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CLINICAL RESEARCH

Surgeon Volume is Associated With Cost and Variation in Surgical Treatment of Proximal Humeral Fractures

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Abstract

Background   The issue of rising costs will likely dominate the healthcare debate in the forthcoming years.

Questions/Purposes   We assessed factors including surgeon volume that were associated with lower hospital costs and variations in surgical treatment for proximal humeral fractures.

Methods   We used national databases for 2001 to 2008 to extract information on 25,731 patients undergoing surgery for proximal humeral fractures. We calculated hospital cost by converting hospital charges based on the hospital accounting reports collected by the Centers for Medicare & Medicaid Services.

Results   In a multivariate linear regression analysis, higher surgeon volume, open reduction and internal fixation (versus hemiarthroplasty), and lower burden of comorbidities were associated with lower hospital cost. Higher surgeon volume was linearly associated with lower hospital costs such that, on average, adjusting for all other factors, a surgeon performing 20 shoulder arthroplasties per year saves a hospital approximately US $1800 per surgery. Factors associated with higher utilization of hemiarthroplasty included high surgeon volume (odds ratio [OR] = 1.46; 95% CI = 1.43, 1.97; as compared with low surgeon volume) and earlier years of our study period (OR = 0.61; 95% CI = 0.56, 0.66; for hemiarthroplasty in 2007–2008 versus 2001–2002).

Conclusions   Higher surgeon volume was associated with lower hospital costs for proximal humeral fractures. Therefore, policies on minimum volume requirements by hospitals may result in substantial cost savings. There is

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provider-based practice variation in the surgical treatment of proximal humeral fractures and evidence-based guidelines in this area are needed.

Level of Evidence Level III, economic analysis. See Instructions for Authors for a complete description of levels of evidence.

Introduction

The issue of rising healthcare costs will likely dominate the healthcare debate in the forthcoming years [34, 44]. It is possible that limited resources in the future may necessitate cost-cutting measures, as is already the case in several healthcare settings. Musculoskeletal care and orthopaedic procedures are major cost drivers for payers and hospitals [5]. Hospitals often operate at small margins. Therefore, an analysis of factors that determine higher hospital costs is valuable and may result in cost savings.

In the emerging value-based healthcare environment, data on comparative effectiveness of surgical procedures will become increasingly salient for reimbursement purposes [13, 20, 29, 35, 43]. This was highlighted in the 2009 Institute of Medicine report [21] and was an emphasis of the American Recovery and Reinvestment Act [13]. Does operative intervention lead to better outcomes as compared with nonoperative treatment? Are outcomes improved with advanced and often more expensive surgical interventions? These questions are addressed using comparative effectiveness methods. Unfortunately, these questions often are addressed based on the expertise and opinion of the treating surgeon in orthopaedic care. This is especially true when applied to scenarios where the role or ability of a patient to make an informed decision is compromised owing to the emergent nature of the issue, such as in some cases of proximal humeral fractures. A previous study showed, using data from 1990 through 2000, there are racial differences in types of surgical procedures used for treatment of proximal humeral fractures [23].

Proximal humeral fractures account for 10% of all fractures in the elderly and result in substantial healthcare resource utilization [8]. In the absence of evidence-based practice guidelines on surgical treatment of proximal humeral fractures, a study of the comparative effectiveness of hemiarthroplasty and open reduction and internal fixation (ORIF) would provide useful data. Before designing such a study, it is essential to determine current practice patterns across provider and patient characteristics. If practice patterns vary, it also would be helpful to understand the factors that most contribute to this variation.

Our aims in performing this study were to assess the current clinical practice in the surgical treatment of proximal humeral fractures across the United States. We also analyzed factors associated with hospital costs for ORIF and hemiarthroplasty in the treatment of proximal humeral fractures. Specifically, we assessed whether age, surgeon volume, hospital teaching status and location, and location of fracture were associated with whether ORIF or hemiarthroplasty was performed. We assessed surgical outcomes by surgeon volume. Finally, we studied the association of hospital cost with surgeon volume, patient sex and age, procedure performed, comorbidities, and payer.

