J Shoulder Elbow Surg (2019) 28, 1334–1340

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

An analysis of costs associated with shoulder arthroplasty

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Background: The purpose of this study was to identify factors associated with variation in direct costs with shoulder arthroplasty.
Methods: This was a retrospective study of all shoulder arthroplasties performed at a single facility between July 1, 2011, and November 30, 2016. We collected patient factors, indications, procedure (including implant details), implant brand (A, B, and other), and complications. We collected direct costs over a 90-day period using a validated internal tool. We identified patient and procedure characteristics associated with costs using multivariable generalized linear models.
Results: A total of 361 patients were included, 19% with revision arthroplasty procedures, 32% with anatomic total shoulder arthroplasties, and 66% with reverse total shoulder arthroplasties (RTSAs). Of total costs, 13% were operative facility utilization costs and 58% were operative supply costs. Factors associated with increased total cost included younger age ($P = .002$) and an indication for surgery of other, that is, not osteoarthritis, a failed arthroplasty, or the sequelae of a rotator cuff tear ($P = .030$). Factors associated with increased operative costs included younger age ($P = .002$), use of an RTSA ($P < .001$), use of a bone graft ($P < .001$), implant brand B ($P = .098$), implant brands other than A and B ($P = .04$), the sequelae of a rotator cuff tear as an indication for surgery ($P = .041$), or an indication for surgery of other ($P = .007$).
Conclusion: Most short-term (90-day) costs with shoulder arthroplasty are operative costs. Nonmodified factors associated with increased cost included younger age and less common indications for surgery, whereas potentially modifiable factors included the intraoperative use of a bone graft, implant brand, and RTSA use.
Level of evidence: Level IV; Economic Study

Keywords: Reverse total shoulder arthroplasty; total shoulder arthroplasty; hemiarthroplasty; cost analysis; shoulder arthroplasty; shoulder replacement

This study was approved by the Institutional Review Board of the University of Utah under protocol # 46622.

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https://doi.org/10.1016/j.jse.2018.11.065

Shoulder arthroplasty is being performed with increasing frequency in the United States, with a recent analysis suggesting that more than 100,000 shoulder arthroplasties are performed in the United States yearly.[28] Another separate analysis found that the hospital charges for a single shoulder arthroplasty exceeded those of coronary artery bypass grafting.[5] Understanding the source of these costs is critical to reducing them. Potential factors include operative time, which generally costs approximately $20-$60 per minute,[15,20] implant costs, and costs associated with the inpatient stay.[19] Although prior studies have attempted to analyze these factors, their methodology has obscured variations. For instance, many of these studies combine anatomic and reverse total shoulder arthroplasty (TSA and RTSA)[4,9-11,19,23-25,27,28] because these procedures do not have independent common procedural terminology codes.[12,14,17,26] In addition, most orthopedic cost analysis studies analyze charges instead of costs.[1,7] Although charges and costs must be closely related in aggregate for hospitals to remain solvent, assuming them to be equivalent obscures interpatient variation.

Our institution has developed and validated an internal tool that measures direct costs within our health care system and attributes them to individual patient encounters.[13] This tool allows us to conduct cost analyses on direct costs and thus to determine patient factors and surgeon factors associated with costs.[4,30] The purpose of this study was to identify factors associated with variation in direct total cost, operative costs, and inpatient costs associated with shoulder arthroplasty. We hypothesized that advanced age, increased medical comorbidities, revision procedures, and complications would be associated with increased costs.

Materials and methods

This is a retrospective study of all patients who underwent shoulder arthroplasty between July 1, 2011, and November 30, 2016. We excluded patients before July 1, 2011, as cost data were not available before that date. As this was a retrospective analysis of a limited dataset, we did not conduct a power analysis and we included all available patients. We identified patients using common procedure terminology codes 23474, 23473, 23472, 23331, 23470, and 23332 to identify all primary and revision shoulder arthroplasties. We excluded only 1 patient, as no operative report could be identified; this was otherwise a consecutive series of patients. The study was purposefully inclusive to be generalizable to different variants of arthroplasty and different operative indications. Minimum follow-up for inclusion was 90 days, as this analysis is based solely on 90-day costs. Our institutional review board approved this study and waived informed consent because this was an analysis of data available within the medical records.

