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Cost analysis and complication profile of primary shoulder arthroplasty at a high-volume institution

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Background: Paralleling the increased utilization of shoulder arthroplasty, bundled-payment reimbursement is becoming increasingly common. An understanding of the costs of each element of care and detailed information on the frequency of and reasons for readmission and reoperation are keys to developing bundled-payment initiatives. The purpose of this study was to perform a comprehensive analysis of complications, readmission rates, and costs of primary shoulder arthroplasty at a high-volume institution.
Methods: Between 2012 and 2016, 2 shoulder surgeons from a single institution performed 1794 consecutive primary shoulder arthroplasties: 636 anatomic total shoulder arthroplasties (TSAs), 1081 reverse shoulder arthroplasties (RSAs), and 77 hemiarthroplasties. A cost analysis was designed to include a period of 60 days preoperatively, the index surgical hospitalization, and 90 days postoperatively, including costs of any readmission or reoperation.
Results: The 90-day complication, reoperation, and readmission rates were 2.3%, 0.6%, and 1.8%, respectively. The 90-day readmission risk was higher among patients with an American Society of Anesthesiologists score of 3 or greater; a 1-unit increase in the American Society of Anesthesiologists score was associated with a $429 increase in index cost. Of the hospital readmissions, 10 were directly related to the index arthroplasty whereas 21 were not. The median standardized costs were as follows: preoperative evaluation, $481; index surgical hospitalization, $15,758; and postoperative care, $183. The median standardized costs for index surgical hospitalization were different for each procedure: TSA, $14,010; RSA, $16,741; and hemiarthroplasty, $12,709.
Conclusion: In this study, primary shoulder arthroplasty was associated with low 90-day reoperation and complication rates. The median standardized costs inclusive of preoperative workup and 90-day postoperative recovery were $14,675 and $17,407 for TSA and RSA, respectively.
Level of evidence: Level IV; Economic Analysis

Keywords: Cost; bundled payment; shoulder arthroplasty; replacement; osteoarthritis; readmission; complication

National trends have witnessed a substantial increase in shoulder arthroplasty in the United States over the past 2 decades. Previous studies have shown an overall increase in the number of total shoulder arthroplasties (TSAs) performed in the United States between 2002 and 2011.[6,9,21] Owing to our aging population, recent literature has projected that shoulder arthroplasty will increase by 755% in patients older than 55 years by 2030.[14] The introduction as

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well as widespread use of reverse shoulder arthroplasty (RSA) has played a major role in the acceleration in the number of shoulder arthroplasties, with roughly 10,000 RSAs performed in the United States in 2007, a 5-fold increase over 2004.[7] The economic burden associated with the increasing volume of shoulder arthroplasty is becoming a focus for health care systems in an attempt to better understand costs and to develop value-based reimbursement models.

Paralleling the increased utilization of shoulder arthroplasty, bundled-payment reimbursement initiatives are becoming more popular in this particular field. The bundled-payment initiative was formally introduced in 2010 with Accountable Care Organizations under the Medicare Shared Savings Program as part of the Patient Protection and Affordable Care Act.[15] The Centers for Medicare & Medicaid Services aimed to link payments for multiple provider services within a single episode of care and formulate a single bundled fee to be paid out to a single facility and subsequently divvied out to individual providers or entities.[17,18] The premise is that health care delivery efficiency and cost containment for the Centers for Medicare & Medicaid Services will be driven by the health care team when the single entity is provided a single lump reimbursement with which to deliver health care services. Hospitals and providers would be incentivized by responsible resource allocation and the provision of cost-effective services to patients.[17,18] Although not yet widely implemented in shoulder arthroplasty, the bundled-payment initiative in knee and hip arthroplasty creates the need for a similar value analysis in shoulder arthroplasty, which will certainly become an area of further interest from government and private payers.