Materials and Methods

We used the Nationwide Inpatient Sample (NIS) databases for 2001 through 2008. The NIS is managed by the Healthcare Cost and Utilization Project, that is made possible by a Federal-State-Industry partnership sponsored by the Agency for Healthcare Research and Quality [3]. The NIS is a 20% stratified sample of community hospitals in the United States [2]. The NIS sampled hospitals according to five hospital characteristics: geographic region (Northeast, North Central, West, and South); ownership (public, private not-for-profit, and private investor-owned); location (urban, rural); teaching status (teaching hospital, nonteaching hospital); and bed size (small, medium, and large).

Information on validation and quality control can be found in detail on the HCUP website [1]. The NIS also was validated extensively against the National Hospital Discharge Survey and confirmed to perform very well for many estimates [45].

The NIS has information on primary ICD-9-CM diagnosis and procedure codes and 14 secondary diagnosis and procedure codes for each patient record. We selected admissions with an ICD-9-CM primary diagnosis code for closed proximal humeral fracture (812.00, 812.01, 812.02, 812.03, and 812.09) and a primary procedure code for hemiarthroplasty (81.81), ORIF (79.31), and total shoulder arthroplasty (81.80). Patients with procedure codes for hemiarthroplasty or total shoulder arthroplasty and ORIF were included in our analysis (n = 563) as these are likely patients who had a proximal humeral fracture and a humeral shaft fracture. Because such patients likely underwent arthroplasty for the proximal humeral fracture, they contribute to hemiarthroplasty and total shoulder arthroplasty data in our analysis. One patient had a procedure code for hemiarthroplasty and total shoulder arthroplasty. This likely represents a coding error, and therefore this patient was excluded from our analysis. The final data set included 25,731 records. Each record in the data sets represented a single patient admission and had a unique identification number.

The majority of patients were 65 years or older (61%). Approximately 73% of patients were female. The majority of patients underwent ORIF (62.2% of patients) as compared with hemiarthroplasty (35.2% patients) (Table 1).

We categorized age into younger than 50 years, 50 to 64 years, 65 to 79 years, and 80 years and older based on clinically meaningful cutoffs. Primary payer in the databases indicates the expected primary payer for the hospital admission. Patient comorbidity was assessed using the Charlson Comorbidity Index (CCI) (categorized into 0, 1, and ≥ 2 by two of us [IK, NBJ]) [12], as modified for administrative data by Deyo et al. [14]. The comorbidities used to calculate the CCI were based on discharge diagnoses from the index admission included in the NIS databases. Each of the diagnoses for every record was used to generate a composite CCI score. We divided the study period into 2001 to 2002, 2003 to 2004, 2005 to 2006, and 2007 to 2008 based on equal intervals.

Table 1. Characteristics of patients with proximal humeral fractures treated surgically

Characteristic	ORIF	Hemiarthroplasty	Total shoulder arthroplasty
Number of patients	15,999 (62.2)	9067 (35.2)	665 (2.6)
Age			
< 50 years	3504 (89)[‡]	389 (10)	20 (1%)
50–64 years	4050 (66)[‡]	1926 (32)	123 (2)
65–79 years	5172 (54)[‡]	4055 (43)	313 (3)
≥ 80 years	3271(53)[‡]	2694 (44)	208 (3)
Sex			
Female	10,977 (58)[‡]	7346 (39)	535 (3)
Male	5009 (73)[‡]	1718 (25)	129 (2)
Primary payer			
Medicare	8171 (55)[‡]	6325 (42)	501 (3)
Medicaid	763 (77)[‡]	211 (21)	22 (2)
Private insurance	5292 (72)[‡]	1986 (27)	116 (2)
Other*	1732 (76)[‡]	535 (23)	26 (1)
Surgeon volume (shoulder arthroplasty)[†]			
< 5 procedures/year	8972 (66)[‡]	4361 (32)	273 (2)
5–14 procedures/year	1102 (50)	1014 (46)	105 (5)
≥ 15 procedures/year	416 (46)	419 (47)	64 (7)
Hospital volume (shoulder arthroplasty)[†]			
< 5 procedures/year	3537 (72)[‡]	1328 (27)	79 (2)
5–14 procedures/year	4993 (61)[‡]	3035 (37)	158 (2)
15–29 procedures/year	3450 (59)[‡]	2229 (38)	157 (3)
≥ 30 procedures/year	4019 (59)[‡]	2475 (37)	271 (4)
Hospital location and teaching status			
Rural	1999 (60)[‡]	1194 (36)	131 (4)
Urban nonteaching	6285 (61)[‡]	3811 (37)	273 (3)
Urban teaching	6240 (64)[‡]	3315 (34)	210 (2)
Year			
2001–2002	2911 (57)[‡]	1998 (39)	164 (3)
2003–2004	3523 (60)[‡]	2243 (38)	122 (2)
2005–2006	4058 (63)[‡]	2211 (34)	148 (2)
2007–2008	5507 (66)[‡]	2615 (31)	231 (3)
Mean hospital cost (2001 US dollars)	$12,141[‡]	$13,669	$15,288

