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Does resident involvement have an impact on postoperative complications after total shoulder arthroplasty? An analysis of 1382 cases

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Background: The impact of resident involvement on total shoulder arthroplasty (TSA) complication rate is unknown. The purpose of this study was to assess whether resident involvement in TSA is associated with 30-day complication rates.

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was searched for all patients who underwent TSA between 2005 and 2012. Data were extracted for patient preoperative demographics, intraoperative variables, resident involvement in surgery, and 30-day postoperative complications. Resident and nonresident cases were grouped by a matched propensity score analysis. Univariate and multivariate analysis was performed to assess the effect of resident involvement on postoperative complications.

Results: We analyzed 1382 patients who underwent primary TSA, with matched groups of 691 with and 691 without resident involvement. The overall rate of 30-day complications was 2.60% in TSAs in which a resident was involved compared with 3.91% when no resident was involved ($P = .173$). Operative time and hospital stay were shorter in cases in which a resident was present ($P = .002$ and $P < .001$, respectively). Independent risk factors significantly associated with TSA complications identified by multivariate regression were higher patient age, higher American Society of Anesthesiologists classification, congestive heart failure, insulin-dependent diabetes, and peripheral vascular disease.

Conclusion: Resident involvement in TSA procedures is not a risk factor for 30-day complications. Patient factors including increased age, diabetes, and cardiac disease are risk factors for TSA complications. This information can be used in preoperative counseling to reassure patients about safety of resident involvement in TSA and to optimize patient comorbidities before surgery.

Keywords: Total shoulder arthroplasty; resident involvement; complications; NSQIP

Total shoulder arthroplasty (TSA), including anatomic and reverse TSA, is an effective treatment for patients with shoulder disorders including glenohumeral degenerative joint disease, rotator cuff arthropathy, and complex proximal humerus fractures.[1-3,17,36] Patients undergoing TSA

No Institutional Review Board approval was necessary for this study because the data were obtained from a de-identified national database.

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experience high rates of functional improvement, pain relief, and improved overall physical well-being.[9,16,26,30] The number of TSA procedures performed in the United States has been dramatically increasing in recent years, and evidence has shown the procedure to be cost-effective.[3,23-25] Nevertheless, both early and long-term TSA complications remain a concern, with recent studies reporting 30-day to 90-day postoperative complication rates of 3.6% to 25%.[8,10,11,28,31,33-35]

Orthopedic residency training prepares residents to transition to independent practice through a system of graduated responsibility. This has led to concern that resident involvement in medical care and surgery in particular could adversely affect patient outcomes.[12,21] In addition, there is concern of the ''July effect,'' in which inexperience among residents who graduated to the next postgraduate year on July 1 would lead to poor patient care at this time of year.[6,7] To date, there have been several analyses of the impact of resident involvement on rates of short-term complications after orthopedic surgery, with most data suggesting no difference in complication rates based on resident involvement in spine surgery and total hip and knee arthroplasty.[4,18-20,27,29,37]

Currently, there are no studies that evaluate the impact of resident involvement on TSA complication rates. Our primary objective was to determine the role of resident involvement in 30-day TSA complication rates using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database. The null hypothesis was that there is no difference in TSA complication rates based on resident involvement, and the alternative hypothesis was that there is a difference in TSA complication rates based on resident involvement. Our secondary objective was to determine patient preoperative and operative risk factors independently associated with 30-day TSA complications in this large nationwide database.