A central component of risk-based reimbursement is a clear understanding of the costs of each element of care as well as detailed information on the frequency of, reasons for, and costs of readmission and reoperation. Two recently published meta-analyses investigated early readmission within 90 days of the index shoulder procedure: Mahoney et al[11] reported 90-day readmission rates of 4.5%, 8.8%, and 6.6% for anatomic TSA, hemiarthroplasty (HA), and RSA, respectively, with surgical-site infection being the leading surgical cause. Schairer et al[16] reviewed a large series of arthroplasties and reported similar rates of 6%, 8.2%, and 11.2% for TSA, HA, and RSA, respectively, with surgical-site infection and dislocation being the leading causes of surgical readmission but accounting for only 18% of readmissions because 82% of readmissions were related to medical comorbidities.

The economic impact of providing cost-efficient and sustainable care for patients has become a major focus for health care systems, warranting thorough investigative efforts. A review of the literature reveals that high-quality information in these areas is lacking. Virani et al[17,18] published preliminary work evaluating early experiences with a limited number of TSA and RSA patients and costs followed prospectively, but there is a paucity of further quality economic analysis of shoulder arthroplasty. Kuye et al[10] recently published a report reviewing current literature performing an economic evaluation of shoulder pathologies; this study suggested a recent significant increase in the interest around economic feasibility studies in the shoulder arena, but there is a clear demand for more rigorous economic evaluation. More recently, Menendez et al[13] have applied a time-driven cost-analysis methodology to shoulder arthroplasty.

Therefore, the purpose of this study was to perform a 5-year comprehensive and detailed analysis of 90-day complications, readmission rates, and costs of primary shoulder arthroplasty at a high-volume institution. We recognize that the nuances of the institution and the preoperative and postoperative protocols examined here will not serve as a standard for all facilities; accordingly, we recommend that this research not be used as a benchmark for the legislature. Instead, we detail the predictors of increased cost during the perioperative period from a high-volume center with very experienced surgeons, which should be viewed as a goal for other centers and should not serve as a benchmark for policy makers.

Materials and methods

Our institutional joint registry database was used to identify all primary TSAs performed by 2 fellowship-trained orthopedic surgeons between 2012 and 2016 at a single institution. A total of 1904 consecutive primary shoulder arthroplasties had been performed during the study period. To avoid confusion between preoperative and postoperative services for patients receiving arthroplasties on both shoulders within a short period, the second case of every pair (n = 103) performed within 1 year was removed from analysis. We excluded 7 additional shoulders from the study because of confounding factors that might artificially increase the cost of conventional arthroplasty such as malignancy or concomitant procedures performed in the same setting as shoulder arthroplasty. After also excluding patients who refused to sign Minnesota Research Authorization forms, we analyzed a final sample of 1794 consecutive primary TSA cases corresponding to 1707 patients: 636 TSAs, 1081 RSAs, and 77 HAs. Patient demographic characteristics are detailed in Table I.

A standardized cost analysis for this study was designed to include a period of 60 days preoperatively, the index surgical hospitalization, and 90 days postoperatively. The period of 60 days prior to surgery was selected because the 2 surgeons participating in this study routinely provide a consultation, refer patients for medical clearance for anesthesia and surgery, and obtain new radiographs and a computed tomography scan of the shoulder to be replaced all within the 2 months preceding surgery. All index surgical hospitalization services from admission through discharge were included in the analysis. Types of index services were categorized by uniform billing revenue codes; Current Procedural Terminology, fourth edition (CPT4), procedure codes; and

Table I Primary shoulder arthroplasty: patient demographic characteristics

	Data
Total, N	1794
Sex, n (%)	
Female	918 (51.2)
Male	876 (48.8)
Laterality, n (%)	
Left	829 (46.2)
Right	965 (53.8)
Year of surgery, n (%)	
2012	347 (19.3)
2013	357 (19.9)
2014	341 (19.0)
2015	375 (20.9)
2016	374 (20.8)
Age at surgery	
n	1794
Mean (SD), yr	69.1 (11.1)
Median, yr	70
Q1, Q3, yr	63.0, 77.0
Range, yr	17.0-94.0
BMI	
n	1790
Mean (SD)	31.0 (6.8)
Median	30.2
Q1, Q3	26.1, 34.6
Range	16.0-66.4
BMI category, n (%)	
<30	869 (48.5)
≥30	921 (51.5)
Surgeon, n (%)	
Surgeon 1	1183 (65.9)
Surgeon 2	611 (34.1)

SD, standard deviation; *Q1*, first quartile; *Q3*, third quartile; *BMI*, body mass index.

internal charge master codes. The diagnosis and CPT4 procedure codes for all services during the preoperative and postoperative periods were examined to determine whether they were related to the arthroplasties.

