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Abstract

Introduction: The two historically dominant surgical options for displaced geriatric proximal humerus (PHFx) fractures are open reduction internal fixation (ORIF) and hemiarthroplasty (HA). However, shoulder arthroplasty (SA), predominantly in the form of reverse total shoulder arthroplasty (RTSA), has emerged as an attractive treatment option. We aim to compare the utilization trends, complications, and costs associated with surgical management of geriatric proximal humerus fractures (PHFs) between 2010 and 2019. We hypothesized that 1) the proportion of patients undergoing SA would increase over time, 2) the short-term complication rate in patients undergoing SA would decline over time, and 3) hospital related costs would decline for SA patients over time.

Patients and Methods: The National Inpatient Sample was queried from 2010 to 2019 to identify all PHFx in patients aged 65 or older that underwent ORIF, SA, or HA. Multivariable regression was used to evaluate differences between fixation methods regarding health care utilization metrics, hospital costs, and index hospital complications. The primary outcome of interest was the method of surgical management utilized in the treatment of geriatric PHFs, and secondary outcomes of interest included hospitalization cost, length of stay (LOS), discharge destination and index hospitalization complications.

Results: A total of 105 886 geriatric patients that underwent surgical management of PHFx were identified. While the proportion undergoing ORIF decreased from 59% to 29%, the proportion undergoing SA increased from 9% to 67%. Hospital costs decreased over time for patients treated with SA and increased for those treated with ORIF. Compared to ORIF, SA was associated with higher cost, decreased length of stay, and lower mortality and complication rates.

Conclusion: Over the last decade, SA has become the most common surgical treatment modality performed for geriatric PHFx. Index hospital complications are reduced in SA patients compared to ORIF patients, driven largely by a lower rate of blood transfusion. Although costs are decreasing and average length of stay is now lower in SA patients compared to ORIF patients, SA remains associated with higher hospital costs overall.

Keywords

Proximal humerus fractures, geriatric fractures, shoulder arthroplasty, trends analysis

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Highlights

1. Shoulder arthroplasty has overtaken ORIF as the most common surgical modality used in the treatment of geriatric proximal humerus fractures (PHFs).
2. Mortality rates, complication rates, and length of stay decreased across all treatment cohorts over the last decade.

3. The cost associated with SA has decreased over time but remains higher than the cost associated with ORIF.

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Introduction

Proximal humerus fractures (PHFs) are the third most common osteoporotic fracture seen in the geriatric population,¹ and as the US population continues to age, both their incidence and their associated societal burden are expected to continue to rise. The majority of PHFs are non-displaced or minimally displaced and can be treated non-operatively.² However, although surgical management has not been shown to be superior to conservative treatment for displaced fractures,³ there has been a growing trend towards surgical management of displaced geriatric PHFs.²

The three most common surgical options for displaced geriatric PHFs are open reduction internal fixation (ORIF), hemiarthroplasty (HA), and shoulder arthroplasty (SA)—predominantly reverse total shoulder arthroplasty (RTSA). Historically, the most common option has been ORIF, but it is associated with high rates of fixation failure and hardware penetration in the geriatric population despite the development of fixed angle locking devices.⁴ Reverse total shoulder arthroplasty (RTSA) was initially developed for rotator cuff arthropathy but has quickly gained traction as an attractive treatment option for complex PHF patterns, especially 3 and 4 part fractures and head-split fractures that have traditionally been managed with HA. Although SA is associated with higher up-front hospital costs,^{5–7} it has been associated with superior outcomes compared to HA⁸ and recent studies have supported the use of SA as a surrogate for ORIF in patients older than 65.^{4,9} Hence, prior database studies as well as recent studies from Europe and Asia have reported a proportional increase of shoulder arthroplasty in the treatment of PHFs over time.^{7,10–12} However, the change in relative performance and cost-effectiveness of SA versus HA or ORIF over the last decade in the United States has not been assessed.

This study aims to use a large national database to compare the utilization trends, complications, and costs associated with surgical management of geriatric PHFs between 2010 and 2019. We hypothesized that (1) the proportion of patients undergoing SA would increase over time, (2) the short-term complication rate in patients undergoing SA would decline over time, and (3) hospital related costs would decline for SA patients over time.