Materials and methods

Data source

The NSQIP database is prospectively collected by the American College of Surgeons, with current data from >400 hospitals (http://site.acsnsqip.org). Hospitals include public and private, academic and nonacademic institutions, of a range of sizes, from across the United States. Surgical clinical reviewers evaluate the patients' medical records to collect preoperative demographics, medical comorbidities, preoperative laboratory results, and intraoperative data including resident involvement. The surgical clinical reviewers prospectively follow the patients' medical records to document complications including morbidity broken down into subcategories, mortality, readmissions, and reoperations in the 30-day postoperative period. The NSQIP data have been shown to be more accurate than other databases reporting complications, databases generated from insurance claims, and traditional surgical mortality and morbidity conferences.[13,15,22] The NSQIP database has been successfully used to determine risk factors for complications in a variety of orthopedic surgical procedures.[4,18-20,27,29,37]

Patient selection and data collection

The NSQIP database was searched to identify all patients who underwent primary TSA between 2005 and 2012. Patients were selected on the basis of *Current Procedural Terminology* (CPT) code 23472, which includes both anatomic and reverse TSA (''Arthroplasty, glenohumeral joint; total shoulder [glenoid and proximal humeral replacement (e.g., total shoulder)]''). Exclusion criteria included preoperative diagnoses of mechanical complications that may indicate a revision procedure and preoperative diagnoses of infection, malignant disease, or fracture. Patients undergoing TSA for fracture made up about 5% of the total cohort and were excluded because there are likely different outcomes expected after fracture than with an elective shoulder arthroplasty for osteoarthritis. In addition, patients were excluded when the presence or absence of surgical resident involvement in the TSA was not recorded or if the 2 distinct database indicators indicating resident involvement were discordant. The data collected were preoperative demographic, comorbidity, and laboratory data; operative variables including resident involvement, operative time, and transfusion rate; and 30-day postoperative complications. Surgical resident involvement data were extracted and analyzed in total and also stratified on the basis of postgraduate year (PGY) level of training (junior resident [PGY1-3], senior resident [PGY4-5], and fellow [PGY6 and above]). The specific outcomes identified in the 30-day postoperative period were surgical site infection, wound dehiscence, pneumonia, unplanned intubation, deep venous thrombosis, pulmonary embolism, ventilation >48 hours, renal insufficiency, acute renal failure, urinary tract infection, coma, stroke, peripheral neurologic deficit, cardiac arrest, myocardial infarction, sepsis, death, unplanned hospital readmission, and reoperation.

Statistical analysis

To account for patient selection bias based on resident involvement that may occur in retrospective analyses of prospectively collected data, a propensity score matching algorithm was used to create 2 groups with similar characteristics, except for 1 with and 1 without resident involvement in the procedure.[18-20] A propensity score determines the conditional probability of a patient's having resident involvement in TSA based on preoperative variables including demographics, comorbidities, laboratory values, and American Society of Anesthesiologists (ASA) grade. Thus, patients with and without resident involvement but with similar preoperative characteristics, and thus similar propensity scores, are selected for inclusion. Propensity score analyses control for the potential effects of confounding and allow improved determination of causal effects in observational studies.[5,14] Of note, preoperative international normalized ratio and blood urea nitrogen level were excluded from propensity score matching because >20% of patients were missing these data.

Preoperative demographic, comorbidity, and laboratory variables were compared for resident-involved and non-resident-involved cases by χ^2 test for categorical data and *t* test for continuous data. In the stratified analysis of resident level of training, a Fisher exact test was used instead of a χ^2 test because of small expected frequencies. Next, intraoperative (operative time and

transfusion requirement) and postoperative complications were compared in univariate analysis with χ^2 (categorical data) and *t* tests (continuous data). Finally, we performed a multivariable analysis using stepwise multiple regression with backward elimination, which initially included all variables from the univariate analysis with a *P* value $< .1$ with iterative removal of variables from the final model until only those with a *P* value of $< .05$ remain.

Stata (version 12.1; StataCorp, College Station, TX, USA) was used for all statistical analysis, with significance determined with a *P* value $< .05$. We chose not to apply Bonferroni correction for multiple comparisons to maintain high sensitivity for detecting differences between resident-involved and non-resident-involved TSA complication rates.