As mentioned earlier, the most frequently provided preoperative period services included preoperative medical evaluation and testing, orthopedic consultation, standard shoulder radiographs, and computed tomography with 3-dimensional reconstruction for surgical planning. The specific services are displayed by CPT4 code in Table II. In addition, over 40% of the patients received an echocardiogram or some other form of cardiovascular testing.

The 90-day postoperative period typically entailed 1 or 2 follow-up evaluations in the clinic, a single 3-view shoulder radiograph session, and physical therapy (PT). Because a substantial portion of the patients included in this study needed to travel more than 6 hours to return for a follow-up evaluation, many patients chose not to return at all but rather sought follow-up care by a local provider or were followed up through telemedicine (electronic review of radiographs and communication through phone calls or e-mails). Any concerns regarding complications or patient questions were addressed directly with the surgical team and documented in the electronic medical record. Standardized costs reported in this study only included services provided by our health system; no modeling was performed to capture the cost of missing services.

Inpatient services and emergency department encounters were further subjected to detailed review of the electronic medical record by us. Some of the complications identified after shoulder arthroplasty occurred before discharge from the index surgical hospitalization; they are therefore included in index, rather than postoperative, costs.

Standardized cost methodology

Standardized costs were obtained from our institutional cost data warehouse, which uses widely accepted health service research methodology. Medicare reimbursement was assigned to all professional billed services, the appropriate Medicare Cost Report cost-to-charge ratios were multiplied by the charges for all hospital billed services, and all resulting costs were adjusted to 2016 dollars with the gross domestic product implicit price deflator.[19]

Ninety-day complications, readmissions, and statistical analysis

Complications and readmissions were analyzed as time-to-event outcomes using survivorship methodology. Specifically, rates were calculated using the Kaplan-Meier method and are reported with 95% confidence intervals. The associations between these outcomes and sex, body mass index, and American Society of Anesthesiologists (ASA) score were evaluated using Cox proportional hazards regression. Although a broad set of descriptive statistics for cost variables including median, mean, and standard deviation are provided, given that health care cost data are generally skewed, the median cost will be emphasized. To adjust for potential confounders, we also conducted a generalized linear modeling regression with gamma distribution for cost and logarithmic link, which was then used to assess the average marginal effect of different predictors on the average index costs. All statistical tests were 2-sided, and $P < .05$ was considered statistically significant.

Results

The median age (interquartile range [IQR]) at the time of primary shoulder arthroplasty cases for the 1707 patients (1794 arthroplasties) included in the study was 70 years (IQR, 63-77 years). Fewer than one-third of the cases (30.5%) corresponded to local patients residing in the surrounding counties at the time of surgery, and even many of the local patients received some care outside our hospital system. Only 12 of 1794 cases (0.67%) were missing preoperative workup costs, whereas 289 of 1794 (16.1%) had no 90-day postoperative costs captured.

The 90-day complication, reoperation, and readmission rates were 2.3%, 0.6%, and 1.8%, respectively. Of the hospital readmissions within 90 days, 68% were not related