Values are expressed as number of patients, with percentage in parentheses; numbers missing: age = 6; sex = 100; payer = 100; hospital location and teaching status = 100; * other includes Workers Compensation, Civilian Health and Medical Program of Uniformed Service, Civilian Health and Medical Program of the Department of Veterans Affairs, Title V, and other government programs; [†]hospital and surgeon volume of shoulder arthroplasty includes total shoulder arthroplasty and hemiarthroplasty; surgeon identifier not present for surgeons in CA, CT, GA, HI, IL, IN, KS (2001–2004), MA, NC, OH, OK (2005–2008), and UT, VT, WI, WV (2004–2008); [‡]variable differs between ORIF and hemiarthroplasty (p < 0.05); ORIF = open reduction and internal fixation.

Hospital teaching status for a given year was obtained from the NIS database [2]. The NIS classifies a hospital as teaching if it had an American Medical Association-approved residency program, was a member of the Council of Teaching Hospitals, or had a ratio of full-time equivalent interns and residents to beds of 0.25 or higher. Hospitals were characterized as urban by the NIS if they were in a metropolitan statistical area and rural if they were in a nonmetropolitan statistical area [23]. Geographic location of the hospital was divided by NIS into Northeast, South, Midwest, and West, as determined by census regions. We calculated hospital volume and surgeon volume per year for shoulder arthroplasty (total shoulder arthroplasty and hemiarthroplasty) using unique hospital and surgeon identifiers for states that provide these data [23]. Annual hospital volume of shoulder arthroplasty was further categorized into fewer than five procedures (low volume), five to 14 procedures (medium volume), 15 to 29 procedures (medium volume), and 30 or more procedures (high volume), based on clinically meaningful cutoffs and our previous work [23]. Annual surgeon volume of shoulder arthroplasty was categorized into fewer than five procedures (low volume), five to 14 procedures (medium volume), and 15 or more procedures (high volume), based on previous publications and clinically meaningful cutoffs [19, 22].

Disposition of patient on discharge was coded into routine and nonroutine dispositions. Nonroutine disposition includes transfer to a short-term hospital, skilled nursing facility, intermediate care facility, and another type of facility or home health care. Routine disposition reflects patients who were discharged home. We also assessed in-hospital complications that included patients with a secondary diagnosis of postoperative infections, pulmonary embolism, and thrombophlebitis or other vascular and nonvascular complications of the procedure. Cases that were likely revisions after a previous primary surgery also were assessed based on diagnostic codes that implied previous device complications. A complete listing of diagnostic codes used to categorize complications and revisions can be obtained from the corresponding author (NBJ).

The NIS includes data on total hospital charges. Generally, total charges do not include professional fees and noncovered charges. If the source provides total charges with professional fees, the professional fees are removed from the charge during database processing. We used the hospital-specific cost-to-charge ratios based on all-payer inpatient cost to convert hospital charges to hospital cost. Cost information was obtained from the hospital accounting reports collected by the Centers for Medicare & Medicaid Services. All hospital costs were discounted to the base year of our study (2001) to adjust for inflation during our study period. The Consumer Price Index for

Medical Care based on the US Bureau of Labor Statistics for each year was used to adjust for inflation [42].