Clinical data collection

We collected the following data for each patient based on preoperative documentation: gender, age, medical comorbidities such that the Elixhauser score could be calculated,[6] operative side, whether the patient had a prior shoulder arthroplasty on the operative side, and whether the patient had any prior shoulder surgery on the operative side. For each patient, we collected the following data based on the intraoperative documentation: American Society of Anesthesiologists (ASA) score, the surgical procedure, the preoperative diagnosis, whether there were any intraoperative complications, if bone grafting was performed, if the humeral component was fixated with cement, if the patient received a regional blockade, the implant brand (coded as A, B, or other), and the length of the humeral stem.

Operative procedure

All procedures were performed by the senior author (R.Z.T.). The surgeon used a deltopectoral approach for all arthroplasties, a lesser tuberosity osteotomy for the management of the subscapularis during TSA and a subscapularis peel without repair during RTSA, and cemented the humeral component in most cases. The senior author used the Tornier© (Bloomington, MN, USA) and Zimmer© (Warsaw, IN, USA) components in the vast majority of cases during the study period. The surgeon placed a drain intraoperatively and admitted all patients postoperatively to the orthopedic inpatient unit for 2 to 3 days. A sling immobilized the arm for the first 6 weeks postoperatively, with TSAs beginning immediate passive range of motion with subscapularis precautions and RTSAs beginning active range of motion 6 weeks postoperatively. Patients underwent supervised physiotherapy on an as-needed basis. The surgeon generally sees patients at 2 weeks, 6 weeks, and 12 weeks postoperatively, with radiographs at each visit.

Cost analysis

We conducted all cost analyses in collaboration with 2 PhD economists with advanced training in statistics (R.N., M.Y.). These individuals are critical to reduce bias and ensure that we conduct these analyses in a rational manner. Our institution (University of Utah) developed and validated an internal tool called the Value-Driven Outcomes (VDO) tool.[3,13] In an effort to reduce costs, our institution has recently made this tool available to physicians, allowing them to monitor their own costs and compare these costs with those of their colleagues at other institutions. This tool is not used by hospital accounting or hospital billing and thus cannot be biased by spurious billing to offset losses. In addition, variation in coding or reimbursement does not affect the data provided by this tool. This tool is only available within our system; thus any care that patients received outside of our system—such as a postoperative stay at an outside nursing facility or a visit to an outside emergency department—is not captured. For this reason, we excluded preoperative costs because there was substantial variation in whether patients obtained their preoperative imaging and medical workup within our regional-referral system.

This tool derives costs by directly measuring actual supply usage costs and also by allocating shared cost-based usage. In the former, the tool assigns laboratory tests, medications, devices, implant, and imaging costs based on actual individual costs in the hospital ledgers. An example of the latter would be the preoperative holding area nurse's salary, that is, a shared cost, which the tool would allocate to individual patients based on the amount of time spent by each individual patient in preoperative holding, that is, usage of the shared cost. The medical record contains operative time, preoperative holding area time, postoperative holding area time, length of stay, and so on; our internal cost analysis tool used these times to allocate facility overhead costs such as maintenance, staff salaries, utilities, and capital equipment. Because patient usage of these resources differs, this analysis provides interpatient variation, unlike facility charges or facility fees, which do not differ on a patient-to-patient basis for the same procedure.

This cost analysis tool provides costs in the following categories: total direct cost (including procedure, inpatient, and all other costs within 90 days of surgery), operative costs (facility utilization, supplies, and implants), inpatient costs (nonoperative facility utilization and supply costs), laboratory costs, pharmacy costs, imaging costs, and other costs. Within our analysis, we described actual inpatient costs in favor of length of stay to provide a more granular assessment of cost specifically. We also divided costs sustained after discharge but before the end of the 90-day follow-up period into total cost, facility utilization costs, supply costs, laboratory costs, pharmacy costs, imaging costs, and other costs.