Table II Most frequent preoperative services

CPT4 code	Description	% of 1787 cases with preoperative services with these CPT4 codes
73030	Radiologic examination, shoulder; complete, minimum of 2 views	55.7
73200	Computed tomography, upper extremity; without contrast material	73.3
76377	3D rendering with interpretation and reporting of computed tomography, magnetic resonance imaging, ultrasound, or other tomographic modality with image postprocessing under concurrent supervision; requiring image postprocessing on an independent workstation	68.7
36415	Collection of venous blood by venipuncture	78.3
86900	Blood typing, serologic; ABO	74.1
86850	Antibody screen, RBC, each serum technique	71.5
82565	Creatinine; blood	60.6
85025	Blood count; complete (CBC), automated (Hgb, Hct, RBC, WBC, and platelet count) and automated differential WBC count	46.4
93000	Electrocardiogram, routine ECG with ≥12 leads; with interpretation and report; 725 patients (40.6%) had some type of cardiac screening, of which 97.4% were in a clinic setting	39.4
99214	Office or other outpatient visit for the evaluation and management of an established patient, which requires ≥2 of these 3 key components: a detailed history, a detailed examination, and medical decision making of moderate complexity; counseling and/or coordination of care with other physicians, other qualified health care professionals, or agencies is provided consistent with the nature of the problem(s) and the patient's and/or family's needs; usually, the presenting problem is of moderate to high severity; typically, 25 min is spent face-to-face with the patient and/or family. (This is the most frequent E&M code.)	32.6

CPT4, Current Procedural Terminology, fourth edition; *3D*, three-Dimensional; *RBC*, red blood corpuscles; *CBC*, complete blood count; *Hgb*, hemoglobin; *Hct*, hematocrit; *WBC*, white blood corpuscles; *ECG*, electrocardiogram; *E&M*, evaluation and management.

to implant failure or surgical-site complications but rather were related to other reasons (cardiopulmonary events, accidental falls, metabolic disturbances, and so on).

The median standardized costs for our cohort were as follows: preoperative evaluation, $481; index surgical hospitalization, $15,758; and postoperative care, $183 (Table III). Preoperative and postoperative costs did not vary significantly based on the type of arthroplasty performed. However, the index surgical hospitalization median standardized costs were affected by the procedure type: TSA, $14,010; RSA, $16,741; and HA, $12,709 (Table IV).

All but 7 shoulders received some form of PT during the index surgical hospitalization and/or postoperative period. The average protocol comprised 1 PT evaluation plus 4 PT treatment sessions, as in our practice most of the therapy is initially taught to the patient and then performed at home by the patient without formal visits with a physical therapist. The median standardized cost of PT was $422 (IQR, $330-$537), with a median percentage of total cost taking place during the index stay of 68.9%.

The highest standardized cost for the index hospitalization was related to the cost of the implant (mean, 25.2%), followed by the operating room facility (24.6%), surgeon (12.6%), and hospital room (12.0%) costs (Table V). Implant cost varied by type of surgery, with the RSA procedure implant being the most expensive (Table VI). On average, the RSA implant also comprised a higher percentage of the total index hospitalization cost, at 28.1% (vs. 21.8% for TSA and 19.2% for HA).

Hospital room cost and length of stay were driven by discharge disposition. The median and mean lengths of stay for the 88.8% of patients discharged home were 1 and 1.2 days, respectively, whereas patients who were not discharged home remained in the hospital for a median of 3 days and mean of 3.3 days.

In the 90-day postoperative period, there were a total of 40 complications, 10 reoperations, and 37 readmissions in 31 patients. The 90-day event rates for complications, reoperations, and readmissions were 2.34%, 0.63%, and 1.82%, respectively (Table VII). These resulted in a very low mean readmission cost of $244 (median, $0). When we considered only those shoulders that had an associated readmission, the median readmission standardized cost per case was $11,031 (IQR, $5948-$16,741). These readmission costs averaged 81% of their index costs, ranging from 20.5% to 247%.

There was no significant difference in complication, reoperation, or readmission rates regarding sex or body mass index (≥30 vs. <30). The risk of readmission within 90 days was higher among patients with an ASA score of 3 or higher than in patients with an ASA score of 2 or less (hazard ratio, 2.1; 95% confidence interval, 1.1-4.3; $P = .03$). Of the

Table III Combined cost analysis for primary shoulder arthroplasty

Procedure	Variable	n	Standardized cost, US $						
			Minimum	Lower quartile	Median	Upper quartile	Maximum	Mean	SD
HA, TSA, and RSA	60 d preoperatively	1782	13	370	481	602	26,057	635	1490
	Index surgical	1794	10,408	14,205	15,758	17,243	81,079	16,198	3386
	90-d postoperatively	1505	21	176	189	232	46,800	531	2523

SD, standard deviation; *HA*, hemiarthroplasty; *TSA*, total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasties.

