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Thirty-day morbidity and mortality after elective total shoulder arthroplasty: patient-based and surgical risk factors

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Background: Total shoulder arthroplasty (TSA) is an effective treatment for painful glenohumeral arthritis, but its morbidity has not been thoroughly documented.
Methods: The National Surgical Quality Improvement Program database was queried to identify all patients undergoing primary TSA between 2006 and 2011, with extraction of selected patient-based or surgical variables and 30-day clinical course. Postoperative complications were stratified as major systemic, minor systemic, major local, and minor local, and mortality was recorded. Odds ratios (ORs) with 95% confidence intervals (95% CIs) were derived from bivariate and multivariable analysis to express the association between risk factors and clinical outcomes.
Results: Among the 2004 patients identified, the average age was 69 years, and 57% were women. Obesity was present in 46%, and 48% had an American Society of Anesthesiologists classification of $\geq$3. The 30-day mortality and total complication rates were 0.25% and 3.64%, respectively. Comorbid cardiac disease (OR, 85.31; 95% CI, 8.15, 892.84) and increasing chronologic age (OR, 1.19; 95% CI, 1.06, 1.33) were independent predictors of mortality, whereas peripheral vascular disease was associated with statistically significant increase in any complication (OR, 6.25; 95% CI, 1.24, 31.40). Operative time >174 minutes was an independent predictor for development of a major local complication (OR, 4.05; 95% CI, 1.45, 11.30). Obesity was not associated with any specified complication after controlling for other variables.

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Conclusions: Whereas TSA has low short-term rates of perioperative complications and mortality, careful perioperative medical optimization and efficient surgical technique should be emphasized to decrease morbidity and mortality.

Level of evidence: Level III, Retrospective Cohort Design, Treatment Study.

Keywords: Total shoulder arthroplasty; mortality; complications; risk factors; incidence rate

With advances in its design and surgical technique[19] since Neer's early description,[25,26] total shoulder arthroplasty (TSA) has evolved as a reliable option for the treatment of degenerative shoulder disease. TSA effectively provides long-term pain relief and restores upper extremity function,[12] and patient demand has increased dramatically during the past 40 years, with an average increase of 9.4% per year for all cases of TSA.[1,11] Despite the increased surgical volume, postoperative complications still occur in an estimated 1 of 10 individuals undergoing TSA.[7] However, complication rates and profiles may vary considerably according to inclusion criteria, sample composition, and duration of clinical surveillance. Prior reports may not adequately reflect the prevalence of medical comorbidities and other unique perioperative risk factors increasingly present in patients undergoing joint arthroplasty.[6,17,38] Similarly, perioperative mortality and complication rates are thought to be underreported.[35]

This study was designed to quantify the 30-day postoperative morbidity and mortality after TSA in a national sample of patients. A secondary objective of this investigation was to evaluate for specific patient-based and surgical risk factors associated with 30-day postoperative mortality and systemic or local complications after TSA. We hypothesized that the presence of medical comorbidities, such as diabetes and cardiac disease, and advanced patient age would be associated with adverse clinical outcomes after TSA.

Materials and methods

Approval was obtained from our Institutional Review Board, and the National Surgical Quality Improvement Program (NSQIP) database was acquired from the American College of Surgeons for this study. Similar investigations of joint arthroplasty[4] and other orthopedic surgical procedures[3,32] have been conducted with the NSQIP, establishing it as a validated tool for developing prognostic clinical information. The methodology used in conjunction with transmitting NSQIP data from participating centers to the American College of Surgeons has been described in prior publications.[3,4] In brief, the NSQIP entails prospective patient enrollment and random sampling from more than 480 participating hospitals within the United States and offers surveillance of specific clinical outcomes, including perioperative complications and mortality, within the 30-day postoperative window. Surgical clinical reviewers at individual institutions ensure accuracy and completeness of prospective data collection while establishing direct patient contact or independent chart review to ascertain the presence or absence of perioperative complications within this window. Secondary surgeries performed within this period and subsequent patient entries are scrutinized for further relevance to the index procedure, and an anonymous data set is generated with consistent interrater reliability.[33]

For the current study, the NSQIP was queried to isolate all enrolled patients who underwent primary unilateral TSA as identified by *Current Procedural Terminology* (CPT) code 23472, which includes both anatomic and reverse TSA. Any patients with concurrent CPT codes indicating bilateral simultaneous TSA, revision TSA, biologic arthroplasty, and resurfacing or traditional hemiarthroplasty were excluded. Patient-specific factors, including demographics and medical comorbidities, and surgical variables, such as mode of anesthesia and total operative time, were extracted for further analysis (Table I). The presence and type of postoperative complications or mortality within 30 days of surgery were also recorded. For the purposes of this study, complications were considered either systemic or local complications and either major or minor on the basis of widely accepted criteria.[3,5,20,27-29] This resulted in 4 defined categories in which to classify postoperative complications (Tables II and III).

