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Open reduction internal fixation has fewer short-term complications than shoulder arthroplasty for proximal humeral fractures

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Background: Open reduction and internal fixation (ORIF), hemiarthroplasty (HA), and anatomic or reverse total shoulder arthroplasty (TSA/RTSA) are surgical treatment options for proximal humeral fractures (PHFx). Little is known about comparative complication rates. We aimed to determine whether ORIF for PHFx has fewer 30-day complications than HA and TSA/RTSA and to define independent risk factors for 30-day complications.
Methods: Patients who underwent ORIF, HA, or TSA/RTSA for PHFx between 2006 and 2013 were identified from the National Surgical Quality Improvement Program database. Potential patient and surgical risk factors and 30-day postoperative complications were extracted. Univariate and multivariate analyses were conducted.
Results: We identified 1791 patients (1262 ORIF, 404 HA, and 125 TSA/RTSA). The overall complication rate was 13.0% in ORIF, 22.0% in HA, and 23.2% in TSA/RTSA ($P < .001$), driven primarily by rates of blood transfusion. Multivariate analyses demonstrated ORIF was an independent protective factor against minor complications ($P = .009$) and overall complications ($P = .028$) but not against major complications ($P = .351$). Risk factors for overall complications included preoperative sepsis ($P < .001$), higher American Society of Anesthesiologists Physical Status Classification ($P < .001$), dependent functional status ($P = .002$), transfusion of at least 5 units in the 72 hours before surgery ($P = .002$), longer operative time ($P = .003$), and a history of chronic obstructive pulmonary disease ($P = .028$).
Conclusions: After adjusting for patient factors, ORIF for PHFx remains an independent protective factor against overall complications and minor complications compared with HA and TSA/RTSA, primarily due to lower rates of blood transfusion. Patient comorbidities play a larger role than the procedure selected in predicting short-term complications.
Level of evidence: Level III, Retrospective Cohort Comparison Using Large Database, Treatment Study.

Keywords: Proximal humeral fractures; open reduction and internal fixation; hemiarthroplasty; shoulder arthroplasty

Proximal humeral fractures (PHFx) are increasingly common injuries, especially afflicting elderly osteoporotic patients.[6,15,45] These injuries were responsible for 185,000 emergency department visits in the United States in 2008

Institutional Review Board approval was not necessary for this study because the data were obtained from a deidentified national database.

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alone.[32] Patients experience significant pain and functional loss, particularly for displaced 3-part and 4-part fractures.[41-43] PHFx treatment paradigms are evolving, with available options including nonoperative treatment,[41,42,57] closed reduction and percutaneous pinning,[26,29] open reduction and internal fixation (ORIF),[41,44,51,52] hemiarthroplasty (HA),[42,52] and anatomic and reverse total shoulder arthroplasty (TSA/RTSA).[10-13,16,20,28,33,37,49] RTSA has increasing interest for complex PHFx in elderly patients.[1,31,48]

ORIF, HA, and TSA/RTSA for PHFx have distinct risks and benefits. ORIF preserves bone stock and the potential for anatomic healing, with complications including loss of reduction, screw cutout, intra-articular screw penetration, and avascular necrosis.[44,51,53] HA avoids the complications of ORIF at the expense of glenoid wear, component loosening, and tuberosity nonunion leading to shoulder dysfunction.[4,7,9,23,34,35,47] RTSA simplifies rehabilitation and is less reliant on greater tuberosity healing,[11,20-22] with complications including scapular notching, hematoma, infection, glenoid loosening, and instability.[2,24,25,56]

There is limited and conflicting literature comparing complications among ORIF, HA, and TSA/RTSA for PHFx. Chalmers et al[13] compared 9 patients undergoing each treatment with 1-year follow-up but could not compare complication rates due to the small sample size. A systematic review found overall complication rates of 11.3% for HA, 15% for ORIF, and 18.9% for RTSA.[25] Another systematic review of 14 studies comparing 232 RTSA patients and 263 HA patients reported complication rate that was almost 4-times higher for RTSA (19.4%) than for HA (5.6%), primarily due to higher rates of neurologic injury and ‘‘pain syndrome’’ for RTSA.[39] The reoperation rate was 5.8% for the RTSA group and 9.1% for HA group, which was not significant.[39] In contrast, prospective studies comparing HA and RTSA have failed to show a difference in the complication rate.[16,49] The American Board of Orthopaedic Surgery (ABOS) database also showed no difference in the complication rate for HA and RTSA.[1]

