars* show 95% confidence intervals.

demonstrated that first-time dislocators have a lower incidence of recurrent dislocation and a lower incidence of concomitant pathology such as bone loss and biceps pathology than recurrent dislocators.[8,11,16,17] Our results suggest that this concomitant pathology translates into a more expensive procedure. In combination, our findings and those of previous studies suggest that surgical stabilization of a first-time dislocator may be a cost-effective strategy to reduce further damage to the shoulder in specific patient populations.

We identified several modifiable factors associated with increased cost, including the addition of a remplissage, the addition of rotator interval closure, the addition of biceps tenodesis, the addition of rotator cuff repair, and the addition of HAGL repair. Each of these additions requires additional operative time and most require additional implants, which likely explains the additional cost associated with each. The numbers provided in our study may be useful to surgeons considering each procedure as these data provide a guideline as to the degree of additional cost incurred with each. Certainly each surgeon's indications for these additional procedures may be different. Within our analysis, surgeons did significantly differ regarding cost, and this variable was thus included in our multivariate analysis. However, there is likely collinearity between surgeon and procedure. For example, one surgeon may always perform a remplissage, and another may never perform a remplissage. The surgeon's individual decision making and surgical philosophy thus likely still play a role in cost. We also found that a postoperative block significantly reduced perioperative cost whereas a postoperative admission significantly increased perioperative cost. Indeed, a postoperative admission created a larger increase in cost than any other factor studied. These findings validate the cost-effectiveness of an outpatient approach with the support of a regional anesthesia team for arthroscopic shoulder stabilization. In our study, adequate postoperative pain control that avoids a lengthy recovery room stay or a postoperative admission significantly reduced overall costs. Within our study, the facility location (surgical center vs. main operating room) did not affect cost, but it should be noted that the study may be underpowered for this specific comparison. Of note, our study does not include billing data, and a postoperative block does include some additional billed expense to the health care system that is not included in this analysis.

Table II
Significant associates with costs

Variable	Change, mean ± SD, %	*P* value
No. of anchors	11 ± 1 per anchor	<.0001
Posterior instability direction	22 ± 6	.001
Recurrent instability	6 ± 2	.025
Remplissage	8 ± 3	.006
Rotator interval closure	13 ± 5	.021
Biceps tenodesis	10 ± 4	.020
Rotator cuff repair	31 ± 8	<.0001
HAGL repair	18 ± 7	.012
Postoperative regional block	−11 ± 4	.003
Postoperative inpatient admission	71 ± 19	.003

SD, standard deviation; *HAGL*, humeral avulsion of glenohumeral ligaments.

Our study has several limitations. The patients and cost data in the study are from only a single center, and thus, our findings may not reflect cost variations in other centers. For this reason, we did not perform a between-surgeon analysis, as this would be even less generalizable. Certainly implant costs can vary between centers depending on contract negotiations. Our study was performed retrospectively via chart review, and thus, errors in documentation may be propagated into our analysis. Our cost analysis does not include preoperative costs such as imaging costs or postoperative costs such as thus incurred with postoperative rehabilitation, readmission, or subsequent surgery. This is also an analysis of costs and not charges and thus reflects the perspective of the hospital and not the perspective of the patient. The analysis also does not include more global costs such as missed work. No outcome data are included; thus, our study is a cost analysis and not a cost-effectiveness analysis and does not truly allow us to conclude which surgical indications would be most appropriate. Finally, our program for cost analysis determined shared costs such as facility utilization as an estimate, which may be inaccurate as not all shared resources can be evenly allocated across time.

Conclusion

Most perioperative costs associated with the arthroscopic treatment of glenohumeral instability are facility utilization and implant costs. Nonmodifiable factors associated with increased cost included posterior direction of instability and recurrent instability, whereas potentially modifiable factors included additional procedures and inpatient stay.

Disclaimer

Peter N. Chalmers is a paid consultant for Mitek and Arthrex.

Patrick Greis receives fellowship support from Mitek and has stock or stock options in Merck.

Robert Z. Tashjian is a paid consultant for Zimmer/Biomet and Mitek; has stock in Conextions, INTRAFUSE, and KATOR; receives intellectual property royalties from Wright Medical, Shoulder Innovations, and Zimmer/Biomet; receives publishing royalties from *The Journal of Bone and Joint Surgery*; and serves on the editorial board for the *Journal of Orthopaedic Trauma*.

The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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