Because actual implant costs were the result of confidential contractual negotiations, actual dollar amounts could not be published nor could the brand names be published adjacent to their relative costs. We adjusted all costs to 2017 US dollars using the Personal Consumption Expenditures price index for health care services.

Statistical analysis

We summarized descriptive statistics of baseline patient characteristics, operative characteristics, and costs. We conducted a series of multivariable analyses to determine those factors associated with total cost, operative cost, and inpatient costs. Although we initially planned a similar model for 90-day follow-up costs, these costs accounted for so little of the total that we did not perform this analysis. To account for a skewed distribution of the cost data, we employed a generalized linear model with the specified link and variance function based on each cost distribution using the modified Park test. Predictors included in each analysis were Elixhauser score, age, gender, ASA score, body mass index (BMI) category as defined using the World Health Organization system, operative side, whether the patient had a prior ipsilateral shoulder arthroplasty or prior ipsilateral shoulder surgery, operative procedure, preoperative diagnosis, whether there were any intraoperative complications, whether any bone grafting was performed, whether the humeral component was cemented, whether the patient received a regional anesthetic blockade, the brand of implant, and the length of the stem as divided into less than 130 mm, 130 mm, and more than 130 mm. Because of confidentiality of the cost data, we presented the effect of each covariate on the predicted cost in percent changes, instead of the marginal effect. We selected a multivariable analysis over subanalyses within arthroplasty type (ie, TSA vs. RTSA) to best tease out the combined effects of both preoperative diagnosis and arthroplasty type.

Source of funding

We did not use any external funding source for this study.

Results

Study group

We included a total of 361 of the 362 cases. The included patients had the mean $\pm$ standard deviation age of 68 ± 11 years and the Elixhauser score of 6 ± 6.6. In the group, 56% were female, 75% had BMI > 30, and 58% had surgery on the right side. When we examined individual comorbidities, 13% had cardiac comorbidities, 16% had diabetes, 3% had renal failure, 1% had liver failure, and 19% had obstructive sleep apnea. A total of 19% were revision arthroplasty procedures and 60% were revision procedures. Of arthroplasty type, 3% were hemiarthroplasties, 32% were TSAs, and 66% were RTSAs. For indications, 32% were performed for glenohumeral osteoarthritis, 40% for rotator cuff pathology, 19% for a prior failed arthroplasty, and 9% for other indications. Of the 9% (34 patients) with other indications, 3 had avascular necrosis, 2 had inflammatory arthropathy, 19 had acute proximal humeral fractures, and 12 had the sequelae of a proximal humerus fracture. Intraoperatively, 11% of patients had concomitant bone grafting, 90% had a cemented humeral component, 86% had a concomitant regional nerve blockade, 65% of patients had a Tornier prosthesis whereas 32% of patients received a Zimmer prosthesis, and 52% of humeral components were less than 130 mm in length whereas 42% were 130 mm in length and 6% were greater than 130 mm in length (Table I).

Total cost

Of total cost (ie, procedure, inpatient, and 90-day follow-up costs), 70% was operative costs, 24% was inpatient costs, and 6% was 90-day follow-up costs. On multivariable analysis, factors associated with increased total cost included younger age (0.4% decrease per year; $P = .002$) and an indication for surgery that was not osteoarthritis, a failed arthroplasty, or the sequelae of a rotator cuff tear, compared with glenohumeral osteoarthritis (16% increase; $P = .030$, Table II).