To assess the effect of individual patient-specific and surgical risk factors, bivariate χ^2 analysis was performed relative to the following identified clinical outcomes: patient mortality, presence of one or more complications, and the development of a major or minor systemic or local complication. Specific patient-based risk factors included for analysis were the following: age (<60, 60-69, 70-79, and ≥80 years old); sex; body mass index (<29.9, 30.0-39.9, and ≥40 kg/m^2); American Society of Anesthesiologists (ASA) classification (ASA 1 or 2 vs ≥3); type of anesthesia; and presence of diabetes mellitus, renal insufficiency, chronic obstructive pulmonary disease, steroid use, peripheral vascular disease, hypertension, or cardiac disease. Comparisons for surgical time were made between those procedures that exceeded the average TSA surgical time by 1 standard deviation compared with those that did not. If a given risk factor achieved a $P < .2$ on initial bivariate analysis, multivariable logistic regression was performed to evaluate its effect on the outcomes of interest while controlling for other predictors. Odds ratios (ORs) with 95% confidence intervals (CIs) were used to quantify risk during both bivariate and multivariable testing. Both a P value $< .05$ and a 95% CI exclusive of 1.0 after multivariable analysis were required for statistical significance.

Results

A total of 2004 patients who underwent TSA at participating hospitals between 2006 and 2011 were extracted from the NSQIP database. The average age of patients at

Table I Patient demographic and preoperative characteristics

Characteristic	Value	Patients for whom characteristic was determined (N)
Age, years, mean ± SD	68.8 ± 11.1	2004
≤59, N (%)	371 (18.5)	
60-69, N (%)	601 (30.0)	
70-79, N (%)	691 (34.5)	
≥80, N (%)	341 (17.0)	
Sex, N (%)		1998
Male, N (%)	859 (43.0)	
Female, N (%)	1139 (57.0)	
Body mass index, kg/m^2, mean ± SD	30.3 ± 6.4	1987
<30, N (%)	1073 (54.0)	
30.0-39.9, N (%)	760 (38.3)	
≥40.0, N (%)	154 (7.7)	
Operative time, minutes, mean ± SD	122.9 ± 51.2	2004
ASA classification, N (%)		2001
1-2, no or mild disturbance, N (%)	1038 (51.9)	
3-4, severe or life-threatening disturbance, N (%)	963 (48.1)	
Medical comorbidities, N (%)		2004
Diabetes	314 (15.7)	
Smoking (current smoker within 1 year)	180 (9.0)	
Regular alcohol use*	40 (2.3)	
COPD	98 (4.9)	
Cardiac issues (congestive heart failure or myocardial infarction)†	213 (10.6)	
Hypertension	1358 (67.8)	
Peripheral vascular disease	9 (0.5)	
Renal insufficiency	7 (0.4)	
Steroid use	89 (4.4)	

SD, standard deviation; *ASA*, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.

* More than 2 drinks per day in the 2 weeks before admission.

† Congestive heart failure within 30 days before surgery or chronic congestive heart failure with new signs or symptoms in the 30 days before surgery; history of myocardial infarction within past 6 months before surgery.

Table II 30-Day mortality, any complication, major or minor systemic complication, and major or minor local complication rates in patients with TSA

Characteristic	Value	
	N*	%
Mortality	5	0.25
Any complication	73	3.64
Major systemic	22	1.10
Minor systemic	43	2.15
Major local	12	0.60
Minor local	5	0.25
Mortality or any major complication	37	1.85

* N represents the total number of unique patients with one or more selected end points.