Results

Patient demographics

A total of 4778 patients underwent TSA between 2005 and 2012. Initially, 50% of cases (2404) were excluded because resident involvement was not recorded in the database. Next, 228 patients were removed after exclusion criteria were applied. After propensity score matching removed 664 patients for missing variables, a total of 1382 patients were included in this study. There were 691 matched cases with and 691 cases without resident involvement. As a result of propensity score matching, all patient preoperative demographics did not differ significantly between resident-involved and non-resident involved TSA cases (Table I).

Complication rates based on resident involvement

A univariate model was used to determine unadjusted 30-day TSA complication rates based on resident involvement (Table II). The overall rate of 30-day complications was 45 of 1382 TSAs (3.26%). Overall complications were not associated with resident involvement, occurring in 18 of 691 cases (2.60%) in which a resident was involved compared with 27 of 691 (3.91%) when no resident was involved ($P = .173$). Operative time and length of hospital stay were both significantly shorter in cases in which a resident was involved (respectively: 113.5 vs. 121.3 minutes, $P = .002$; and 1.98 vs. 2.29 days, $P < .001$).

Level of training

TSA complications were further stratified by resident level of training (junior resident, senior resident, and fellow) (Fig. 1). Compared with 27 complications in 691 cases without resident involvement (3.91%), cases involving junior residents had 1 complication in 136 cases (0.74%), cases involving senior residents had 9 complications in 288 cases (3.13%), and cases involving fellows had 8 complications in 267 cases (3.00%). There was no significant difference in TSA complication rates based on resident level of training ($P = .285$).

Table I Preoperative demographics, medical comorbidities, and preoperative laboratory values of total shoulder arthroplasty patients based on resident involvement

Demographics	Resident present	Resident not present	*P* value
Number	691	691	—
Age (years)	69.85	69.92	.888
Female	0.61	0.60	.869
ASA class	2.48	2.48	.887
BMI	30.66	30.71	.878
Race			
White	85.24%	86.69%	.439
Black	3.76%	2.89%	.370
Asian	0.14%	0.29%	.571
Other	10.85%	10.13%	.661
Anesthesia, general	100.00%	100.00%	
CHF	0.14%	0.14%	1.000
MI	0.14%	0.14%	1.000
Prior cardiac surgery	7.24%	5.50%	.187
Percutaneous cardiac intervention	7.81%	7.38%	.761
Angina	0.58%	0.43%	.706
COPD	4.49%	4.49%	1.000
Alcohol abuse	2.46%	2.75%	.736
Peripheral vascular disease	0.43%	0.29%	.656
CVA with deficits	1.74%	1.30%	.511
CVA no deficits	2.75%	1.88%	.286
Hemiplegia	0.87%	0.43%	.325
Steroid use	6.08%	4.05%	.088
Weight loss (>10%)	0.14%	0.14%	1.000
Bleeding disorder	3.62%	2.46%	.213
Recent operation	0.43%	0.29%	.656
Hypertension	71.06%	70.62%	.859
TIA or CVA	7.96%	6.08%	.172
Smoking	8.83%	8.25%	.700
DM, noninsulin	12.59%	12.74%	.936
DM, insulin dependent	4.34%	4.05%	.789
Independent	94.50%	94.93%	.718
Inpatient procedure	97.68%	97.97%	.712
Preoperative creatinine level	0.93	0.93	.719
Preoperative albumin level	3.99	4.08	.050
Preoperative WBC count	6.96	6.98	.882
Preoperative Hct	40.08	40.20	.618
Preoperative platelet count	237.16	243.56	.075

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CHF*, congestive heart failure; *MI*, myocardial infarction; *COPD*, chronic obstructive pulmonary disease; *CVA*, cerebrovascular accident; *TIA*, transient ischemic attack; *DM*, diabetes mellitus; *WBC*, white blood cell; *Hct*, hematocrit.

Propensity score matching model is shown in the *P* value column. Not listed in this table are patient demographic variables identified in no patients in either group: renal failure, dialysis, paraplegia, quadriplegia, chemotherapy, and metastatic cancer.

