Increasing Rate of Shoulder Arthroplasty for Geriatric Proximal Humerus Fractures in the United States, 2010–2019

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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,\(^5\) it has been associated with superior outcomes compared to HA \(^8\) and recent studies have supported the use of SA as a surrogate for ORIF in patients older than 65.\(^7\)\(^9\) 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 31\(^{\text{st}}\), 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, 10\(^{\text{th}}\) 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,
Baseline comorbidity was quantified using the Elixhauser Comorbidity Index (ECI), a composite score of 30 comorbid conditions using all admission diagnoses and the comorbidity package in R. Higher ECI scores corresponded to greater burden of comorbid conditions. ECI score component variables were also extracted.

All result sample sizes represented national annual estimates, accounting for individual discharge-level weights from the NIS’s stratified two-stage cluster design. Descriptive statistics were used to describe both baseline characteristics and outcome parameters within each comparison group. Continuous variables were reported using mean and standard error (SE). Proportions were reported using mean and 95% confidence interval. Analysis was done using a two tailed Student’s t-test after ensuring normal distributions. For skewed, nonparametric distributions, continuous variables are presented as median (interquartile range), and analyzed using the Wilcoxon rank-sum test. Chi-squared tests were used for categorical analysis. Trend analysis for fixation method utilization was performed using univariate regression evaluating a linear relationship for year. Multivariate logistic and linear regression was used to adjust for patient and hospital characteristics associated with outcomes of interest. Patients with missing covariates were excluded from multivariate analysis. Statistical significance was defined as $P < .05$. Statistical analyses were performed using R 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

### Results

A total of 105,886 surgically managed geriatric PHF patients were identified between 2010 and 2019. Over this time period, the proportion of patients undergoing ORIF decreased from 59% to 29% and the proportion undergoing HA decreased from 32% to 4%. Meanwhile, the proportion of patients undergoing SA increased from 9.5% to 67.1% (Table 1) (Figure 1).

On average, PHF patients treated with SA were older than ORIF patients ($P < .001$) (Table 2). The likelihood of being treated with SA instead of ORIF/HA increased as age increased from 65 to 75 years old before declining as age increased past 75 (Figure 2). ORIF patients had a higher average comorbidity score ($P < .001$) and were more likely to be Black or Hispanic ($P < .001$). Specific comorbidities that were associated with an increased likelihood of ORIF instead of SA included chronic heart failure, cardiac arrhythmia, uncontrolled diabetes, metastatic cancer, coagulopathy, weight loss, fluid/electrolyte disorders, alcohol abuse, and psychosis. Renal failure or liver disease were not associated with method of PHF management.

The inpatient mortality rate was 0.58% among all patients across the entire time period and the incidence of any complication was 30.0%, with the most common being post-operative

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### Table 1. Trends in Geriatric Proximal Humerus Fracture Utilization, Cost, and Length of Stay from 2010 to 2019.

| Year | Count | ORIF (USD) | Hemi (USD) | SA (USD) | Cost (USD) | ORIF (Days) | Hemi (Days) | SA (Days) | LOS (Days) |
|------|-------|------------|------------|----------|------------|-------------|-------------|----------|-----------|
| 2010 | 6057  | 5970.38    | 625.5      | 4860.4   | 8915.9     | 5.68        | 6.7          | 5.64     | 7.78      |
| 2011 | 5390  | 5697.48    | 635.6      | 4760.8   | 9417.1     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2012 | 5455  | 5732.34    | 637.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2013 | 5450  | 5775.3    | 639.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2014 | 5500  | 5812.7    | 641.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2015 | 5450  | 5850.1    | 643.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2016 | 5500  | 5897.6    | 645.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2017 | 5450  | 5944.1    | 647.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2018 | 5450  | 5991.6    | 649.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |
| 2019 | 5450  | 6039.1    | 651.5      | 4720.7   | 9556.6     | 5.85        | 6.6          | 5.93     | 7.96      |

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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.