Operative costs

Among operative costs, 18% were facility utilization costs and 82% were supply use costs. When analyzing just operative costs, factors associated with increased cost included younger age (0.3% decrease per year, $P = .004$), use of a reverse shoulder arthroplasty compared with the use of total shoulder arthroplasty (21% increase, $P < .001$), an indication for surgery because of rotator cuff pathology (8% increase, $P = .032$) or an indication for surgery that was not osteoarthritis, a failed arthroplasty, or the sequelae of a rotator cuff tear (10% increase, $P = .013$) compared with glenohumeral osteoarthritis, use of a bone graft (14%

Table I Demographics

Variable	N	Percentage
Female sex	202	56
ASA 2	192	53
ASA 3	148	41
ASA 4	8	2
BMI overweight	126	35
BMI obese	145	40
Cardiac comorbidities	47	13
Diabetes	57	16
OSA	67	19
Right side	153	42
Prior shoulder arthroplasty	70	19
Prior surgery	216	60
TSA	115	32
RTSA	237	66
GHOA	116	32
RCT	143	40
Failed arthroplasty	34	9
Intraoperative complication	3	1
Bone graft	39	11
Cemented humerus	326	90
Regional block	244	68
Implant brand A	236	65
Implant brand B	117	32
Stem length >130 mm	21	6

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *OSA*, obstructive sleep apnea; *TSA*, total shoulder arthroplasty; *RTSA*, reverse total shoulder arthroplasty; *GHOA*, glenohumeral osteoarthritis; *RCT*, rotator cuff tear arthropathy and glenohumeral osteoarthritis in the setting of a rotator cuff tear.

increase, P = .001), implant brand B (6% decrease, P = .044), or implant brands other than A or B (30% decrease, P = .023) compared with implant brand A (Table III).

Inpatient costs

Among inpatient costs other than those associated with the procedure, 63% were facility utilization costs, 18% were pharmacy costs, 7% were laboratory costs, 4% were supply costs, 2% were imaging costs, and 7% were other costs. When analyzing just the inpatient costs not associated with the procedure, significant factors associated with increased cost included the ASA score of 4, compared with the ASA score of 1 (61% increase, P = .001); whether there were any intraoperative complications (32% increase, P = .038); operative indications of rotator cuff pathology (29% increase, P = .25) or other (47% increase, P = .006), compared with glenohumeral osteoarthritis (Table IV).

Discussion

As shoulder arthroplasty is performed with increased frequency,[14] the associated total cost[5] of shoulder arthroplasty to society will increase. We thus conducted this cost analysis to identify factors associated with variation in direct total costs, operative costs, and inpatient costs for shoulder arthroplasty. In our study, 70% of the cost associated with shoulder arthroplasty was incurred in the operating room. Nonmodifiable factors associated with increased cost included younger age, an ASA score of 4, intraoperative complications, and disease processes other than osteoarthritis, a failed arthroplasty, or the sequelae of a rotator cuff tear. Nonmodifiable factors, including age and disease process, should be accounted for in future cost analyses and in future bundled-payment programs. Modifiable factors associated with increased costs included RTSA use as compared with TSA use, the use of a bone graft, and the brand of implant used. Surgeons should evaluate potentially modifiable factors, such as bone graft use, implant type, and implant brand, to evaluate whether these factors warrant the additional cost.

In our analysis, most of the cost associated with shoulder arthroplasty was incurred in the operating room. Factors associated with increased total cost included younger age and less common indications for surgery such as proximal humerus fractures and their sequelae. These results suggest that future cost-reduction efforts should focus on the operating room, as even the most austere cost reduction programs outside of the operating room would leave 70% of costs unaddressed. In addition, these results suggest that procedures performed for nonroutine indications may be good targets for cost-reduction efforts. It is unclear why younger age was associated with higher cost, although we suspect that younger patients may be more likely to have more advanced pathologies to warrant an arthroplasty, which would then require longer operative times. Prior cost analyses have suggested that costs can be reduced through a bundled-payment approach[16] and by transitioning shoulder arthroplasty to an ambulatory procedure.[2] With rising overall health care costs and the increasing incidence of shoulder arthroplasty, analyses to determine the most significant sources of costs will be imperative to address cost reduction without impacting patient care.