We studied the distribution of demographic, clinical, and other variables such as patient age and sex, surgeon volume, location of fracture across ORIF, hemiarthroplasty, and total shoulder arthroplasty using means and proportions. Outcomes such as in-hospital mortality and length of hospital stay across categories of surgeon volume also were assessed. We used a linear regression model to assess the association between hospital cost and demographic and provider variables for hemiarthroplasty and ORIF. Multivariate logistic regression was used to assess the association of demographic, clinical, and provider variables with the surgical procedure (ORIF versus hemiarthroplasty). Total shoulder arthroplasty was not included in regression models as it is not frequently performed for proximal humeral fractures and clinical characteristics of such patients are usually different from those of patients undergoing hemiarthroplasty or ORIF. However, with the advent of reverse shoulder arthroplasty, this trend may change and it is possible that patients coded as having total shoulder arthroplasty underwent reverse arthroplasty in our study. We performed a stepwise regression analysis by including variables significant at the 0.05 level or those that altered the odds ratio of surgeon volume by 10% or more for the linear and logistic regression models [38]. Statistical analyses were performed with Intercooled STATA® for Windows® (Version 11.2; Stata Corp, College Station, TX, USA) and SAS® for Windows® (Version 9.1; SAS Institute Inc, Cary, NC, USA).

Results

ORIF was performed more frequently in patients younger than 50 years (89%) than in patients 80 years or older (53%). The proportion of patients undergoing hemiarthroplasty operated on by high-volume surgeons (47%) was higher than the proportion operated on by low-volume surgeons (32%). This trend also was observed across hospital volume. There was little variation in the proportion of patients undergoing hemiarthroplasty across hospital teaching status (Table 1) and hospital geographic location (data not shown). As expected, most patients with a fracture of the surgical neck underwent ORIF (75%) (Table 2). However, contrary to expectation, only 49% of patients with a fracture of the anatomic neck underwent hemiarthroplasty. Mortality, length of stay, and rate of in-hospital complications were similar for hemiarthroplasty and ORIF (Table 3). A higher proportion of patients undergoing ORIF were discharged home as compared with those undergoing hemiarthroplasty. Revision procedures were more likely to be hemiarthroplasties than ORIF.

Table 2. Clinical characteristics of patients with proximal humeral fracture treated surgically

Clinical characteristic	ORIF	Hemiarthroplasty	Total shoulder arthroplasty
Number of patients	15,999 (62.2)	9067 (35.2)	665 (2.6)
Diagnosis (ICD-9-CM)			
Closed fracture of unspecified part of upper end of humerus (812.00)	4736 (61)[†]	2771 (36)	247 (3)
Closed fracture of surgical neck of humerus (812.01)	5593 (75)[†]	1729 (23)	121 (2)
Closed fracture of anatomic neck of humerus (812.02)	284 (49)	286 (49)	12 (2)
Closed fracture of greater tuberosity of humerus (812.03)	2717 (76)[†]	820 (23)	47 (1)
Closed fracture of head or upper epiphysis of humerus (812.09)	3887 (45)[†]	4435 (52)	293 (3)
Charlson Comorbidity Index			
0	10,678 (64)[†]	5520 (33)	404 (2)
1	1775 (61)[†]	1072 (37)	78 (3)
≥ 2	3546 (57)[†]	2475 (40)	183 (3)
Admission type			
Emergency	7238 (68)[†]	3218 (30)	198 (2)
Urgent	2436 (62)[†]	1379 (35)	102 (3)
Elective	5655 (55)[†]	4222 (41)	354 (4)
Other*	670 (72)[†]	248 (27)	11 (1)

Values are expressed as number of patients, with percentage in parentheses; * other includes delivery, trauma center, newborn, other admission types, and missing data; [†]variable differs between ORIF and hemiarthroplasty (p < 0.05); ORIF = open reduction and internal fixation.