Table III Total major or minor systemic complications and major or minor local complications

Characteristic	N (%)
Major systemic complications	
Pulmonary embolism	5 (0.25)
Other systemic complication*	7 (0.35)
Postoperative sepsis	6 (0.30)
Septic shock	1 (0.05)
Cerebrovascular accident	4 (0.20)
Acute renal failure	0 (0)
Cardiac arrest requiring CPR	2 (0.10)
Minor systemic complications	
Urinary tract infection	30 (1.50)
Deep venous thrombosis	6 (0.30)
Pneumonia	10 (0.50)
Renal insufficiency	0 (0)
Major local complications	
Deep wound infection or organ space infection	3 (0.15)
Peripheral nerve injury	9 (0.45)
Periprosthetic fracture	1 (0.05)
Minor local complications	
Superficial wound infection	2 (0.10)
Wound dehiscence	3 (0.15)

CPR, cardiopulmonary resuscitation.

* Includes myocardial infarction (n = 4), unplanned intubation (n = 2), and failure to be weaned from the ventilator after 48 hours (n = 1).

the time of surgery was 68.8 (±11.1) years. The majority of patients in this study were female (57.0%), body mass index <30 (54.0%), and nonsmoking (91.0%) (Table I). Overall health status, as defined by ASA classification, was fairly evenly divided between class 1-2 (51.9%) and class 3-4 (48.1%). Hypertension (67.8%), diabetes mellitus (15.7%), and cardiac disease (10.6%) were the most common medical comorbidities. Mean operative time was 122.9 (±51.2) minutes.

The 30-day mortality rate was 0.25%. Seventy-three patients (3.64%) experienced a total of 89 complications (Table II). Twenty-five major systemic complications occurred in 22 patients (1.10%), and 46 minor systemic complications presented in 43 patients (2.15%) (Tables II and III). Pulmonary embolism occurred in 5 patients (0.25%), representing 20.0% of all major systemic complications (Table III). Urinary tract infection (1.50%) and pneumonia (0.50%) were the most common minor systemic complications. There were 12 patients with major local

Table IV Results of bivariate χ^2 analyses evaluating the influence of risk factors for mortality, any complication, minor systemic complications, and major or minor local complications

	Risk factor	*P* value	OR (95% CI)
Mortality	Age continuous	.011	1.21 (1.05, 1.40)
	Cardiac disease (MI or CHF)	.0004	62.22 (6.25, 619.76)
	Renal insufficiency	.0491	24.16 (1.01, 576.52)
Any complication	Age continuous	.0477	1.02 (1.00, 1.05)
	COPD	.0198	2.48 (1.16, 5.32)
	Peripheral vascular disease	.0122	7.63 (1.56, 37.38)
Major local complication	Operative time >174 minutes	.0144	4.07 (1.32, 15.54)
Minor systemic complication	Age continuous	.0034	1.05 (1.02, 1.09)
	Age ≥80 years vs <60 years	.0176	6.15 (1.35, 27.95)
	ASA classification ≥ 3	.0271	2.04 (1.08, 3.85)
	COPD	.0085	3.30 (1.36, 8.00)
	Peripheral vascular disease	.0014	13.62 (2.75, 67.55)
	Steroid use	.0042	3.67 (1.51, 8.94)
Minor local complication	Renal insufficiency	.0491	24.16 (1.01, 576.52)

OR, odds ratio; *CI*, confidence interval; *MI*, myocardial infarction; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *ASA*, American Society of Anesthesiologists.

Table V Significant predictors for mortality, any complication, major local complication, and minor systemic complication by multivariate logistic regression analysis

	Risk factor	*P* value	OR (95% CI)
Mortality	Age continuous	.0043	1.19 (1.06, 1.33)
	Cardiac disease (MI or CHF)	.0002	85.31 (8.15, 892.84)
Any complication	Peripheral vascular disease	.0262	6.25 (1.24, 31.40)
Major local complication	Operative time > 174 minutes	.0075	4.05 (1.45, 11.30)
Minor systemic complication	Peripheral vascular disease	.0099	10.59 (1.76, 63.60)
	Steroid use	.007	3.58 (1.42, 9.06)

OR, odds ratio; *CI*, confidence interval; *MI*, myocardial infarction; *CHF*, congestive heart failure.

(0.60%) and 5 patients with minor local (0.25%) complications (Table II). Peripheral nerve injury (0.45%), deep wound infection (0.15%), and periprosthetic fracture (0.05%) were the major local complications. Wound dehiscence (0.15%) and superficial wound infection (0.10%) were the only minor local complications.