Table IV Cost analysis for primary shoulder arthroplasty by procedure

Procedure	Variable	n	Standardized cost, US $						
			Minimum	Lower quartile	Median	Upper quartile	Maximum	Mean	SD
HA	60 d preoperatively	77	104	396	467	553	13,270	661	1476
	Index surgical	77	10,408	12,138	12,709	13,042	22,896	13,239	2312
	90 d postoperatively	56	30	157	189	227	46,800	1031	6228
RSA	60 d preoperatively	1071	13	382	486	607	26,057	684	1760
	Index surgical	1081	13,168	15,664	16,741	18,236	81,079	17,407	3524
	90 d postoperatively	903	29	176	189	238	37,007	538	2280
TSA	60 d preoperatively	633	21	349	482	589	18,011	550	859
	Index surgical	636	11,451	13,350	14,010	14,888	30,592	14,501	2042
	90 d postoperatively	546	21	179	189	226	36,325	471	2241

SD, standard deviation; *HA*, hemiarthroplasty; *RSA*, reverse shoulder arthroplasties; *TSA*, total shoulder arthroplasty.

Table V Costs of index hospitalization

Service	Mean % of index cost
Implant	25.2
Operating room	24.6
Surgeon	12.6
Hospital room	12.0
Supplies	6.7
Pharmacy	4.5
Recovery	4.3
Anesthesia	4.3
Other	5.8

hospital readmissions within 90 days, 10 (32%) were related to the shoulder arthroplasty whereas 21 (68%) were not directly related to the procedure or prosthesis. Shoulder- and implant-related causes of readmission included dislocation (n = 4), periprosthetic joint infection (n = 2), hematoma (n = 2), periprosthetic fracture requiring reoperation (n = 1), and implant loosening (n = 1). Non–shoulder-related entities such as pneumonia, urinary tract infection, cerebrovascular accident, cardiopulmonary compromise, and metabolic imbalance accounted for 21 other readmissions.

Using generalized linear modeling of index cost, we found ASA score, age at surgery, surgical type, and discharge status to be statistically significant. Specifically, the marginal effect of the ASA score was $429, implying that a 1-unit increase in the ASA score was associated with a $429 increase in index cost. Similarly, the marginal effect of age at index surgery was –$16, indicating a decrease of $16 in index cost with an increase in the patient's age by an additional year. Compared with HA, RSA and TSA were associated with $4230 and $1501 higher index costs, respectively. Patients who were discharged home rather than a skilled nursing facility had on average a $3647 lower index cost (Table VIII).

Discussion

By the year 2030, the demand for shoulder arthroplasties is projected to increase by 333.3% for patients 55 years or younger and by 755.4% for patients older than 55 years.[14] Increasing demand coupled with rising health care costs carries substantial planning implications for both the health care system at large and the medical education community in addressing the need for qualified shoulder specialists to meet this demand. Moreover, as cost containment and bundled payments become an increasingly common focus for health care systems, payers, and surgeons, the key to sound decision making is quality health care economics research. Previous studies by Gartsman et al[8] and Virani et al[17,18] have provided clear evidence of the positive impact of shoulder arthroplasty on pain reduction and functionality improvement. The goal remains to provide

Table VI Shoulder implant costs

Procedure	Observations, n	Variable	Minimum, $	Lower quartile, $	Median, $	Upper quartile, $	Maximum, $	Mean, $	SD, $
HA	77	Implant	581	2220	2492	2844	3143	2484	417
Reverse	1081	Implant	2340	4179	4565	5163	11,918	4796	964
TSA	636	Implant	1158	2859	2940	3527	5276	3090	429

SD, standard deviation; *HA*, hemiarthroplasty; *TSA*, total shoulder arthroplasty.