Table 3. Outcomes of patients with proximal humeral fractures treated surgically

Clinical characteristics	ORIF	Hemiarthroplasty	Total shoulder arthroplasty
Number of patients	15,999 (62.2)	9067 (35.2)	665 (2.6)
Mortality			
Died	83 (0.5)	47 (0.5)	5 (0.8)
Missing	41 (0.3)	26 (0.3)	1 (0.2)
Disposition on discharge			
Routine	8257 (52)[†]	3595 (40)	265 (40)
Nonroutine	6947(43)[†]	5016 (55)	371 (56)
Data missing, patient died or left against medical advice	795 (5)	456 (5)	29 (4)
Revision	73 (0.4)[†]	64 (0.7)	12 (1.8)
Hospital length of stay (days)*	4.9 ± 5.8	5.0 ± 4.7	4.9 ± 5.0
Complications	215 (1.3)	138 (1.5)	16 (2.4)

* Values are expressed as mean ± standard error; the remaining values are expressed as number of patients, with percentage in parentheses; [†]variable differs between ORIF and hemiarthroplasty (p < 0.05); ORIF = open reduction and internal fixation.

Surgeons with high procedure volume had lower in-hospital mortality rates (0.2%) and lower length of stay than surgeons with low procedure volume (0.6%). Their length of stay was 3.4 days (p < 0.01) versus 5.5 days for low volume surgeons (Table 4). The distribution of clinical characteristics of the patient such as comorbid status (CCI) and diagnosis was similar across surgeon volume categories (data not shown). Adjusting for confounders, the odds of a patient undergoing hemiarthroplasty were 1.68 times (95% CI = 1.43, 1.97) when operated on by a high-volume surgeon versus a low-volume surgeon (Table 5). Conversely, the odds of undergoing hemiarthroplasty were

Table 4. Outcomes of patients according to surgeon volume

Surgeon volume*	Number of patients	Mortality	Length of stay (days)[†]	Complications
ORIF				
< 5 procedures/year	8972	59 (0.7)	5.3 ± 6.4	121 (1.3)
5–14 procedures/year	1102	2 (0.2)	3.2 ± 3.5[‡]	11 (1.0)
≥ 15 procedures/year	416	0 (0)	2.8 ± 3.2[‡]	2 (0.5)
Hemiarthroplasty				
< 5 procedures/year	4361	26 (0.6)	5.5 ± 5.4	77 (1.8)
5–14 procedures/year	1014	4 (0.4)	3.8 ± 3.0[‡]	12 (1.2)
≥ 15 procedures/year	419	1 (0.2)	3.4 ± 3.1[‡]	4 (1.0)

* Hospital and surgeon volume of shoulder arthroplasty includes total shoulder arthroplasty and hemiarthroplasty; surgeon identifier not present for surgeons in CA, CT, GA, HI, IL, IN, KS (2001–2004), MA, NC, OH, OK (2005–2008), and UT, VT, WI, WV (2004–2008); [†]values are expressed as mean ± standard error; the remaining values are expressed as number of patients, with percentage in parentheses; [‡]p < 0.01, compared with less than five procedures; ORIF = open reduction and internal fixation.

0.61 times (95% CI = 0.56, 0.66) in 2007 to 2008 as compared with 2001 to 2002.

Because the relationship between hospital cost and surgeon volume was linear (Figs. 1 and 2), surgeon volume was used as a continuous variable in the regression analysis for hospital cost. Factors that contributed to lower hospital cost included higher surgeon volume, female sex, ORIF (versus hemiarthroplasty), lower burden of comorbidities (as measured by CCI), younger age, and Medicare as the primary payer (Table 6). Adjusting for sex, procedure, CCI, age, and payer, on average, the hospital cost per procedure was reduced by $90 for each additional arthroplasty performed by a surgeon.

Discussion

The issue of rising costs will likely dominate the healthcare debate in the forthcoming years. Limited resources may necessitate cost-cutting measures. Proximal humeral fractures account for 10% of all fractures in the elderly. We therefore assessed factors associated with lower hospital costs and variations in surgical treatment for proximal humeral fractures.