Logistic regression model

Multivariate regression was performed to determine independent risk factors for TSA complications (Table III). In this model, resident involvement was not associated with

Table II Univariate analysis of total shoulder arthroplasty complication rates with and without resident involvement

	Resident present	Resident not present	*P* value
Operative time (minutes)	113.55	121.32	**.002**
Length of stay (days)	1.98	2.29	**<.001**
Time to OR (days)	0.02	0.01	.908
Transfusion	4.49%	2.60%	.062
Death	0.29%	0.00%	.500
Unplanned readmission	3.49%	4.00%	.724
Reoperation	0.75%	1.67%	.257
Complication (all combined)	**2.60%**	**3.91%**	**.173**
Medical complication	2.32%	3.18%	.324
Surgical complication	0.43%	0.87%	.506
Complication, major systemic			
Unplanned intubation	0.14%	0.00%	1.000
PE	0.14%	0.87%	.124
Acute renal failure	0.00%	0.00%	
Coma	0.00%	0.00%	
Stroke	0.29%	0.00%	.500
Cardiac arrest	0.14%	0.00%	1.000
MI	0.00%	0.00%	
Sepsis	0.00%	0.29%	.500
Organ space infection	0.00%	0.00%	
Complications, minor systemic			
Pneumonia	0.29%	0.58%	.687
DVT	0.29%	0.58%	.687
Ventilated > 48 hours	0.00%	0.00%	
Renal insufficiency	0.00%	0.00%	
UTI	1.30%	1.16%	.807
Complications, major local			
Deep infection	0.00%	0.00%	
Peripheral neurologic deficit	0.00%	0.00%	
Complications, minor local			
Superficial infection	0.00%	0.14%	1.000
Wound dehiscence	0.14%	0.00%	1.000

OR, operating room; *PE*, pulmonary embolism; *MI*, myocardial infarction; *DVT*, deep venous thrombosis; *UTI*, urinary tract infection.
Bold values indicate statistical significance (P<.05).

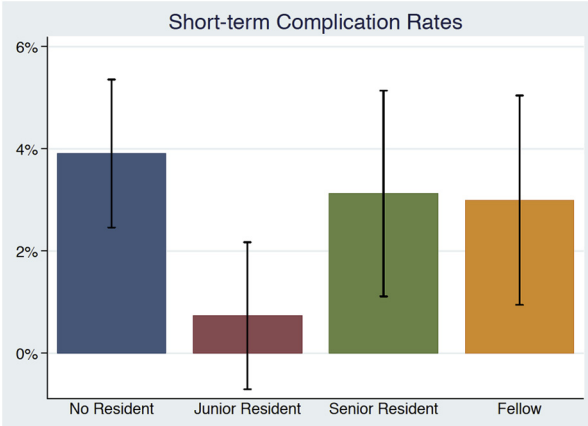

Figure 1 Thirty-day complication rates after primary total shoulder arthroplasty, stratified by resident training level into junior resident, senior resident, and fellow. There were no significant differences in complication rates based on resident involvement or resident training level.

Table III Independent risk factors for total shoulder arthroplasty complication identified by multivariate logistic regression

	Odds ratio [95% CI]	Adjusted *P* value
Resident involvement*	0.64 [0.34-1.19]	.159
Age (per 10 years)	1.57 [1.09-2.27]	.016
ASA class (per level)	1.86 [1.06-3.26]	.030
History of CHF	26.27 [1.25-553.23]	.036
History of insulin-dependent DM	2.95 [1.11-7.79]	.029
History of PVD	13.59 [1.93-95.97]	.009

CI, confidence interval; *ASA*, American Society of Anesthesiologists; *CHF*, congestive heart failure; *DM*, diabetes mellitus; *PVD*, peripheral vascular disease.
* Resident involvement was not a significant risk factor for TSA complication.