The aims of this study were to use the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database (1) to determine whether ORIF for PHFx has fewer 30-day complications than HA and TSA/RTSA after accounting for patient characteristics, (2) to define independent patient and surgical risk factors for 30-day complications after surgical treatment of PHFx, and (3) to analyze trends in surgical management of PHFx from 2006 to 2013 in the United States. We hypothesized that patient comorbidities would be better predictors of risk factors than procedure type for 30-day complications after surgically treated PHFxs. We also hypothesized that between 2006 and 2013, TSA/RTSA would be more frequently used and that HA would be less frequently used.

Materials and methods

Data source and patient selection

The American College of Surgeons NSQIP database contains prospectively collected data for patients who have surgery at more than 400 participating academic and community hospitals in the United States.[14,17,27,36] Surgical Clinical Reviewers (SCRs) at NSQIP hospitals assess hospita]l records to collect defined patient demographics, medical comorbidities, intraoperative data, and 30-day postoperative complications based on criteria specified by the NSQIP program. SCRs undergo specific training from NSQIP and regular audits of SCR interobserver reliability to exclude hospitals with an SCR disagreement rate exceeding 5% or less than 80% 30-day follow-up data (http://site.acsnsqip.org/wp-content/uploads/2014/11/ACS_NSQIP_PUF_User_Guide_2013.pdf).

We queried the NSQIP database to identify all patients undergoing surgical treatment of acute PHFx between 2006 and 2013. The interval was dictated by all years of data available in the NSQIP database, which at the time of analysis were 2006 to 2013. A combination of International Classification of Diseases-9th Revision (ICD-9) codes and Current Procedural Terminology (CPT; American Medical Association, Chicago, IL, USA) codes were used to identify patients undergoing TSA/RTSA, HA, and ORIF for acute PHFx. ORIF was defined as CPT code 23615 or 23630. HA was defined as CPT code 23470 or 23472 combined with one of the following ICD-9 codes: 812.00, 812.01, 812.02, 812.03, 812.09, 812.10, 812.11, 812.12, 812.13, 812.19, 812.20, or 812.30 (online Appendix). TSA/RTSA was defined as CPT code 23472 combined with one of the same ICD-9 codes. Patients with preoperative wound infections and patients aged younger than 18 years were excluded. Patients undergoing closed reduction and percutaneous pinning were excluded because the sample size was too small to allow meaningful comparison.

Data collection

Patient demographics, potential risk factors, and 30-day postoperative complications were extracted from the NSQIP database. Complications were divided into major and minor complications, as previously defined, with death considered a major complication.[38] All of the complications for patients with multiple complications were reported toward individual complication rates, but major, minor, and overall complication rates counted such patients once. Continuous variables were converted to categoric variables: age <30, 30-60, >60 years; operative time <90 or >90 minutes; and BMI <18.5, 18.5-25, 25-30, >30 kg/m^2. The Charlson Comorbidity Index was determined.[8]

Statistical analysis

We performed three separate analyses. To determine trends over time, the number of ORIF, HA, and TSA/RTSA procedures for a given year was divided by the total number of surgeries in the NSQIP database for that year to generate a percentage. Next, the number of patients undergoing HA, ORIF, and TSA/RTSA was divided by the total number of patients undergoing surgical treatment for PHFx. Pearson correlations were used for analysis.