Patients and Methods

Our study cohort was identified using the National Inpatient Sample (NIS) over a 10-year period (January 1, 2010 to December 31st, 2019). The NIS is a nationally representative database developed from all hospitals participating in the Healthcare Cost and Utilization Project (HCUP) and validated through a federal–state–industry partnership sponsored by the Agency for Healthcare Research and Quality (AHRQ). It is based on inpatient data from over 40 states derived from billing and discharge information, covering approximately 96% of the U.S. population using an estimate of 20%

stratified sample of discharges from U.S. hospitals. A stratified formula based on discharge weights reported by participating HCUP institutions was designed to allow an estimation of nationally representative statistics. Available variables include demographic data, diagnoses, procedures, hospital length of stay (LOS), hospital cost, and hospital characteristics.¹³ Since the NIS database has been sufficiently de-identified of any personal health information or identifiers, this study was deemed exempt by the Institutional Review Board at our institution.

Specific International Classification of Diseases, ninth Revision, (ICD-9) and International Classification of Diseases, 10th Revision, (ICD-10) diagnosis codes were used as inclusion criteria to identify all patients 65 years of older with closed PHFs (Supplement Table 1). ICD-9 and ICD-10 procedure codes were used to identify those that underwent surgical treatment and categorize patients as having undergone ORIF, HA, or shoulder arthroplasty (SA). As the ICD-9 procedure codes do not distinguish between anatomic (total shoulder arthroplasty (TSA)) and reverse shoulder arthroplasty (RTSA), we were unable to report exclusively on RTSA alone and designated all patients undergoing TSA or RTSA as having undergone shoulder arthroplasty (SA). Exclusion criteria included age less than 65, open fracture, pathologic fracture, and any periprosthetic fracture identified by removal of hardware procedure codes. For ICD-10 diagnostic codes, no differentiation was made between modifiers for initial encounter, subsequent encounter or sequelae.

The primary outcome studied was the method of surgical management utilized in the treatment of geriatric PHFs fractures. Secondary outcomes included hospitalization cost, length of stay (LOS), discharge destination and index hospitalization complications. Individual hospitalization cost was calculated using diagnosis-related group (DRG) codes multiplied by hospital-specific cost-to-charge ratios provided by the AHRQ. The cost was subsequently standardized for inflation using rates from United States Bureau of Labor Statistics and described in December 2019 U.S. dollars. Discharge locations included home and skilled nursing facility (SNF). ICD-9 and ICD-10 codes were used to identify cardiac complications, myocardial infarction, cerebrovascular accident, respiratory complications, pneumonia (PNA), pulmonary embolism (PE), other pulmonary complications, deep vein thrombosis (DVT), acute kidney injury, wound complications, post-operative blood transfusions or any in-hospital complications (Supplement Table 2).

Patient demographics and hospital characteristics were summarized and analyzed with regard to primary and secondary outcomes. Patient demographics included age (years), sex (male and female), race/ethnicity (white, black, Hispanic, Asian, Native American, and other), and insurance (Medicare, Medicaid, private, and self-pay). Hospital characteristics included hospital type (urban non-teaching, urban teaching,

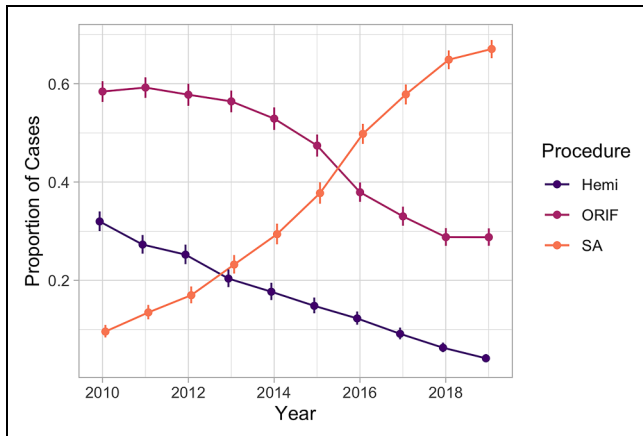


Figure 1. Relative rate of methods of proximal humerus fracture fixation over the past decade. Error bars represent 95% confidence interval.

blood transfusion (17.8%). On multivariate analysis when adjusting for age, ECI, hospital setting, and insurance status, SA patients had significantly lower rates of mortality compared to ORIF (OR 0.63, $P = .035$). SA patients also had a significantly lower rate of blood transfusion compared to ORIF (13.5% vs 19.3%, OR 0.69, $P < .001$), while HA patients had a higher rate than ORIF patients (24.1% vs 19.3%, OR 1.35, $P < .001$). Finally, SA patients had significantly lower rates of significant vascular event (myocardial infarction or stroke) (OR 0.62, $P < .001$), wound complications (OR 0.51, $P = .004$), pneumonia (OR 0.64, $P < .001$) and other pulmonary complications (OR 0.69, $P < .001$) compared to ORIF patients.