Bivariate analysis identified several significant predictors for mortality, any complication, major local complication, minor systemic complication, and minor local complication (Table IV). After multivariable logistic regression analysis, significant independent predictors for mortality, any complication, major local complications, and minor systemic complications were determined (Table V). Cardiac disease (OR, 85.31 [95% CI, 8.15, 892.84]; $P = .0002$) and age (OR, 1.19 [95% CI, 1.06, 1.33]; $P = .0043$) were significant risk factors for mortality. Peripheral vascular disease was identified as an independent predictor for development of any postoperative complication (OR, 6.25 [95% CI, 1.24, 31.4]; $P = .0262$). A longer operative time, >174 minutes, was independently associated with a major local complication (OR, 4.05 [95% CI, 1.45, 11.30]; $P = .0075$). Minor systemic complications were independently associated with peripheral vascular disease (OR, 10.59 [95% CI, 1.76, 63.60]; $P = .0099$) and steroid use (OR, 3.58 [95% CI, 1.42, 9.06]; $P = .007$)].

Discussion

Previous literature has offered estimates of adverse patient outcomes after joint arthroplasty, including TSA,[8,23] but limited data are available discussing the risks of postoperative complications in the setting of specific patient-based and surgical variables.[7,21,34] In the current study, we sought to identify the 30-day incidence rate of mortality and cumulative perioperative complications after TSA in a broad demographic sample and to ascertain the role of individual risk factors on these outcomes of interest. Of 2004 patients undergoing TSA, the short-term mortality was 0.25%.

Mortality rates may vary considerably because of inconsistencies in reporting or fundamental differences in population sampling. Our figure lies within the range of previous reports in the literature,[15,34,35] although many

works are limited by the characteristics of the populations under study[15,34] or a tendency to include cases of TSA and hemiarthroplasty in a single cohort.[21]; [34] In contradistinction to prior single-center studies,[7,34,35] our mortality rate may be more generalizable to a broader demographic with higher prevalence of comorbidities undergoing surgery in diverse practice settings across the United States.

Cardiac disease, defined as the presence of congestive heart failure or a history of myocardial infarction, was the most significant independent risk factor for mortality in the current patient population (OR, 85.31; 95% CI, 8.15, 892.84). Humphries et al[21] showed that patients with substantial medical comorbidities, as quantified by an elevated Deyo index score, had 12-fold higher risk of hospital mortality after shoulder arthroplasty than their counterparts without comorbidities. Furthermore, Singh et al[34] revealed that patients with ASA class 3 or 4, Deyo-Charlson Index $\geq$1, or an underlying tumor diagnosis had significantly higher mortality rates when other variables were controlled for. However, these studies failed to evaluate for or to establish other specific predictors or individual medical conditions (Table I), as presented in this study. Furthermore, whereas prior authors have emphasized the importance of general medical clearance for hip and knee arthroplasty, this investigation further underscores the necessity for preoperative cardiac risk stratification according to the American College of Cardiology/American Heart Association 2007 guidelines[16] before TSA as well.

The current study also demonstrated that advancing chronologic age is associated with a moderately increased risk of mortality with each successive year (OR, 1.19; 95% CI, 1.06, 1.33), equivalent to an approximate 2-fold elevation in the odds of death with each decade of life. In the only known study to specifically assess the effect of age on surgical risk after TSA, Ricchetti et al[30] reported no difference in the rate of postoperative complications or mortality between 90 individuals aged >80 or <70 years old. The discrepancy in findings between our work and that of Ricchetti et al[30] may result from our larger and more diverse patient population.

Within the current NSQIP cohort, postoperative complications within 30 days of surgery were encountered in 3.64% of patients. More than half of all complications were classified as minor systemic, whereas nearly a third were identified as major systemic. This more severe category included postoperative sepsis (n = 6; 0.3%), thromboembolism (n = 5; 0.25%), cerebrovascular event (n = 4; 0.2%), and cardiac arrest (n = 2; 0.1%). Cumulative early perioperative complication rates have varied substantially in prior studies (1.2%-30%), and rates are highly dependent on the length of follow-up and the level of detail used to assess and to record complications after TSA.[7,9,10,13,15,22,30,37] Fehringer et al[15] reported a total postoperative complication rate of 2.8%, with comparable or lower rates of systemic complications in all categories considered here except for any cardiac complications (0.8%), myocardial infarction (0.3%), cerebrovascular events (0.4%), and pneumonia (0.8%). In comprehensive evaluation of medical and surgical morbidity after TSA, Ricchetti et al[30] reported the highest 90-day total and systemic complication rates (30% and 26%, respectively), although only one medical complication was deemed major.