The limitations of our study include nonavailability of data for patients who did not undergo surgery because the NIS includes only inpatient admissions. The databases also do not provide information regarding degree of displacement or fracture classifications. Long-term functional outcomes such as pain and ROM also are not available in the NIS. We also do not have information for patients who were managed nonoperatively.

We found there was a linear association between reduced hospital costs and higher shoulder arthroplasty volume of the surgeon for treatment of proximal humeral fractures. We also found there was variation in practice patterns for surgical treatment of proximal humeral

fractures. High-volume surgeons and hospitals were more likely to perform hemiarthroplasty as compared with ORIF, after adjusting for potential confounders. Contrary to expectation, the odds of a patient undergoing hemiarthroplasty were reduced during our study period from 2001 to 2008. The length of stay for patients operated on by high-volume surgeons was approximately 40% shorter than for patients operated on by low-volume surgeons.

As is evident from the current healthcare debate, issues relating to cost will be critical. This especially will be the case for costs associated with surgical procedures. Cost-cutting measures may not only aim at eliminating procedures and treatments that are not supported by outcome data but also at assessing factors that contribute to increased costs. Several studies have reported on the association of higher surgical volume with better outcomes [11, 17, 22, 24–28]. However, to our knowledge, no prior study has assessed the association between surgical volume and hospital costs for orthopaedic procedures. Auerbach et al. [6] reported lowest-volume hospitals had 19.8% higher costs and low surgeon volume was associated with 3.1% higher costs for coronary artery bypass grafting. Gourin et al. [16] also reported a negative correlation between hospital volume and hospital costs for laryngeal cancer surgery. However, for complex cancer surgery, Auerbach et al. [7] reported there were no consistent associations between higher hospital or surgeon volume and mortality, readmission, length of stay, or costs. Studies in the orthopaedic literature also have reported on the association of provider volume and hospital charges [17, 26, 28]. However, hospital charges are often an overestimation and offer little insight into the true costs or reimbursement associated with a procedure. Our results provide evidence that surgeons with high volumes of shoulder arthroplasties per year are associated with lower hospital costs. As an example, on average, adjusting for all other factors, a surgeon performing 20 shoulder

Table 5. Factors associated with surgical procedure (hemiarthroplasty versus ORIF) for treatment of proximal humeral fracture

Factor	Total number of patients	Number of patients with hemiarthroplasty	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Surgeon volume*				
< 5 procedures/year	13,606	4361	1.00	1.00
5–14 procedures/year	2221	1014	1.75 (1.60, 1.91)	1.46 (1.32, 1.61)
≥ 15 procedures/year	899	419	1.91 (1.66, 2.19)	1.68 (1.43, 1.97)
Age				
< 50 years	3913	389	0.13 (0.12, 0.15)	0.15 (0.13, 0.17)
50–64 years	6099	1926	0.58 (0.54, 0.62)	0.58 (0.52, 0.65)
65–79 years	9540	4055	0.95 (0.89, 1.02)	0.86 (0.80, 0.93)
≥ 80 years	6173	2694	1.00	1.00
Sex				
Female	18,858	7346	1.95 (1.83, 2.08)	1.30 (1.21, 1.39)
Hospital volume*				
< 5 procedures/year	4944	1328	1.00	1.00
5–14 procedures/year	8186	3035	1.62 (1.50, 1.75)	1.68 (1.54, 1.83)
15–29 procedures/year	5836	2229	1.72 (1.58, 1.87)	1.74 (1.58, 1.90)
≥ 30 procedures/year	6765	2475	1.64 (1.51, 1.78)	1.72 (1.57, 1.89)
Year				
2001–2002	5073	1998	1.00	1.00
2003–2004	5888	2243	0.93 (0.86, 1.00)	0.91 (0.83, 0.99)
2005–2006	6417	2211	0.79 (0.74, 0.86)	0.73 (0.67, 0.80)
2007–2008	8353	2615	0.69 (0.64, 0.74)	0.61(0.56, 0.66)
Primary payer				
Medicare	14,997	6325	1.00	1.00
Medicaid	996	211	0.36 (0.31, 0.42)	0.93 (0.77, 1.12)
Private insurance	7394	1986	0.49 (0.46, 0.52)	0.85 (0.77, 0.93)
Other[†]	2293	535	0.40 (0.36, 0.44)	0.88 (0.78, 1.01)
Diagnosis (ICD-9-CM)				
Closed fracture of unspecified part of upper end of humerus (812.00)	7754	2771	1.00	1.00
Closed fracture of surgical neck of humerus (812.01)	7443	1729	0.59 (0.55, 0.63)	0.61 (0.57, 0.65)
Closed fracture of anatomic neck of humerus (812.02)	582	286	2.13 (1.79, 2.53)	2.58 (2.15, 3.10)
Closed fracture of greater tuberosity of humerus (812.03)	3584	820	0.54 (0.49, 0.58)	0.60 (0.55, 0.65)
Closed fracture of head or upper epiphysis of humerus (812.09)	8615	4435	2.47 (2.32, 2.62)	2.78 (2.61, 2.96)
Admission type				
Emergency	10,654	3218	1.00	1.00
Urgent	3917	1379	1.27 (1.18, 1.38)	1.18 (1.09, 1.29)
Elective	10,231	4222	1.68 (1.58, 1.78)	1.48 (1.39, 1.58)
Other[‡]	929	248	0.83 (0.72, 0.97)	1.07 (0.90, 1.27)