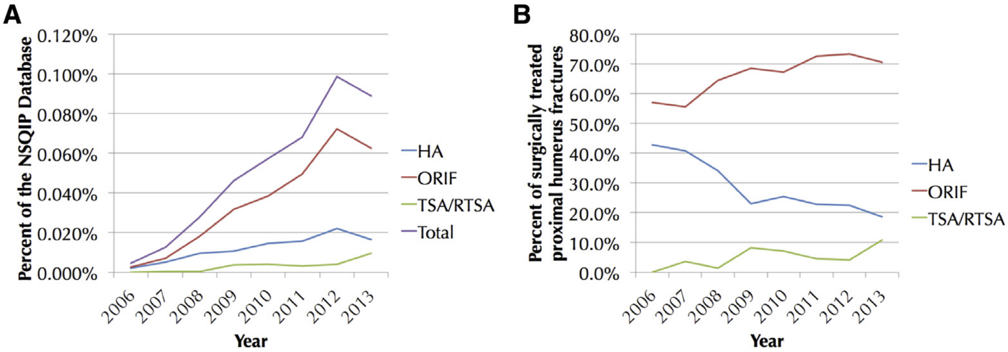

Figure 1 (**A**) Surgical treatment of proximal humeral fractures increased over time for operative years 2006 to 2013. This is expressed as a percentage of overall surgical procedures in the National Surgical Quality Improvement Program (*NSQIP*) database for a given year. (**B**) Open reduction and internal fixation (*ORIF*) and total shoulder arthroplasty/reverse total shoulder arthroplasty (*TSA/RTSA*) have increasingly been used, whereas use of hemiarthroplasty (*HA*) has declined.

To determine whether ORIF, HA, and TSA/RTSA differed in patient characteristics and complication rates, χ^2 tests and Fisher exact tests were used as appropriate.

Multivariate regression analyses were performed to determine risk factors for complications. Univariate analyses were conducted first for overall complications, major complications, and minor complications to determine which variables should be included in the multivariate analyses. Categoric variables were compared using χ^2 tests and the Fisher exact tests, as appropriate, and continuous variables were compared using Mann-Whitney *U* tests, because all were non-Gaussian based on Kolmogorov-Smirnov testing. To be inclusive, any variable with $P < .2$ on any of the univariate analysis and with >60% of data present was included in all multivariate analyses. Three multivariate logistic regression analyses were performed to identify independent risk factors for overall complications, major complications, and minor complications. Procedure type (ORIF, HA, and TSA/RTSA) was included as a variable in the univariate and multivariate regression analyses. Significance was $P < .05$. SPSS 18 software (IBM Corp, Armonk, NY, USA) was used for statistical analyses.

Results

Demographics

The study included 1791 patients who underwent PHFx treatment, comprising 1262 (70.5%) with ORIF, 404 (22.6%) with HA, and 125 (7.0%) with TSA/RTSA. Surgical treatment of PHFx as a percentage of total surgical procedures in the NSQIP database increased from 0.005% in 2006 to 0.089% in 2013 ($P < .001$), with significant absolute increases in ORIF ($P < .001$), HA ($P = .001$), and TSA/RTSA ($P = .005$; Fig. 1, *A*). As a percentage of PHFx procedures, ORIF increased from 57.1% to 70.5% and TSA/RTSA from 0% to 10.9%, with HA decreasing from 42.9% to 18.6% ($P < .001$; Fig. 1, *B*).

Patient demographics differed among the ORIF, HA, and TSA/RTSA groups (Supplementary Table I). ORIF patients were more commonly male (29.6% for ORIF, 23.1% for HA, and 16.8% for TSA/RTSA; $P = .001$), younger (63 ± 14 years for ORIF, 70 ± 11 years for HA, and 75 ± 9 for TSA/RTSA; $P < .001$), and smokers (20.9% for ORIF, 14.1% for HA, and 9.6% for TSA/RTSA; $P < .001$). Comorbidities differed among the groups, including history of myocardial infarction ($P < .001$), hypertension ($P < .001$), dialysis ($P = .019$), history of transient ischemic attack ($P = .016$), diabetes ($P = .024$), American Society of Anesthesiologists (ASA) Physical Status Classification ($P < .001$), and Charlson Comorbidity Index ($P = .005$). ORIF patients had the fewest comorbidities. ORIF patients more commonly had outpatient surgery (33.0% for ORIF, 9.7% for HA, and 4% for TSA/RTSA; $P < .001$), shorter operative times (115 ± 61 minutes for ORIF, 126 ± 51 minutes for HA, and 143 ± 69 minutes for TSA/RTSA; $P < .001$), and were discharged home (81.8% for ORIF, 69.6% for HA, and 55.3% for TSA/RTSA; $P < .001$). The percentage of cases with surgical resident involvement differed among the groups (32.5% for ORIF, 23.7% for HA, and 41.7% for TSA/RTSA; $P = .01$).