30-day complication rate after TSA (odds ratio, 0.64; confidence interval [0.34-1.19]; $P = .159$). Independent risk factors significantly associated with TSA complications identified by multivariate regression were higher patient age, higher ASA classification, congestive heart failure, insulin-dependent diabetes, and peripheral vascular disease.

Discussion

TSA is an increasingly common procedure that results in excellent pain relief, functional outcomes, and quality of life for patients with debilitating shoulder disorders.[3,9,16,23-26,30] Reported TSA complication rates are relatively high,[8,10,11,28,31,33-35] which has prompted interest in identifying the risk factors for TSA complications that could potentially be modified and incorporated into the preoperative decision-making process between surgeon and patient. This study uses the nationwide, high-quality NSQIP database from the American College of Surgeons to perform the first analysis of the role of resident involvement in TSA complications. We analyzed 1382 TSAs and found in both univariate and multivariate models that resident involvement in TSA does not significantly increase 30-day complication rates. In fact, cases in which residents were involved had a nonsignificant trend toward lower complication rates (2.60% vs. 3.91%; $P = .173$) and significantly shorter operative time and hospital stay.

Although no study has addressed TSA, there have been a number of studies in the orthopedic literature analyzing complication rates based on resident surgical involvement, primarily in the hip and knee arthroplasty and spine arenas.[4,18-20,27,29,37] An analysis of 24,529 primary total

knee arthroplasty (TKA) procedures from the NSQIP database found no increase in short-term complication rates based on resident involvement or level of training.[19] Similarly, an analysis of 13,109 primary total hip arthroplasty (THA) procedures used NSQIP data to show no increase in short-term complication rates based on resident involvement or level of training.[20] Single-institution studies in the spine and hip and knee arthroplasty literature have also shown no difference in complication rates based on resident involvement,[4,37] with 1 study finding a higher rate of acetabular malposition in resident-involved THA cases without increased dislocation rate.[37] Moreover, analyses of NSQIP complication rates at the beginning of the residency academic year in July vs. later in the year have been unable to demonstrate a July effect of higher complication rates based on resident inexperience soon after advancing to the next PGY in both the arthroplasty and spine literature.[6,7] Our findings regarding TSA are in agreement with the literature from the spine and THA and TKA specialties that there is no significant association of resident involvement with 30-day complication rate. In addition, our finding that resident level of training does not have an impact on TSA complication rate is in agreement with prior literature from other orthopedic procedures.

Several NSQIP studies have addressed the impact of resident involvement on 30-day complications of a heterogeneous combination of orthopedic procedures.[18,29,32] One study of all procedures in which orthopedics was the primary service found a decreased rate of complications based on resident involvement[18]; another study of numerous CPTs spanning primary and revision TKA and THA, arthroscopy, spine arthrodesis, and lower extremity fracture treatment found no association between resident involvement and complication rate[29]; and a third study of 12 common orthopedic CPT codes found that resident involvement was associated with higher complication rate.[32] The heterogeneity of included procedures between these studies and variable statistical methodology likely account for the divergent conclusions. For instance, the study reporting a higher complication rate with resident involvement likely did not perform adequate statistical control for selection bias with propensity score methodology, so its finding of an association of resident involvement and complication rate could be due to confounding variables rather than to causality.[32] Although these studies provide some valuable big-picture information, analysis of resident involvement across multiple procedures could cloud important differences between procedures. Therefore, our study addressed resident involvement in a more uniform procedure in primary TSA.

This study revealed that resident involvement significantly decreases operative time. This lies in contrast to the literature on resident involvement in TKA, THA, and studies combining multiple orthopedic procedures, which indicates that resident involvement significantly increases operative time.[18-20,29] Moreover, we found that resident involvement tends to decrease length of hospital stay for TSA, which was not identified in studies of other orthopedic procedures that have tended to show no impact of resident involvement on length of stay or tendency to increase length of stay.[18-20,29] The reason for these discrepancies is unclear but could relate to shorter operative times and more efficient postoperative protocols by high-volume shoulder arthroplasty surgeons at academic institutions that more than counteract any tendency of resident involvement to increase operative time or length of hospital stay.