The overall complication rate decreased over the last decade for both SA and ORIF patients. Patients undergoing SA in 2019 had significantly lower rates of mortality (0.30% vs 1.50%, $P = .015$), any complication (16.8% vs 44.5%, $P < .001$), or blood transfusion (7.7% vs 33%, $P < .001$) compared to those undergoing SA in 2010. Patients

Table 2. Patient and Hospital Characteristics.

Hemi (N, %)	ORIF (N, %)	SA (N, %)	P-value*
Age			
65-74	7444 (43.2%)	21 488 (45.2%)	<.001
75 +	9781 (56.8%)	26 081 (54.8%)	17 814 (43.4%) 23 278 (56.6%)
Race/Ethnicity			
White	14 016 (87.3%)	38 957 (87.3%)	<.001
Black	278 (1.7%)	1127 (2.5%)	35 630 (90.5%) 620 (1.6%)
Hispanic	1125 (7%)	2929 (6.6%)	1961 (5%)
Other	630 (3.9%)	1601 (3.6%)	1163 (3%)
Elixhauser Comorbidity Index			
0	1375 (8%)	4031 (8.5%)	<.001
1	3123 (18.1%)	8493 (17.9%)	3616 (8.8%) 7107 (17.3%)
2	4071 (23.6%)	10 079 (21.2%)	9687 (23.6%)
3	3230 (18.8%)	9386 (19.7%)	8095 (19.7%)
4	2425 (14.1%)	6867 (14.4%)	5754 (14%)
5	3001 (17.4%)	8712 (18.3%)	6833 (16.6%)
Region			
Mid-West	3475 (20.2%)	10 212 (21.5%)	<.001
Northeast	3255 (18.9%)	7721 (16.2%)	9732 (23.7%) 6017 (14.6%)
South	6612 (38.4%)	19 648 (41.3%)	18 092 (44%)
West	3883 (22.5%)	9987 (21%)	7251 (17.6%)
Payer			
Medicare	15 159 (88.1%)	41 350 (87%)	<.001
Private	1513 (8.8%)	4590 (9.7%)	36 606 (89.2%) 3113 (7.6%)
Medicaid	148 (0.9%)	429 (0.9%)	260 (0.6%)
Other	381 (2.2%)	1155 (2.4%)	1077 (2.6%)
Hospital Type			
Rural	1851 (10.8%)	4680 (9.9%)	<.001
Urban Non-teaching	7442 (43.4%)	17 401 (36.7%)	4005 (9.8%) 12 221 (29.8%)
Urban Teaching	7847 (45.8%)	25 269 (53.4%)	24 831 (60.5%)
Discharge Destination			
In-hospital mortality	94 (0.5%)	348 (0.7%)	<.001
Facility	9241 (53.7%)	24 288 (51.1%)	168 (0.4%) 17 277 (42%)
Home	7730 (44.9%)	22 656 (47.6%)	23 368 (56.9%)
Other	155 (0.9%)	261 (0.5%)	274 (0.7%)