In the present analysis, peripheral vascular disease independently predicted the occurrence of any complication. Furthermore, peripheral vascular disease and corticosteroid use were the only factors associated with the development of minor systemic complications after control for other variables. Peripheral vascular disease often reflects combined arterial and venous insufficiency that results in relative limb ischemia and venous stasis, thereby contributing to diminished wound healing, elevated risk of infection, and unplanned procedures. Similarly, peripheral vascular disease is frequently associated with diabetes mellitus and other ischemic cardiovascular disease, which may also contribute to increased risk of local and systemic complications. Other studies have shown similar correlations between increasing comorbidities and heightened complication profiles after arthroplasty. For example, Chalmers et al[7] found that elevated Charlson comorbidity scores were significantly associated with both overall complication rates and medical complications after TSA. When collectively considering TSA and other major joint arthroplasties, Jain et al[22] also suggested that hypertension and diabetes independently increased the risk of postoperative complications.

Major local complications were uncommon in the current study, occurring in only 0.60% of patients. Notably, operative times longer than 174 minutes were associated with significantly higher rates of major local complications, which included periprosthetic infection requiring surgical treatment (n = 3; 0.15%) and neurologic injury (n = 9; 0.45%). Similar trends between longer operative times and local wound complications have also been reproduced for knee arthroplasty[4] as well as for other surgical procedures.[3,27,32] Ostensibly, neurapraxia and marginal wound ischemia can result from prolonged tissue retraction, and this may also contribute to poor wound healing and increased risk of surgical site infection. Singh et al[34] demonstrated a similar correlation between increased operative time and periprosthetic infection, with the relative risk of infection increasing by 8% for every additional 15 minutes of operating room time. Similar results regarding operative time and the risk of complications have also been appreciated for other shoulder procedures in the NSQIP, including arthroscopy.[24]

The primary limitations of this study stem from its reliance on data from a national patient registry. Because of existing limitations in the coding scheme, cases of reverse and conventional TSA were collectively considered under the CPT code 23472, and we were unable to differentiate short-term outcomes on the basis of implant

design. Early clinical series with reverse TSA have described significantly higher cumulative complication rates than with conventional TSA, with estimates up to 68% in some small cohorts at varying follow-up.[5,8,14,31,36] However, more contemporary reports have shown more modest postoperative morbidity that approaches that of conventional TSA, and the disparity in rates may be less notable within the 30-day postoperative window.[2,18] As with any database, we must also acknowledge the potential that miscoding may confound our results. Similarly, the NSQIP cannot account for patients receiving treatment at outside medical facilities, and this data set does not include those complications that occur beyond the 30-day postoperative time frame. In addition, several potentially clinically relevant patient- and surgeon-specific variables were not available within the NSQIP data set, such as disease severity, surgeon experience, and hospital volume. Whereas increased body mass index ($\geq$25) and other specific medical comorbidities (e.g., diabetes) were not associated with adverse patient outcomes in this cohort, the current investigation may be underpowered to detect statistically significant differences that might be elucidated in larger multicenter studies.

Conclusion

Within this diverse national patient sample of 2004 patients in the United States, comorbid cardiac disease and, to a lesser extent, increasing chronologic age were independent predictors of patient mortality within 30 days of TSA; peripheral vascular disease was significantly associated with a more than 6-fold greater risk of any postoperative complication. Longer operative times (i.e., >174 minutes) were also associated with a 4-fold increased incidence of major local complications. Whereas TSA is associated with low short-term rates of complications and mortality, careful perioperative medical optimization and efficient surgical technique should be emphasized to avoid secondary morbidity and mortality. Our findings can be immediately translated to clinical practice by providing better data for preoperative counseling and estimations of complication risk. Furthermore, this study identifies at-risk patients who require heightened vigilance for adverse events after TSA.

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