### Table 2. Patient and Hospital Characteristics.

|                  | Hemi (N, %) | ORIF (N, %) | SA (N, %) | \( P\)-value* |
|------------------|-------------|-------------|-----------|---------------|
| **Age**          |             |             |           |               |
| 65-74            | 7444 (43.2%)| 21488 (45.2%)| 17814 (43.4%)| < .001        |
| 75+              | 9781 (56.8%)| 26081 (54.8%)| 23278 (56.6%)|               |
| **Race/Ethnicity**|             |             |           | < .001        |
| White            | 14016 (87.3%)| 38957 (87.3%)| 35630 (90.5%)|               |
| Black            | 278 (1.7%)   | 1127 (2.5%)  | 620 (1.6%)  |               |
| Hispanic         | 1125 (7%)    | 2929 (6.6%)  | 1961 (5%)   |               |
| Other            | 630 (3.9%)   | 1601 (3.6%)  | 1163 (3%)   |               |
| **Elixhauser Comorbidity Index**|             |             |           | < .001        |
| 0                | 1375 (8%)    | 4031 (8.5%)  | 3616 (8.8%) |               |
| 1                | 3123 (18.1%) | 8493 (17.9%) | 7107 (17.3%)|               |
| 2                | 4071 (23.6%) | 10079 (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**       |             |             |           | < .001        |
| Mid-West         | 3475 (20.2%) | 10212 (21.5%)| 9732 (23.7%)|               |
| Northeast        | 3255 (18.9%) | 7721 (16.2%) | 6017 (14.6%)|               |
| South            | 6612 (38.4%) | 19648 (41.3%)| 18092 (44%) |               |
| West             | 3883 (22.5%) | 9987 (21%)   | 7251 (17.6%)|               |
| **Payer**        |             |             |           | < .001        |
| Medicare         | 15159 (88.1%)| 41350 (87%)  | 36606 (89.2%)|               |
| Private          | 1513 (8.8%)  | 4590 (9.7%)  | 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**|             |             |           | <0.001        |
| Rural            | 1851 (10.8%) | 4680 (9.9%)  | 4005 (9.8%) |               |
| Urban Non-teaching| 7442 (43.4%)| 17401 (36.7%)| 12221 (29.8%)|               |
| Urban Teaching   | 7847 (45.8%) | 25269 (53.4%)| 24831 (60.5%)|               |
| **Discharge Destination**|     |             |           | < .001        |
| In-hospital mortality | 94 (0.5%) | 348 (0.7%)   | 168 (0.4%)  |               |
| Facility         | 9241 (53.7%) | 24288 (51.1%)| 17277 (42%) |               |
| Home             | 7730 (44.9%) | 22656 (47.6%)| 23368 (56.9%)|               |
| Other            | 155 (0.9%)   | 261 (0.5%)   | 274 (0.7%)  |               |
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, \( P < .001 \)) while HA patients were more likely (OR 1.1, \( P = .032 \)). When limiting analysis to 2019 alone, the hospital

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

|                | ORIF 2010 (N = 6087) | P-value | SA 2010 (N = 987) | P-value | SA 2019 (N = 8400) | P-value |
|----------------|----------------------|---------|-------------------|---------|--------------------|---------|
| Mortality      | 0.99%                | .66     | 1.50%             | .005    | 0.30%              | .015    |
| Any Complication | 38.3%               | <.001   | 44.5%             | .06     | 16.8%              | <.001   |
| MI             | 1.31%                | .96     | 3.0%              | .03     | 0.36               | <.001   |
| PE             | 4.11%                | .54     | 0.50%             | .91     | 0.65               | .16     |
| SSI            | 0.16%                | .69     | 1.00%             | .06     | 0.06               | .015    |
| Transfusion    | 25.7%                | <.001   | 33.0%             | .001    | 7.74%              | <.001   |
| Wound complication | 1.07%            | .28     | 1.00%             | .23     | 0.238%             | .0663   |

1Abbreviation: SSI, surgical site infection.

**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.

**Figure 3.** Mean hospital costs by year and treatment group in December 2019 USD. Error bars represent 95% confidence interval.
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, 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. 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. 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. Thorsness et al limited their analysis to HA and ORIF and similarly found a lower complication rate in ORIF patients. 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.

Recent studies have also begun to report improved functional outcomes with SA compared to ORIF. Greiw 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.\textsuperscript{9} Also in 2020, the DelPhi randomized controlled trial reported significantly improved Constant score in PHF patients in the RTSA cohort instead of ORIF at 2 years follow up.\textsuperscript{5}

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,\textsuperscript{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,\textsuperscript{18} infected shoulder arthroplasty represents a far more serious complication and typically requires long-term antibiotics in addition to a two-stage revision.\textsuperscript{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.\textsuperscript{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\textsuperscript{23,24} and has been associated with worse outcomes than primary SA.\textsuperscript{25} Finally, SA for PHF is associated with significantly higher cost compared to ORIF,\textsuperscript{5,7} likely due to higher implant costs.\textsuperscript{26} Rosas et al reported an initial day reimbursement cost of more than $16,000 for RTSA compared to $6,700 for ORIF.\textsuperscript{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.\textsuperscript{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 PHF. 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

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