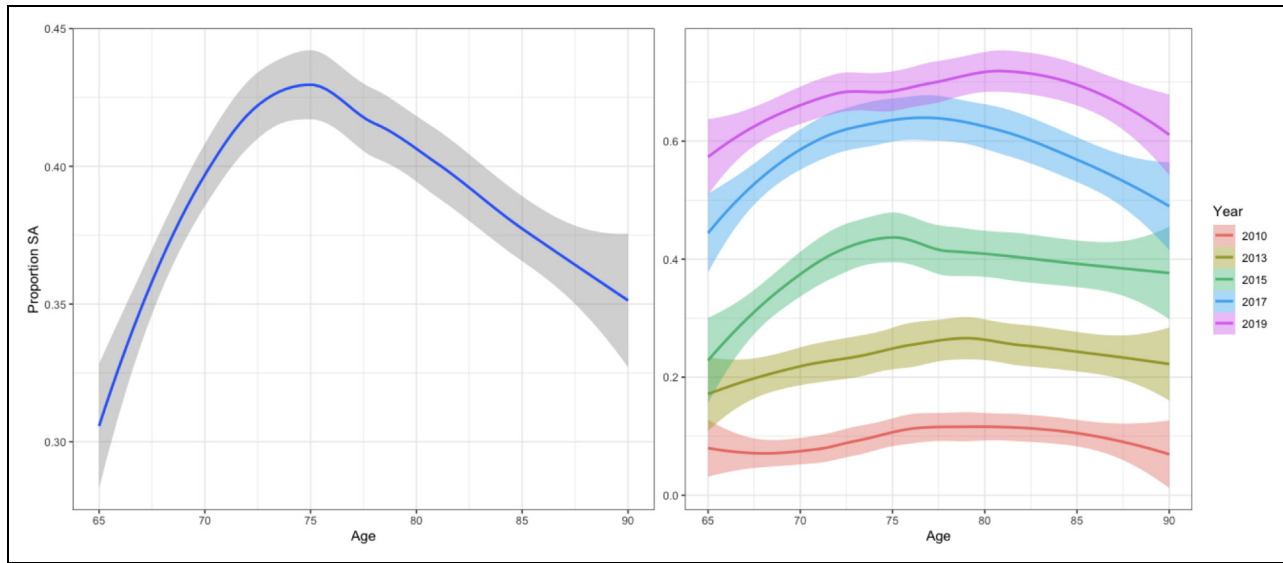


Figure 2. Proportion of patients undergoing SA instead of ORIF or HA, by age. Left: All years, Right: Stratification by select years. Shaded areas represent 95% confidence interval.

Table 3. Comparison of Complication Profile after ORIF or SA in 2010 versus 2019.

	ORIF 2010 (N = 6087)	2019 (N = 3605)	P-value	SA 2010 (N = 987)	2019 (N = 8400)	P-value
Mortality	0.99%	0.83%	.66	1.50%	0.30%	.015
Any Complication	38.3%	23.3%	<.001	44.5%	16.8%	<.001
MI	1.31%	1.39%	.961	3.0%	0.36%	<.001
PE	4.11%	6.93%	.541	0.50%	0.65%	.910
SSI	0.16%	0.28%	.699	1.00%	0.06%	.015
Transfusion	25.7%	7.35%	<.001	33.0%	7.74%	<.001
Wound complication	1.07%	0.555%	.282	1.00%	0.238%	.0663

¹Abbreviation: SSI, surgical site infection.

undergoing ORIF in 2019 also had significantly lower rates of any complication (23.3% vs 38.3%, $P < .001$) or blood transfusion (7.4% vs 26%, $P < .001$) compared to those undergoing ORIF in 2010 (Table 3). When limiting analysis to 2019 alone, SA patients demonstrated a favorable complication profile to ORIF patients, with significantly lower rates of any complication (OR 0.717, $P = .006$) or significant vascular event (OR 0.34, $P = .013$).

From 2010 to 2019, hospital costs associated with ORIF rose from \$18 412 to \$21 179 ($P < .001$) whereas the hospital costs associated with SA dropped from \$28 672 to \$25 602 ($P < .001$) (Figure 3). Length of stay decreased for all patients during this time period, with the average LOS for SA patients decreasing from 5 days in 2010 to 3.5 days in 2019 ($P < .001$) (Figure 4). After controlling for age, comorbidities, and other factors, the hospital costs of SA and HA were \$6300 ($P < .001$) and \$3627 ($P < .001$) more than ORIF. The length of stay was 0.6 days less for SA compared to ORIF ($P < .001$). Arthroplasty patients were less likely to undergo non-home discharge compared to ORIF patients (OR 0.68,

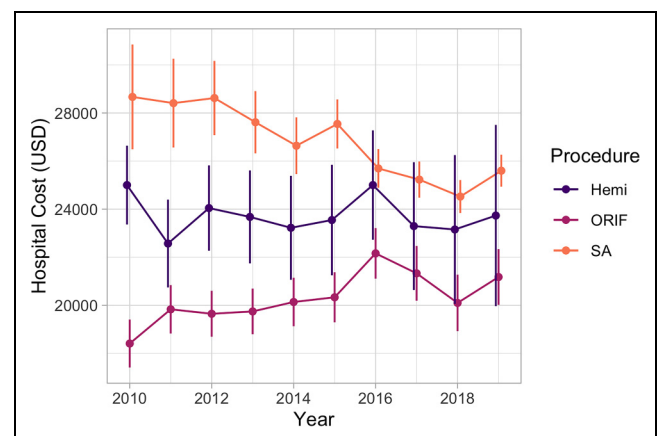


Figure 3. Mean hospital costs by year and treatment group in December 2019 USD. Error bars represent 95% confidence interval.