Complications

Supplementary Table II reports 30-day postoperative major, minor, and overall complications of ORIF, HA, and TSA/RTSA. Major complications occurred in 4.0% of ORIF, 4.5% of HA, and 5.6% of TSA/RTSA ($P = .691$), most commonly return to the operating room. Minor complications occurred in 10.1% of ORIF, 18.3% of HA, and 20.8% of TSA/RTSA ($P < .001$), most commonly a higher rate of bleeding requiring transfusion for the HA and TSA/RTA groups. Bleeding requiring transfusion represented 67.0% of overall complications. The mortality rate did not differ among the procedure types (1.0% for ORIF, 0.7% for HA, and 2.4% for TSA/RTSA; $P = .251$). The overall complication rate was 13.0% in ORIF, 22.0% in HA, and 23.2% in TSA/RTSA ($P < .001$), driven by higher rates of bleeding requiring transfusion for HA and TSA/RTSA. Within those who underwent TSA/RTSA, the operative year was not different between those with and without major complications ($P = .831$), minor complications ($P = .069$), or overall complications ($P = .068$).

Multivariate analyses

Univariate analysis was performed to identify potential risk factors for minor, major, and overall complications of surgical PHFx treatment (Supplementary Table III). Those variables identified by univariate regression as potentially significant were then used to perform multivariate logistic regression analyses to determine independent risk factors for minor, major, and overall complications, as well as whether procedure type is an independent risk factor for complications (Table I).

For overall complications, multivariate analysis (odds ratio [95% confidence interval]) revealed independent risk factors were preoperative sepsis (3.937 [2.123-7.299], $P < .001$), ASA class (1.848 [1.422- 2.402], $P < .001$), dependent functional status (1.933 [1.280-2.917], $P = .002$), transfusion of at least 5 units in 72 hours before surgery (3.039 [1.493-6.173], $P = .002$), longer operative time (1.690, [1.194, 2.391], $P = .003$), and a history of chronic obstructive pulmonary disease (COPD; 2.020 [1.081-3.773], $P = .028$). ORIF was protective against complications (0.572 [0.348-0.942], $P = .028$). HA was not associated with complications ($P = .800$), and TSA/RTSA was the reference category. This model explained 17.5% of the variance in the complication rate and correctly predicted complication occurrence in 84.6% of cases.

For major complications, multivariate analysis (odds ratio [95% confidence interval]) revealed independent risk factors were preoperative sepsis (4.444 [1.931-10.204], $P < .001$), higher BMI (1.558 [1.149-2.110], $P = .004$), history of COPD (3.390 [1.224-2.110], $P = .004$), dependent functional status (2.138 [1.099-4.156], $P = .025$), and male gender (1.832 [1.044-3.205], $P = .035$). Neither ORIF nor HA was predictive of major complications ($P = .351$ and $P = .463$, respectively) with TSA/RTSA as the reference category. This model explained 16.7% of the variance in major complication rate and correctly predicted major complication occurrence in 95.8% of cases.

For minor complications, multivariate analysis (odds ratio [95% confidence interval]) revealed independent risk factors were ASA class (1.947 [1.465-2.589], $P < .001$), preoperative sepsis (2.646 [1.368-5.128], $P = .004$), longer operative time (1.740 [1.186-2.553], $P = .005$), transfusion of at least 5 units in 72 hours before the procedure (2.740 [1.340-5.618], $P = .006$), dependent functional status (1.753 [1.128-2.724], $P = .013$), and history of a bleeding disorder (1.908 [1.067-3.413], $P = .029$). ORIF was protective against minor complications (0.498 [0.295-0.839], $P = .009$). HA was not associated with minor complications ($P = .564$), and TSA/RTSA was the reference category. This model explained 16.0% of the variance in the minor complication rate and correctly predicted minor complication occurrence in 87.1% of cases.