Table VII Complications and reoperations

Variable	Level	n	Events	90-d rate (95% CI)	HR (95% CI)	*P* value
90-d complication rate including reoperations						
Overall	Overall	1794	40	2.3% (1.6, 3.1)	NA	NA
Sex	F	918	21	2.4% (1.4, 3.4)	1.1 (0.6, 2.0)	.856
	M	876	19	2.3% (1.2, 3.3)	1.0 (ref)	
BMI	<30	869	24	2.9% (1.8, 4.1)	1.0 (ref)	
	≥30	921	16	1.8% (0.9, 2.7)	0.6 (0.3, 1.2)	.135
ASA score	1 or 2	1131	22	2.1% (1.2, 2.9)	1.0 (ref)	
	3, 4, or 5	649	18	2.9% (1.6, 4.2)	1.4 (0.8, 2.7)	.245
Age	Per 10 yr	1794	40		0.8 (0.6, 1.1)	.212
90-d reoperation rate						
Overall	Overall	1794	10	0.6% (0.2, 1.0)	NA	NA
Sex	F	918	3	0.4% (0.0, 0.8)	1.0 (ref)	
	M	876	7	0.9% (0.2, 1.5)	2.4 (0.6, 9.4)	.196
BMI	<30	869	6	0.8% (0.2, 1.4)	1.0 (ref)	
	≥30	921	4	0.5% (0.0, 0.9)	0.6 (0.2, 2.1)	.437
ASA score	1 or 2	1131	4	0.4% (0.0, 0.8)	1.0 (ref)	
	3, 4, or 5	649	6	1.0% (0.2, 1.8)	2.7 (0.8, 9.4)	.122
Age	Per 10 yr	1794	10		0.7 (0.5, 1.1)	.111
90-d complication rate excluding reoperations						
Overall	Overall	1794	30	1.7% (1.1, 2.3)	NA	NA
Sex	F	918	18	2.0% (1.1, 3.0)	1.4 (0.7, 3.0)	
	M	876	12	1.4% (0.6, 2.2)	1.0 (ref)	.329
BMI	<30	869	18	2.2% (1.2, 3.1)	1.0 (ref)	
	≥30	921	12	1.3% (0.6, 2.1)	0.6 (0.3, 1.3)	.200
ASA score	1 or 2	1131	18	1.7% (0.9, 2.4)	1.0 (ref)	
	3, 4, or 5	649	12	1.9% (0.8, 3.0)	1.2 (0.6, 2.4)	.669
Age	Per 10 yr	1794	30		0.9 (0.6, 1.3)	.532
90-d readmission rate						
Overall	Overall	1794	31	1.8% (1.2, 2.5)	NA	NA
Sex	F	918	17	2.0% (1.0, 2.9)	1.2 (0.6, 2.4)	
	M	876	14	1.7% (0.8, 2.6)	1.0 (ref)	.663
BMI	<30	869	18	2.2% (1.2, 3.3)	1.0 (ref)	
	≥30	921	13	1.5% (0.7, 2.2)	0.7 (0.3, 1.4)	.263
ASA score	1 or 2	1131	14	1.3% (0.6, 2.0)	1.0 (ref)	
	3, 4, or 5	649	17	2.8% (1.5, 4.1)	2.1 (1.1, 4.3)	.034
Age	Per 10 yr	1794	31		1.0 (0.7, 1.4)	.997

CI, confidence interval; *HR*, hazard ratio; *F*, female; *M*, male; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *NA*, not applicable; *ref*, reference value.

value with a balanced interest in both high-quality patient care and fiscal accountability.