$P < .001$) while HA patients were more likely (OR 1.1, $P = .032$). When limiting analysis to 2019 alone, the hospital

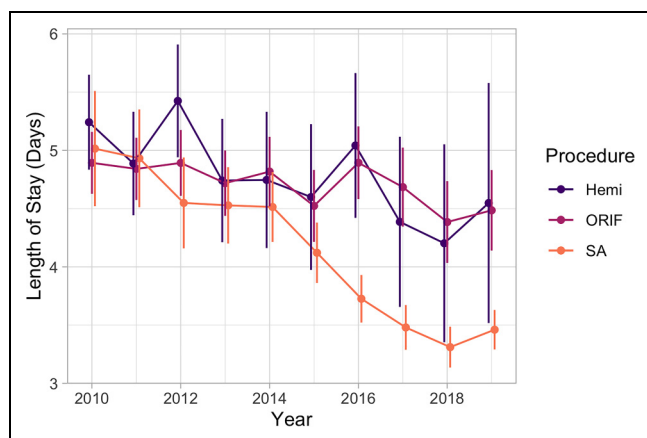


Figure 4. Mean length of stay by year and treatment group. Error bars represent 95% confidence interval.

costs of SA and HA were \$4976 ($P < 0.001$) and \$2765 ($P < .001$) more than ORIF on multivariate analysis. Length of stay was 0.8 days less for SA compared to ORIF ($P < .001$) and SA patients were less likely to undergo non-home discharge (OR 0.59, $P < .001$) than ORIF patients.

Discussion

Over the last decade, the proportion of geriatric PHFx patients treated with shoulder arthroplasty increased from 10% to 67%. These numbers represent both a continuation of previously reported trends^{7,10,15} and an amplification of trends reported in Europe and Asia.^{11,12} Han et al used Medicare data from 2005 to 2012 to analyze the relative frequency of operative versus non-operative management of PHFs as well as trends in operative treatment modality, finding that the proportion of patients undergoing hemiarthroplasty dropped from 42% to 24% while the rate of SA rose from 3% to 17%. While Han et al reported relative stability in the rate of ORIF from 55% of all cases in 2005 to 60% in 2012, our study found a significant drop in ORIF rate in the most recent decade. This suggests that while SA began to replace HA in the early 2000s, it is now seen as an increasingly attractive alternative to ORIF in the geriatric patient population as well. While the trends are similar, our findings represent a significant difference in treatment compared to the rest of the world. McLean and colleagues utilized an Australian national healthcare database to assess trends in PHFx management between 2008 and 2017 and found that while ORIF and HA both decreased over this time period, RTSA still only accounted for 24.5% of all operative PHFx management in 2017.¹² In comparison, we found that SA was being used for approximately 23% of operative PHFx in the US as early as 2013 (Table 1). Klug and colleagues demonstrated similar trends in Germany between 2007 and 2016, but in contrast to our study, SA represented only 5.6% of all operative PHFx during their study time period.¹¹

Although the proportion of patients undergoing SA increased each year, we found that age and comorbidity status were primary determinants of treatment choice. Geriatric patients treated with SA were older on average, with the likelihood of being treated with SA dramatically rising as age increased from 65 to 75. Interestingly, the likelihood of arthroplasty decreased as age went past 75. This likely reflects two competing factors. ORIF is likely a more attractive option for younger, high-demand individuals as it preserves bone stock, avoids the weight-bearing and activity restrictions after shoulder arthroplasty,¹⁶ and provides a potentially permanent solution to the fracture. Furthermore, ORIF avoids the higher risk of revision reported in younger patients that undergo primary arthroplasty.¹⁷ On the other end of the age spectrum, surgeons may be hesitant to perform SA in geriatric patients that are more likely to have significant comorbidities and lower physiologic reserve, factors that have been associated with increased short-term complications.¹⁸ In our patient sample, ORIF patients were more likely to have major comorbidities such as heart failure, arrhythmia, end-stage diabetes, coagulopathy, and metastatic cancer, reflecting that surgeons may be less willing to perform SA in geriatric patients with significant medical comorbidities.