* Hospital volume of shoulder arthroplasty represents volume of total shoulder arthroplasty and hemiarthroplasty; [†]other includes Workers Compensation, Civilian Health and Medical Program of Uniformed Service, Civilian Health and Medical Program of the Department of Veterans Affairs, Title V, and other government programs; [‡]other includes delivery, trauma center, newborn, other admission types, and missing data; ORIF = open reduction and internal fixation.
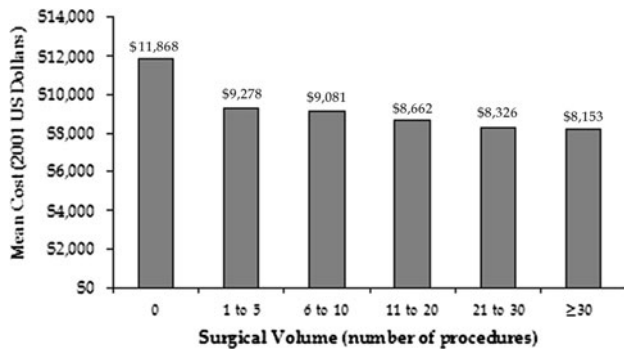
Fig. 1 Linear decrease in hospital cost of ORIF with surgeon arthroplasty volume (n = 14,342). Note: Procedures with hospital cost greater than US $50,000 were excluded to avoid outliers (n = 270).
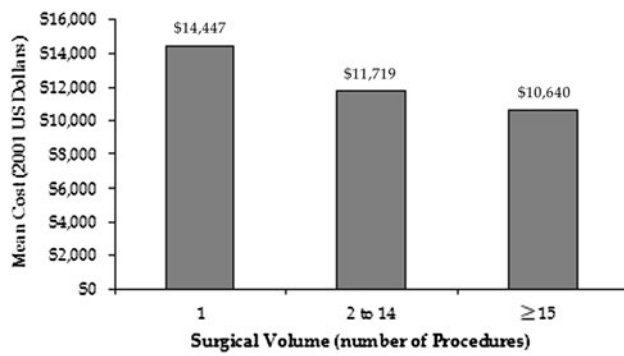

Fig. 2 Linear decrease in hospital cost of hemiarthroplasty with surgeon arthroplasty volume (n = 8115).