Several of the cost correlates we identified in our study are nonmodifiable or only partially modifiable, including younger age, indications for surgery other than glenohumeral osteoarthritis, and an ASA score of 4 as compared with 1. Prior studies have shown increased patient comorbidities to be associated with increased hospital charges.[5,22] BMI has also been associated with increased cost in prior analyses.[8,18] Although it is unclear why BMI was not associated with cost in this analysis, differences in variances of BMI within the underlying sample set and inability to account for concomitant confounders may explain the differences in findings.

Although surgeons must accept nonmodifiable factors associated with cost, several of the cost correlates identified in our study are modifiable, including the use of an RTSA, use of a bone graft, and specific implant brands. Several

Table II Significant factors associated with total costs in an analysis including Elixhauser score, age, gender, ASA scores body mass index, laterality, whether there was a prior shoulder arthroplasty, whether there was a prior surgery, procedure, preoperative diagnosis, whether there were any intraoperative complications, whether a bone graft was used, whether the humeral component was cemented, whether a regional block was used, implant brand, and humeral stem length

Variable	Percentage change [95% CI]	*P* value
Age, yr	−0.4% [−0.7% to −0.2%]	.002
ASA 4 (reference: ASA 1)	16% [−0% to 35%]	.051
Diagnosis other than GHOA, RCT, failed arthroplasty (reference: GHOA)	16% [1% to 33%]	.030

ASA, American Society of Anesthesiologists; *CI*, confidence interval; *GHOA*, glenohumeral osteoarthritis; *RCT*, rotator cuff tear.

Table III Significant factors associated with operative costs in an analysis including Elixhauser score, age, gender, ASA scores body mass index, laterality, whether there was a prior shoulder arthroplasty, whether there was a prior surgery, procedure, preoperative diagnosis, whether there were any intraoperative complications, whether a bone graft was used, whether the humeral component was cemented, whether a regional block was used, implant brand, and humeral stem length

Variable	Percentage change [95% CI]	*P* value
Age, yr	−0.3% [−0.5% to −0.1%]	.004
RTSA	21% [11% to 31%]	.000
Diagnosis of sequelae of RCT	8% [1% to 17%]	.032
Diagnosis other than GHOA, RCT, failed arthroplasty (reference: GHOA)	10% [2% to 19%]	.013
Bone graft use	14% [6% to 22%]	.001
Implant brand B (reference: implant brand A)	−6% [−11% to 0%]	.044
Implant brands other than A and B (reference: implant brand A)	−30% [−48% to −5%]	.023

ASA, American Society of Anesthesiologists; *CI*, confidence interval; *RTSA*, reverse total shoulder arthroplasty; *GHOA*, glenohumeral osteoarthritis; *RCT*, rotator cuff tear.

Table IV Significant factors associated with inpatient costs excluding operative costs in an analysis including Elixhauser score, age, gender, ASA scores body mass index, laterality, whether there was a prior shoulder arthroplasty, whether there was a prior surgery, procedure, preoperative diagnosis, whether there were any intraoperative complications, whether a bone graft was used, whether the humeral component was cemented, whether a regional block was used, implant brand, and humeral stem length

Variable	Percentage change [95% CI]	*P* value
ASA 4	61% [20% to 116%]	.001
Diagnosis of RCT	29% [3% to 60%]	.025
Diagnosis other than GHOA, RCT, failed arthroplasty	47% [12% to 94%]	.006
Intraoperative complication	32% [2% to 73%]	.038

ASA, American Society of Anesthesiologists; *CI*, confidence interval; *RCT*, rotator cuff tear arthropathy and glenohumeral osteoarthritis in the setting of a rotator cuff tear; *GHOA*, glenohumeral osteoarthritis.