Our study observed low 90-day complication, reoperation, and readmission rates (2.3%, 0.6%, and 1.8%, respectively) when shoulder arthroplasty was performed by 1 of 2 high-volume shoulder surgeons with a standardized perioperative care plan. Although there is interest in performing outpatient shoulder arthroplasty in select patients, at this point this is not part of our practice. Our patients routinely stay in the hospital ward for 1 night, with the vast majority leaving on postoperative day 1 and 88% being discharged home or to a local hotel prior

Table VIII Marginal effects of various factors

	Marginal effects, $	*P* value	95% CI, $
ASA score	429.20	<.001	216.48 to 641.91
Age	16.61	.01	28.26 to 4.96
Surgery type			
Reverse vs. HA	4229.65	<.001	3603.91 to 4855.38
TSA vs. HA	1500.99	<.001	879.95 to 2122.03
Geographic area			
National vs. local	39.22	.79	243.87 to 322.30
Regional vs. local	3.05	.99	310.32 to 316.42
Discharge status (home vs. SNF)	3646.93	<.001	4027.39 to 3266.47

CI, confidence interval; *ASA*, American Society of Anesthesiologists; *HA*, hemiarthroplasty; *SNF*, skilled nursing facility.

to travel; 12% of our patients are discharged to a skilled nursing facility. Previous studies have reported 90-day readmission rates of 4.5% to 8.8% and 6% to 11.2%.[11,16] Schairer et al[16] reviewed 8180 shoulder arthroplasties and attributed 82% of readmissions to medical complications. Matsen et al[12] reported 90-day readmission rates of 2.5% for TSAs and 3.2% for HAs. Our readmission rate of 1.8% is slightly lower than the rates in the aforementioned studies; similarly to previous literature, 68% of 90-day readmissions in our study were attributed to medical complications. It is interesting to note that only 2 of 1794 cases in our study (0.11%) were readmitted for a periprosthetic infection within 90 days. Of note, delayed infection presentation, after 90 days, was not captured in this study.

Our 90-day complication rate of 2.3% is on par with, although at the low end of, previously reported ranges between 3% and 11%.[2,3,5,17,18,20] The majority of complications identified in this study were medically related and consistent with common reasons previously reported by other studies; the most frequent complications were respiratory, renal, and cardiac in nature.[1]

Current literature reflects an interest in cost analysis within orthopedics, but the methods have varied substantially in the calculation and reporting of cost. Chalmers et al[4] recently performed an analysis investigating the direct costs of shoulder arthroplasty, although their cohort was smaller and more heterogeneous. Preoperative and postoperative costs were also excluded in their study, as the primary focus was purely on the index procedure; similarly, readmissions and subsequent readmission cost impact were not analyzed in their study.[4] Virani et al[17,18] published similar analyses prospectively evaluating smaller cohorts of patients (N = 83 and N = 55) and following direct costs within their local health care system. In our study, costs that accrued in the hospital system were provided for each patient as direct allocated costs, which included the cost of materials, personnel, resource utilization, rent, and other necessary factors; costs that accrued outside the hospital system were defined for each patient by the year-specific regional Medicare reimbursement during the study period.[17]

Our study design produced a large cohort of patients and provides a combination of standardized costs, a previously validated cost analysis model used for hip and knee arthroplasty, and resource allocation as percentages of direct costs for the perioperative period to include 60 days preoperatively, index hospitalization, and 90 days postoperatively. With implant cost accounting for a quarter of the index hospitalization and with facility costs accounting for another quarter, half of the total cost of index hospitalization is captured by these 2 elements. Notably, the implant costs of RSA represented a higher proportion (28.1%) of index costs compared with TSA (21.8%) or HA (19.2%). Currently, reimbursement for TSA and RSA is identical under most payer systems owing to Current Procedural Terminology coding, despite the higher cost incurred when performing an RSA procedure; this represents an area that deserves future consideration.

Perioperative factors also had a large impact on costs for some of the patients included in this study. Discharge disposition carries a significant impact on the cost of care. Of our patients, 88% were discharged home, with a median hospital stay of 1 day, whereas the remaining 12% were discharged to a skilled nursing facility or rehabilitation facility after a median stay of 3 days. We believe this finding is likely partially attributed to the mandated 3-night inpatient rule for Medicare reimbursement for these step-down care facilities. Many of these patients would be able to leave earlier than the 3-night average if not for the reimbursement issue just mentioned. Similarly, postoperative readmissions significantly impacted cost and should continue to be an area of focus for providers to minimize. In our cohort, only 1.8% of patients required readmission within 90 days, but among the associated readmissions, the readmission costs averaged 81% of the index cost, with 1 instance reaching nearly 250% of the index cost. As bundled-payment discussions progress, the focus on minimizing readmissions will remain critical.