Table I Independent significant risk factors for minor, major, and overall complications of surgical treatment of proximal humeral fracture based on multivariate logistic regression analyses*

Variable	Odds ratio	95% Confidence interval	*P* value
Overall complications			
Preoperative sepsis	3.937	2.123-7.299	<.001
Higher ASA class	1.848	1.422-2.402	<.001
Functional dependence	1.933	1.280-2.917	.002
Preoperative transfusion ≥5 units in 72 hours	3.040	1.493-6.173	.002
Longer operative time	1.69	1.194-2.391	.003
History of COPD	2.020	1.081-3.774	.028
ORIF	0.572	0.348-0.942	.028
Major complications			
Preoperative sepsis	4.444	1.931-10.204	<.002
Higher BMI	1.558	1.149-2.110	.004
History of COPD	3.390	1.224-9.434	.019
Functional dependence	2.138	1.099-4.156	.025
Male gender	1.832	1.044-3.205	.035
Minor complications			
ASA class	1.947	1.465-2.589	<.001
Preoperative sepsis	2.646	1.368-5.128	.004
Longer operative time	1.740	1.186-2.553	.005
Preoperative transfusion ≥5 units in 72 hours	2.740	1.340-5.618	.006
ORIF	0.498	0.295-0.839	.009
Functional dependence	1.753	1.128-2.724	.013
Bleeding disorder	1.908	1.067-3.413	.029

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *ORIF*, open reduction internal fixation.

* ORIF was protective against minor complications.

Discussion

PHFxs are increasingly common and often result in pain and loss of function.[6,15,41-43,45] Surgical treatment options include ORIF, HA, and TSA/RTSA, but conflicting data exist on complication rates for these options.[1,16,25,39,49] This study analyzed 1791 patients from the NSQIP database undergoing surgical treatment for PHFx from 2006 to 2013 and found that overall surgical volume increased and that use of ORIF and TSA/RTSA was increasing but that HA declined. The overall complication rate was lower for ORIF (13%) than for HA (22.0%) and TSA/RTSA (23.2%). After controlling for patient differences among the treatment groups, ORIF continued to be an independent protective factor against overall and minor complication rates, driven by higher rates of blood transfusion for HA and TSA/RTSA. Significant risk factors for overall complications of surgically treated PHFx were preoperative sepsis, ASA class, dependent functional status, transfusion of at least 5 units in the 72 hours before surgery, longer operative time, and a history of COPD.

PHFxs are increasing in incidence, likely related to an aging population leading to increased osteoporosis and the potential for fragility fractures.[6,45] Several authors have analyzed recent shifts in management of these fractures, finding increased surgical management and a recent shift toward RTSA and away from HA.[1,5,31,48] A recent study of the New York State database from 1990 to 2010 found an increase in the incidence of PHFxs, particularly among those aged older than 65 years, and operative management increased by more than 40%, with a similar trend toward ORIF and TSA and away from HA between 2001 and 2010.[31] Using the ABOS database, Acevedo et al[1] demonstrated an increase in RTSA use for treating PHFxs from 2% of fractures in 2005 to 38% in 2012. Schairer et al[48] used the Nationwide Inpatient Sample from 2011 to determine that RTSA represented 26.1% of the arthroplasty treatments of PHFxs compared with 69.8% for HA and 4.1% for anatomic TSA.

Our findings confirm the rapid increase in TSA/RTSA relative to HA, showing that this trend applies to practice patterns from the more than 400 hospitals across the United States participating in NSQIP. If we exclude ORIF, our data show an increase from 0% to 36.8% in the proportion of surgically treated PHFxs in which TSA/RTSA is used. These trends likely relate to both the increasing incidence of PHFx and a tendency among orthopedic surgeons toward surgical management of these fractures with modern proximal humeral locking plates and RTSA techniques.

Rates of complications after ORIF, HA, and TSA/RTSA for PHFxs are a subject of controversy in the literature. Prospective studies comparing RTSA and HA have failed to show a difference in the complication rate.[16,49] Acevedo et al[1] reported no significant difference in complication rates between HA (19.1%) and RTSA (24.6%) using ABOS data. In contrast, several systematic reviews have demonstrated that RTSA has significantly higher complication rates.[19,25,39] A comprehensive systematic review of 4536 patients in 92 studies showed the overall complication rate was 11.3% for HA, 15% for ORIF, and 18.9% for RTSA.[25] Namdari et al[39] found in a systematic review that RTSA had a complication rate of 19.4% vs only 5.6% for HA. In a study using the National Hospital Discharge Survey data from 2003 to 2007, the risk of in-hospital adverse events was higher for the combined arthroplasty group (37%) than for the ORIF group (26%).[40] The bulk of adverse events in that study were related to postoperative anemia and the need for transfusion, similar to the minor complication findings in our study. Differences among studies in what is considered a complication, follow-up interval, and methods for accounting for differences in patient medical comorbidities between treatments likely account for much of the variation in reported complication rates. All of these studies are hampered in that they do not focus on orthopedic-specific complications.