This study is the first national database study to demonstrate lower rates of both complications and transfusion in the SA cohort compared to ORIF patients. The rate of inpatient complications for geriatric patients undergoing SA was found to be significantly lower than ORIF patients even when adjusting for demographics, comorbidities, and hospital factors. Using National Surgical Quality Improvement Program (NSQIP) data from 2006 to 2013, Cvetanovich et al found an overall higher rate of 30-day complications after HA (22%) and SA (23%) compared to ORIF (13%), largely driven by higher transfusion rates in the arthroplasty groups.¹⁸ Thorsness et al limited their analysis to HA and ORIF and similarly found a lower complication rate in ORIF patients.¹⁹ Although we adjusted for ECI, the increased risk of short-term complications after ORIF found in our study may relate to their overall more severe comorbidities than the SA cohort. It is also possible that previous studies published more than 5 years ago fail to capture the improvement in outcomes over the last decade. We found that although ORIF patients enjoyed a lower complication rate than SA patients in 2010 (38% vs 45%), the trends reversed by 2019, with 17% of SA patients experiencing complications compared to 23% of ORIF patients. This corroborates the broader findings of Bixby et al, who used NSQIP from 2005 to 2018 to compare short-term outcomes after SA for all indications (not limited to fractures) and reported a significant reduction in complication rate, operative time, blood transfusion rate, and length of stay over the study period.²⁰ Recent studies have also begun to report improved functional outcomes with SA compared to ORIF. Greiwe et al (2020) compared 25 age-matched ORIF patients with RTSA patients

and reported superior outcomes in the RTSA cohort with respect to complication rate, re-operation rate, and range of motion and subjective scores at average 4 year follow-up.⁹ Also in 2020, the DeIphi randomized controlled trial reported significantly improved Constant score in PHF patients in the RTSA cohort instead of ORIF at 2 years follow up.⁴

Despite these promising results and the momentum in favor of RTSA for PHFs, it is important to remember the procedure's inherent limitations when compared to ORIF. Many surgeons enforce strict weight bearing and activity restrictions after RTSA,¹⁶ making it a less appealing option for patients who lead an active lifestyle. Furthermore, while studies have reported similar infection rates between ORIF and SA,¹⁸ infected shoulder arthroplasty represents a far more serious complication and typically requires long-term antibiotics in addition to a two-stage revision.²¹ Revision for other indications is also more challenging in patients with failed arthroplasty. Due to preserved bone stock, ORIF patients that experience failure of fixation may either undergo revision ORIF or conversion to arthroplasty.²² However, the sole treatment option for failed SA is a revision RTSA, which is often technically demanding due to high rates of bone loss^{23,24} and has been associated with worse outcomes than primary SA.²⁵ Finally, SA for PHF is associated with significantly higher cost compared to ORIF,^{5,7} likely due to higher implant costs.²⁶ Rosas et al reported an initial day reimbursement cost of more than \$16 000 for RTSA compared to \$6700 for ORIF.⁵ While the cost associated with SA has dropped while the cost associated with ORIF has risen over the same time period, we found that SA was still associated with \$4976 of additional hospital costs compared to ORIF as recently as 2019. Admittedly, these numbers do not take into account the cost of revision surgery, and further studies are required to compare long-term revision rates and associated costs after RTSA versus ORIF.

As a nationally representative database, the NIS is well suited for reporting trends in utilization and cost. However, our study does have a few significant limitations. First, the NIS only includes information from the initial hospitalization, preventing analysis of long-term outcomes or complications that occur after discharge. This also prevents analysis of costs accrued after discharge including the cost of any re-operation. However, while costs related to post-operative rehabilitation or care are not included in NIS, we do report the rate of non-home discharge which gives a rough surrogate of post-discharge costs. Second, as the NIS only records inpatient encounters, it fails to include patients who underwent elective outpatient surgery, potentially introducing bias due to including patients with more comorbidities or more severe fracture types. Third, as the ICD-9 procedure codes do not distinguish between anatomic and reverse shoulder arthroplasty, we were unable to report exclusively on RTSA alone. This should not have a significant impact on our findings, however, as fewer than 5% of arthroplasties

performed for PHFs are anatomic TSA.²⁷ Fourth, as in most national database studies, there are no operative notes or radiographs included, limiting ability to stratify by fracture type or severity.

Conclusion

Over the last decade, SA has become the most common surgical treatment modality performed for geriatric PHFx. Index hospital complications are reduced in SA patients compared to ORIF patients, driven largely by a lower rate of blood transfusion. Although costs are decreasing and average length of stay is now lower in SA patients compared to ORIF patients, SA remains associated with higher hospital costs overall. Long-term follow-up studies are required to determine if the promising short-term outcomes will persist over time.


Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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