A number of limitations exist in our study, including its retrospective, single-center, nonrandomized nature. The efficiency and high-volume nature of the practice of the 2 senior authors is not generalizable to low-volume practices and hospitals. The senior authors perform 400-500 primary and complex revision shoulder arthroplasties annually with standardized perioperative protocols and almost 40 years of combined shoulder reconstruction experience. A significant number of patients in this practice—as a quaternary referral center—are first evaluated by an outside provider and referred for a single consultation visit prior to surgery. Similarly, many of our patients receive postoperative 90-day care by their referring provider or through telemedicine. Most of our patients are instructed on a home PT regimen during a single inpatient therapy session prior to dismissal on postoperative day 1. Similarly, many patients receive 4 outpatient PT sessions as instruction for a home therapy program as progressive motion and strengthening commence at 3-6 weeks postoperatively. The remainder of the postoperative therapy is home based. As such, the 90-day postoperative period typically entailed 1 clinic visit, a limited number of PT sessions, and a single 3-view shoulder radiograph session. This postoperative protocol with minimal formal PT likely serves as a change of practice for lower-volume centers and must be considered a limitation in broadly applying these metrics to all institutions. The shoulder surgeons in this study routinely see their arthroplasty patients at 1-2 visits within 90 days. Because a significant number of the patients in this cohort travel from more than 6 hours away, many patients chose not to return at all but rather sought follow-up care by a local provider. Patients have 1 set of radiographs obtained within 90 days; radiographs are often mailed to the primary surgeon and reviewed remotely for abnormalities. Local wound care and postoperative visits are often handled by a local provider rather than by the primary surgeon. Any concerns regarding complications or patient questions are addressed directly with the surgeon and team and documented in the electronic medical record. These practice nuances may lower preoperative and postoperative costs in this study.

Another limitation of our study, as with most cost studies, is an imperfect economic analysis tool; standardized costs are useful for understanding cost components but are not easily translated to a particular provider's or payer's costs. Certain preoperative and postoperative costs may not be captured by services incurred at other facilities; however, our large cohort and resource allocation metrics aim to offset these potential limitations. Moreover, despite standardized costs reported in this study, the direct medical costs reported in this study are not directly applicable to bundled-payment formulation by Accountable Care Organizations. With patients with ASA grade 3 or 4 having a statistically significantly higher rate of 90-day readmission in our study, payers should consider risk adjustment for these patients, which would cover not only a higher likelihood of complications but also the likely additional preoperative testing such as echocardiograms and other advanced studies. Medically complicated patients will continue to be best treated in the inpatient setting, whereas providers may elect to perform shoulder arthroplasty as an outpatient procedure in healthy patients at an ambulatory surgery center. The potential cost impact of increased risk in more unhealthy patients will need to be considered in future bundled-payment discussions.

Conclusion

In a health care system with standardized preoperative and postoperative protocols and high-volume shoulder surgeons, primary shoulder arthroplasty yielded low 90-day reoperation and readmission rates of 0.6% and 1.8%, respectively. The 90-day complication rate was 2.3%; the majority of these complications were attributable to medically related complications rather than shoulder-related complications. The median standardized costs for primary shoulder arthroplasty inclusive of the 60-day preoperative workup and 90-day postoperative recovery were $14,675 and $17,407 for TSA and RSA, respectively. This retrospective cost analysis and complication profile serve as preliminary information in achieving the overarching goal of decreasing the economic burden of this procedure while providing high-quality outcomes for patients. This study may further serve as a useful reference for surgeons as they consider shoulder arthroplasty bundled-payment models. A multicenter cost study using claims data is a logical next step in providing more generalizable economic metrics.

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