Multiple studies have recently assessed risk factors for complications after shoulder arthroplasty using the NSQIP database and others,[3,18,50,54,55] although none to our knowledge has compared complications of ORIF, HA, and TSA/RTSA for PHFxs while controlling for patient comorbidities. Shields et al[50] used NSQIP data for HA and TSA/RTSA performed for all indications, finding on multivariate analysis that risk factors for major complications were emergency case, pulmonary comorbidity, anemia with a hematocrit of less than 36%, and wound class III or IV. In a multistate database study, Zhang et al[55] found that each patient comorbidity increased readmission risk by 20% and that other factors were female gender, African American race, discharge to nursing facility, and Medicaid insurance. Petrigliano et al[46] reported complications and risk factors for ORIF of PHFx using the California inpatient database from 1994 to 2005, finding patients older than 65 years, male sex, residence in a low-income area, and medical comorbidities were associated with short-term complications. Our study found that patient factors play a larger role in predicting complications than the surgical procedure selected. ORIF was protective against overall and minor complications due to the higher transfusion rates in HA and TSA/RTSA. Longer operative time was also associated with overall, major, and minor complications, possibly related to blood loss.

This study has limitations, mostly related to the limitations of the NSQIP database itself. First, TSA and RTSA share a CPT code, so it is not possible to separately analyze these procedures using this database, and ICD-9 procedure codes are not available in the database. Anatomic TSA is rarely used for acute PHFxs, and therefore this group likely represents mainly RTSA. For instance, Schairer et al[48] found that in 2011, anatomic TSA was used for only 4.1% of arthroplasty treatment of PHFxs compared with 26.1% for RTSA and 69.8% for HA.

Second, although we identified patient history of bleeding disorder and preoperative transfusion as risk factors for postoperative complications including transfusion, the database does not allow us to tease out the contributions of these and other inter-related factors. Surgeons should consider these factors on a case-by-case basis.

Third, this study did not include nonoperative treatment as a control group because the NSQIP database only collects data for patients undergoing surgical treatment.

Fourth, surgeon and hospital volume were not analyzed because this information is not contained in the NSQIP database to protect confidentiality, even though this factor may play a role in complication rates.[1,30]

Fifth, the NSQIP database does not contain orthopedic-specific variables, such as fracture pattern, osteoporosis, rotator cuff status, axillary nerve injury, implant choice, and incision choice, which might affect treatment choice and complication rate. Also not included are orthopedic-specific complications such as scapular notching, screw cutout or intra-articular penetration, dislocation, arthrofibrosis, nonunion, malunion, greater tuberosity migration, and component loosening.

Sixth, the NSQIP database only contains data for the 30-day postoperative period. Complications that occur after this period would be missed, so the complication rates reported in this study would tend to underestimate the true rates. In addition, midterm and long-term complications and outcomes of ORIF, HA, and ORIF are important considerations that cannot be analyzed with this database.

Seventh, we are unable to calculate an incidence relative to a baseline population because NSQIP contains only patients who underwent surgery.

Finally, database studies such as this result in large sample sizes that may result in many statistically significant findings that may have small effect size. For this reason, the multivariate results are reported with odds ratios to demonstrate the magnitude of each statistically significant independent risk factor for complications.

Conclusion

After adjusting for patient factors, ORIF for PHFxs remains an independent protective factor against overall complications and minor complications compared with HA and TSA/RTSA, primarily due to lower rates of blood transfusion. Surgeons should counsel patients undergoing surgical treatment of PHFxs that patient comorbidities play a larger role than the procedure selected in predicting short-term complications.

Disclaimer

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jse.2015.09.011.