prior analyses have demonstrated RTSA to have higher direct costs[29] and hospital charges.[19] As RTSA becomes increasingly more prevalent,[28] implant costs may decrease. However, the RTSA itself has more components than a TSA (screws, baseplate, etc.) and thus may be costlier anyway, despite downward pressure on price. Because of the dramatic increase in RTSA procedures, methods to mitigate the increased cost associated with the implant should be considered, as the combination of increased incidence and increased cost per procedure may lead to an overall exponential increase in national costs. Certainly, prior studies have demonstrated that RTSA is ‘‘worth’’ the cost because of the quality of life improvements associated with the procedure; however, surgeons must weigh these benefits against relatively increased procedural costs.[21,31] Specifically, in cases where an anatomic arthroplasty may be considered as an equivalent option to a reverse shoulder arthroplasty (eg, mild-to-moderate B2 glenoid in an elderly patient), the choice of an anatomic arthroplasty may be a method of reducing initial costs, although certainly longer term analyses will be needed as early revision could negate initial cost savings. Regarding variations in costs based on brand, these data emphasize the importance of negotiations between hospitals and companies and how variable pricing can have a direct influence on final costs. Focus should be placed on negotiating the lowest possible implant costs as they significantly influence operative costs. Certainly, these decisions must be made in the context of those features available, desirable, and necessary within the implants of each brand. These decisions will be different between surgeons, and thus we did not analyze them on a case-by-case basis here as such analysis would not be generalizable. Within our study, the 2 implant brands commonly used (Zimmer and Tornier) offer a range of implant types and stem lengths and both have been used interchangeably in common clinical situations by the 2 senior authors. Finally, the benefits of bone grafting will also have been weighed against the increased costs.[2] Glenoid and humeral bone grafts typically occur in more severe deformities that if left uncorrected or partially corrected could lead to implant failure and early complications. In less severe deformities, partial correction may be a method to reduce cost and needs to be evaluated and compared with bone-grafted cases to determine the impact on outcomes. Many implant companies now have augmented implants that may also be a cost saving method of dealing with moderate glenoid or severe humeral defects although increases in implant costs may outweigh any possible benefits derived from eliminating a graft.

Our study has several limitations. This is a single-center, retrospective, nonrandomized study with short-term follow-up. We did not perform TSA and RTSA for the same indications. Because this was a retrospective chart review, our analysis was limited by the accuracy and completeness of information documented within the chart. Although multivariate analysis partially mitigates this issue, likely there were unmeasured residual confounding factors. Because this is a single-center and single-surgeon analysis, our results may not be generalizable to other centers and other surgeons. Our cost analysis does not capture preoperative costs, costs beyond 90 days from surgery, and costs incurred within other systems. Certainly, this is not a comprehensive analysis because it does not consider other factors such as return to work, outside physical therapy visits, and patient travel. Our analysis does not include patient outcome scores, and thus this is solely a cost analysis and not a cost-effectiveness analysis. In addition, from a personnel perspective, cost reductions may only be seen in efficiencies that can eliminate an entire full-time employee, and thus changes made based on the factors identified here may not affect costs. Finally, because our cost tool estimates facility use based on times, shared costs are estimates.

Conclusion

Most short-term (90-day) costs with shoulder arthroplasty are operative costs. Nonmodifiable factors associated with increased cost included younger age, patient disease, and severe medical comorbidities, whereas potentially modifiable factors included the type and brand of implant used as well as the use of a bone grafts.

Acknowledgment

The work for this manuscript was performed at the University of Utah in Salt Lake City, UT.

Disclaimer

Robert Z. Tashjian reports that he is a paid consultant for Zimmer/Biomet, Wright Medical, and Mitek; has stocks in Conextions, INTRAFUSE, Genesis, and KATOR; receives intellectual property royalties from Wright Medical, Shoulder Innovations, and Zimmer/Biomet; receives publishing royalties from JBJS, Springer, and the *Journal of the American Academy of Orthopaedic Surgeons*, and serves on the editorial board for the *Journal of Orthopaedic Trauma*, the *Journal of the American Association of Orthopedic Surgeons*, and the *Journal of Shoulder and Elbow Arthroplasty*. 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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