Table 6. Determinants of hospital cost of ORIF and hemiarthroplasty

Factor	Cost (US dollars) (n = 14,202)
Surgeon volume*,†	−90 ± 11‖
Female	−2864 ± 296‖
Hemiarthroplasty‡	2414 ± 197‖
Charlson Comorbidity Index†	394 ± 27‖
Age	
< 50 years	1301.81 ± 554
50–64 years	−11 ± 404
65–79 years	−168 ± 205
≥ 80 years	Reference group
Primary payer	
Medicaid	2536 ± 920‖
Private insurance	1046 ± 382‖
Other§	1489 ± 527‖
Medicare	Reference group

Values are expressed as mean ± standard error; * surgeon volume includes total shoulder arthroplasty and hemiarthroplasty; surgeon identifier not present for surgeons in CA, CT, GA, HI, IL, IN, KS (2001–2004), MA, NC, OH, OK (2005– 2008), and UT, VT, WI, WV (2004–2008); †used as a continuous variable; ‡compared with ORIF; §other includes Workers Compensation, Civilian Health and Medical Program of Uniformed Service, Civilian Health and Medical Program of the Department of Veterans Affairs, Title V, and other government programs; ‖p < 0.01; ¶p < 0.05; ORIF = open reduction and internal fixation.

arthroplasties per year saves a hospital approximately US $1800 in costs per surgery performed for proximal humeral fractures. This saving amounts to approximately 15% of the cost of an ORIF and 13% of the cost of a hemiarthroplasty. This is substantial from a hospital perspective given a flat rate of reimbursement provided for by Diagnostic Related Groups. Our finding is of critical importance to hospital leaderships and administrators as it may help to guide policies requiring a minimum procedure volume criterion during the hospital credentialing of surgeons.

The treatment of proximal humeral fractures has been debated by experts in several reports [18, 32, 36]. Studies in this area have provided little guidance owing to small sample sizes, lack of comparison groups, and bias in subject selection and study execution [15, 33, 37, 41, 46]. Petit et al. [36] provided evidence for poor agreement between shoulder and trauma surgeons regarding treatment of proximal humeral fractures. A Cochrane Review in 2010 concluded there was insufficient evidence to inform management of proximal humeral fractures, and it was unclear whether surgery provided better long-term outcomes [18].

Moreover, in the future it is likely that patients with proximal humeral fractures will be older with more comorbidities. Thus, optimal treatment in such patients, including nonoperative management, needs further investigation. Many shoulder surgeons use Neer's classification of two- versus three- versus four-part fractures for classifying proximal humeral fractures [30, 31]. However, there is no evidence that this classification informs surgical decision making. Moreover, several studies have reported poor agreement among surgeons for the Neer classification [10, 39, 40].

Our data show there is considerable variation in the surgical treatment of proximal humeral fractures by surgeon and hospital volume. Moreover, time trends show patients were more likely to undergo ORIF as compared with hemiarthroplasty in the later parts of our study. It is possible the increase in ORIF was attributable to the increased use of locking plates during the later years of the study [4]. However, this information is not available from our data sets. Although, total shoulder arthroplasty is not performed routinely for proximal humeral fractures, 2.6% of patients in our study underwent total shoulder arthroplasties. These patients likely had a chronic fracture or had failure of the hemiarthroplasty. It also is possible

that these patients underwent reverse shoulder arthroplasty. Bell et al. [9] reported substantial regional variation in surgical versus nonsurgical treatment of proximal humeral fractures. They did not report on the variation in use of hemiarthroplasty versus ORIF. We did not find regional variations in the use of hemiarthroplasty versus ORIF likely because we studied broad regions in the United States (Northeast, Midwest, South, and West).

To our knowledge, this is the first study to report on the association of higher surgeon volume and lower hospital costs in the area of musculoskeletal care. Because our findings can result in substantial savings, hospital leaderships and administrators should consider framing policies on minimum volume requirements for orthopaedic procedures if our findings are confirmed in future studies. Our study also provides evidence for provider-driven practice variations in the surgical treatment of proximal humeral fractures. This is likely because of the absence of evidence-based treatment guidelines. In the future, reimbursement for orthopaedic procedures will likely be driven by data on comparative effectiveness and will not be based on individual provider practices. Therefore, it is essential for clinicians providing musculoskeletal care to offer evidence for their practices in addition to focusing on improvisation of surgical and nonsurgical techniques.

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