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Supplementary Table I Demographic comparison of patients undergoing ORIF, HA, and TSA/RSA for proximal humeral fractures

Variable	ORIF (%)	HA (%)	TSA/RTSA (%)	Total (%)	*P* value*
Sex					
Female	70.4	76.9	83.2	72.8	**.001**
Male	29.6	23.1	16.8	27.2	
Age					
<30 y	2.7	0.3	0.0	2.0	**<.001**
30-60 y	38.6	15.2	9.8	31.4	
>60 y	58.7	84.5	90.2	66.6	
Race					
Asian	2.1	1.3	2.5	1.9	.885
Black	3.7	3.5	2.5	3.6	
Hispanic	6.5	6.7	7.4	6.6	
Native American	0.5	1.1	0.0	0.6	
White	87.1	87.5	87.6	87.2	
Functional status					
Dependent	9.4	12.9	10.4	10.3	.136
Independent	90.6	87.1	89.6	89.7	
Smoking	20.9	14.1	9.6	18.6	**<.001**
Alcohol	5.3	7.7	0.0	5.6	.097
Dyspnea	6.0	7.9	11.2	6.8	.055
COPD	6.3	6.9	9.6	6.6	.347
CHF	1.2	1.0	1.6	1.2	.854
History of MI	0.2	0.0	6.3	0.5	**<.001**
Hypertension	50.1	66.3	73.6	55.5	**<.001**
Dialysis	0.8	0.0	2.4	0.7	**.019**
History of TIA	3.1	7.7	2.1	4.2	**.016**
Stroke	2.7	1.5	6.3	2.7	.188
Steroid use	3.8	4.2	7.2	4.1	.19
Diabetes	18.4	22.3	27.2	19.9	**.024**
ASA class					
1	6.6	2.2	0.0	5.1	**<.001**
2	44.1	36.2	34.4	41.6	
3	43.1	55.1	57.6	46.8	
4	6.3	6.5	8.0	6.4	
BMI					
<18.5 kg/m^2	2.7	1.8	1.6	2.4	.091
18.5-25 kg/m^2	31.6	24.3	25.2	29.5	
25-30 kg/m^2	27.6	30.2	31.7	28.5	
>30 kg/m^2	38.2	43.7	41.5	39.7	
Admission status					
Inpatient	67.0	90.3	96.0	74.3	**<.001**
Outpatient	33.0	9.7	4.0	25.7	
Discharge destination					
Acute rehab	4.3	8.3	16.0	6.0	**<.001**
Home	81.8	69.6	55.3	77.3	
Skilled nursing	13.9	21.9	28.7	16.6	
Resident involvement					
Yes	32.5	23.7	41.7	30.9	**.01**
No	67.5	76.3	58.3	69.1	
Operative time					
<90 min	38.4	22.0	16.8	33.2	**<.001**
>90 min	61.6	78.0	83.2	66.8	

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *HA*, hemiarthroplasty; *MI*, myocardial infarction; *ORIF*, open reduction and internal fixation; *TIA*, transient ischemic attack; *TSA/RTSA*, total shoulder arthroplasty/reverse total shoulder arthroplasty.

* Values in bold are statistically significant ($P < .05$).

Supplementary Table II Major, minor, and overall complications for open reduction and internal fixation, hemiarthroplasty, and total shoulder arthroplasty/reverse total shoulder arthroplasty