Our secondary aim was to use multivariate logistic regression to identify independent risk factors for TSA complications using the NSQIP database. We found the following independent risk factors: higher patient age, higher ASA classification, congestive heart failure, insulin-dependent diabetes, and peripheral vascular disease. Our results are generally similar to those of 2 studies to date that have used the NSQIP database to determine risk factors for TSA 30-day complications, although neither of these analyzed resident involvement.[33,35] Shields et al[33] compared TSA and hemiarthroplasty, finding no difference between the procedures in complication rates after controlling for patient factors. They did identify emergency case, pulmonary comorbidity, anemia with hematocrit $<36\%$, and wound class III or IV as independent factors increasing complication rate. Waterman et al[35] found that cardiac disease, increasing age, peripheral vascular disease, and operative time were risk factors for TSA complications.

Our study has multiple strengths, including the use of the NSQIP database, a large database with high-quality preoperative, intraoperative, and 30-day postoperative data on private, public, academic, and nonacademic hospitals of various sizes from across the United States.[13,15,22] To our knowledge, this is the largest database of short-term complications that includes data on resident involvement, and it has been validated in several studies of resident involvement in orthopedic procedures to date.[6,7,18-20,29,32] Furthermore, we used propensity score matching to address possible selection bias of patients for cases with resident involvement. Propensity score matching controls for the effects of potential confounding variables to allow improved determination of causal effects of resident involvement on TSA complication rate.[5,14] In addition, our study specifically addresses TSA rather than a heterogeneous set of orthopedic procedures, which allows more applicable data for providers and patients considering TSA.

Limitations

Although it is uniquely suited to address the role of resident involvement in TSA rate of complications, the NSQIP database does have several limitations. First, data are provided only for specific complications in the 30-day

postoperative period, which precludes analysis of longer term complications or impact of resident involvement on functional outcome after TSA. Second, although the NSQIP database indicates whether a surgical resident was involved in the operating room, there are no data on degree of involvement in the operating room and no data on resident involvement in anesthesiology and preoperative or postoperative patient care. Moreover, many TSA cases had to be excluded because of lack of data on resident involvement, which is a limitation inherent to the NSQIP database but could introduce bias. In addition, until recently, current CPT coding does not allow determination of differences in complication rates between anatomic TSA and reverse TSA. Although we performed propensity score matching to control for as many confounding variables as the NSQIP database allowed, other uncontrolled confounders could exist. For instance, experience and volume of the attending surgeon with TSA could not be taken into account, which is relevant as residents may be more likely to be involved in cases with higher volume TSA surgeons at academic centers who may have lower complication rates and shorter operative times. Similarly, the NSQIP database does not include technical TSA variables that determine the complexity of the TSA case, such as need for bone graft, glenoid version, and status of the rotator cuff. Finally, although the NSQIP is, to our knowledge, the largest database available to assess resident involvement in TSA, the finding that resident involvement does not have an impact on TSA complication rate could represent a type II error if our large sample size of 1382 is underpowered. A post hoc power analysis for rate of overall complications based on resident involvement revealed power of 0.231. In an attempt to increase our sensitivity for finding an association of resident involvement and TSA complications, we avoided use of the Bonferroni correction for multiple hypothesis testing. Therefore, it is likely that if there is truly an association between resident involvement and TSA complication rate, the effect size is small.

Conclusion

Resident involvement in TSA procedures is not a risk factor for 30-day complications. Patient factors including increased age, diabetes, and cardiac disease are risk factors for TSA complications. This information can be used in preoperative counseling to reassure patients about safety of resident involvement in TSA and to optimize patient comorbidities before surgery.

Disclaimer

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