Complication	ORIF		HA		TSA/RTSA		*P* value*
	No.	%	No.	%	No.	%	
Major							
Deep infection	5	0.4	1	0.2	0	0.0	.432
Sepsis	4	0.3	0	0.0	1	0.8	.299
Septic shock	4	0.3	0	0.0	0	0.0	.432
Dehiscence	0	0.0	0	0.0	0	0.0	
Pulmonary embolism	4	0.3	3	0.7	1	0.8	.444
Ventilator for >48 hours	6	0.5	1	0.2	1	0.8	.693
Unplanned intubation	6	0.5	2	0.5	1	0.8	.887
Acute renal failure	2	0.2	0	0.0	0	0.0	.657
Cardiac arrest	2	0.2	0	0.0	1	0.8	.159
Myocardial infarction	0	0.0	0	0.0	0	0.0	
Cerebrovascular accident	2	0.2	2	0.5	0	0.0	.395
Coma	0	0.0	0	0.0	0	0.0	
Return to the OR	23	1.8	8	2.0	1	0.8	.674
Total major (including death)	51	4.0	18	4.5	7	5.6	.691
Minor							
Superficial infection	3	0.2	3	0.7	1	0.8	.275
Pneumonia	11	0.9	3	0.7	1	0.8	.969
Urinary tract infection	14	1.1	7	1.7	0	0.0	.27
Deep venous thrombosis	8	0.6	1	0.2	0	0.0	.451
Bleeding requiring transfusion	101	8.0	63	15.6	25	20.0	**<.001**
Peripheral nerve injury	4	0.3	0	0.0	0	0.0	.432
Renal Insufficiency	2	0.2	1	0.2	0	0.0	.831
Total minor	128	10.1	74	18.3	26	20.8	**<.001**
Death	12	1.0	3	0.7	3	2.4	.251
Overall complication	164	13.0	89	22.0	29	23.2	**<.001**

HA, hemiarthroplasty; *OR*, operating room; *ORIF*, open reduction with internal fixation; *TSA/RTSA*, total shoulder arthroplasty/reverse total shoulder arthroplasty.

* Values in bold are statistically significant ($P < .05$).

Supplementary Table III Significant differences identified on univariate analysis of risk factors for minor, major, and overall complications

Variable	Minor complications		*P*	Major complications		*P*	Overall complications		*P*
	With	Without		With	Without		With	Without	
Female gender	74	73	.549	60	73	.011	73	73	.948
Race			.149			.936			.249
Asian	1	2		1	2		1	2	
Black	6	3		3	4		6	3	
Hispanic	8	7		6	7		7	7	
White	84	88		90	87		85	88	
Smoker	14	19	.058	28	18	.038	16	19	.283
Dyspnea	10	6	.069	16	6	.002	10	6	.012
Functional independence	80	91	<.001	75	90	<.001	80	92	<.001
History of									
Ventilator dependence	0.4	0.0	.127	0.1	0.0	1.000	0.4	0.0	.157
COPD	14	6	<.001	21	6	<.001	15	5	<.001
CHF	2	1	.174	4	1	.056	2	1	.359
Steroid use	7	4	.019	8	4	.092	7	4	.017
Weight loss	1.3	0.6	.189	6.6	0.4	<.001	2.1	0.4	.001
Ascites	1	0	.016	0.0	0.1	1.000	0.7	0.0	.025
Hypertension	68	54	<.001	62	55	.256	67	53	<.001
Disseminated cancer	3	1	.136	7	1	.005	3	1	.046
Bleeding disorder	12	5	<.001	9	5	.135	11	4	<.001
Prior transfusion	8	2	<.001	8	2	.003	8	2	<.001
Prior sepsis	9	3	<.001	16	3	<.001	10	2	<.001
BMI, kg/m^2	30 ± 8	29 ± 7	.492	27 ± 8	29 ± 8	.001	29 ± 9	29 ± 7	.321
CCI	0.8 ± 1.3	0.4 ± 1.0	<.001	0.9 ± 1.7	0.5 ± 1.0	<.001	0.8 ± 1.3	0.4 ± 1.0	<.001
Diabetes	28	19	.002	18	20	.745	26	19	.006
Age, y	71 ± 11	64 ± 14	<.001	67 ± 13	65 ± 14	.063	70 ± 12	64 ± 14	<.001
<30	0	2		0	2		0	2	
30-60	17	33		25	32		19	34	
>60	83	65		75	66		81	64	
Operative time, min	146 ± 89	116 ± 54	<.001	134 ± 56	119 ± 60	.122	144 ± 84	115 ± 54	<.001
ASA class	2.9 ± 0.7	2.5 ± 0.7	<.001	2.8 ± 0.7	2.5 ± 0.7	.002	2.9 ± 0.7	2.5 ± 0.7	<.001
Procedure			<.001			.691			<.001
HA	33	21		24	23		32	21	
ORIF	56	73		67	71		58	73	
RTSA	11	6		9	7		10	6	

BMI, body mass index; *CHF*, congestive heart failure; *CCI*, Charleson Comorbidity Index; *COPD*, chronic obstructive pulmonary disease.