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journal homepage: www.jseinternational.org

The role of hypertensive status in the preoperative patient selection of TSA



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ARTICLE INFO

Keywords:

Total shoulder arthroplasty
Hypertension
Postoperative complications
Reoperation
Shoulder
Arthroplasty

Level of evidence: Level III; Retrospective
Cohort Comparison Using Large Database;
Prognosis Study

Background: This study investigates the relationship between hypertension and postoperative complications following total shoulder arthroplasty (TSA).

Methods: All patients who underwent TSA between 2015 and 2020 from the American College of Surgeons National Surgical Quality Improvement database were surveyed. The study population was divided into patients with no hypertension and patients with hypertension. Patient demographics, comorbidities, and 30-day postoperative complications were collected. Logistic regression analysis was used to investigate the relationship between hypertension and postoperative complications.

Results: Compared to no hypertension, hypertension was significantly associated with an increased likelihood of experiencing sepsis ($P = .021$), pneumonia ($P = .019$), myocardial infarction ($P = .038$), blood transfusions ($P = .006$), readmission ($P < .001$), reoperation ($P < .001$), non-home discharge ($P < .001$), and any complication ($P < .001$). After accounting for significant patient variables, compared to no hypertension, hypertension was independently significantly associated with an increased likelihood of experiencing reoperation (odds ratio 1.48; 95% CI, 1.142–1.905; $P = .003$) and any complication (odds ratio 1.10; 95% CI, 1.008–1.205; $P = .033$).

Conclusion: In this study, we identified hypertension as an independent significant predictor for both reoperation and any complication following TSA. This study provides evidence for incorporating a patient's hypertensive status into preoperative screening, aiming to improve surgical candidate selection and surgical outcomes following TSA.

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Total shoulder arthroplasty (TSA) is indicated for the treatment of conditions including osteoarthritis, rotator cuff arthropathy, and proximal humerus fractures with the goal of alleviating pain, enhancing range of motion, and restoring strength. Due to its functional benefits, TSA has gained popularity over the last decade, resulting in a two-fold increase in the number of procedures performed, with the largest growth reported in patients aged 55–64 years.¹⁷ Given the substantial increase in TSA incidence within this demographic, it is imperative to acknowledge the presence of multiple comorbidities, including hypertension, that impact this patient group.

Hypertension exacerbates the global prevalence of illness and is a significant risk factor for conditions such as cardiovascular disease, kidney disease, and dementia.¹⁴ Roughly 45.4% of the

United States' population is affected by hypertension, of which more than half are inadequately controlled.^{4,12} Hypertension may present as an isolated condition but also may co-occur or predispose patients to comorbidities such as diabetes, dyslipidemia, and obesity.¹⁸ Preoperative hypertension has been linked to cardiovascular instability and postoperative mortality.¹⁶

The cause of hypertension in most patients is labeled as idiopathic, though much of the condition can be attributed to a combination of genetic, demographic, and environmental factors. Significant pathophysiologic mechanisms of hypertension include overactivation of the sympathetic nervous system and the closely linked renin-angiotensin-aldosterone system, where increased stressful environments, high-sodium diet, and obesity are among the major causes of its stimulation.^{6,11} Such imbalances in autonomic function cause increased vascular tone, cardiac output, and elevated blood pressure (BP). In addition, alterations in the structural and functional integrity of the vascular system may lead to perturbations in BP.¹³ Abnormal vascular remodeling resulting from oxidative stress, endothelial dysfunction, and age is a key factor in

Institutional review board approval was not required for this study.

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<https://doi.org/10.1016/j.jseint.2024.02.002>

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the pathogenesis of hypertension.¹³ Examples of this include hypertrophy of vessels in hypertensive diabetics and natural reductions in arterial elasticity observed in older individuals from atherosclerosis.¹³

In the setting of orthopedic surgery, several studies have suggested that preoperative hypertension is associated with a greater risk of complications and an increased hospital length of stay in the postoperative period when compared to normotensive patients.^{1,5,7} In particular, hypertensive individuals who underwent total hip arthroplasty were observed to experience delayed wound healing.¹ Revision total knee arthroplasty in the geriatric population yielded similar findings, with hypertension contributing significantly toward the incidence of unplanned reintubation, myocardial infarction, and longer hospital stay.⁷ The objective of this study is to describe the influence of preoperative systemic hypertension on early postoperative complications following TSA.

Methods

The American College of Surgeons National Surgical Quality Improvement (NSQIP) database was surveyed for all patients who underwent TSA between 2015 and 2020. The American College of Surgeons NSQIP is a validated tool for monitoring surgical outcomes. Since the NSQIP database is fully deidentified, this study is exempt from approval by our university's institutional review board. Data in the NSQIP database is obtained from more than 600 hospitals across the United States and is collected by skilled surgical clinical reviewers.

The Current Procedural Terminology code 23472 was used to identify patients who underwent TSA from 2015 to 2020. The NSQIP database automatically excludes patients younger than 18 years of age. Any cases that were missing body mass index (BMI), functional status prior to surgical intervention, American Society of Anesthesiologists (ASA) classification, readmission status, and discharge destination were excluded.

Variables collected in this study included patient demographics, comorbidities, surgical characteristics, preoperative laboratory values, and 30-day postoperative complication data. Patient variables analyzed included sex, age, BMI, functional status prior to surgery, ASA classification, smoking status, hypertension, as well as preoperative congestive heart failure (CHF), insulin-dependent diabetes, chronic obstructive pulmonary disease (COPD), bleeding disorder, disseminated cancer, and operation time. Age categories were selected based on a previous published NSQIP analysis.⁹ Several complications that occurred within 30 days postoperatively were included in the analysis including sepsis, septic shock, pneumonia, stroke, cardiac arrest requiring resuscitation, myocardial infarction, blood transfusion, deep vein thrombosis requiring therapy, pulmonary embolism, failure to wean off of the ventilator within 48 hours, deep incisional surgical site infection (SSI), superficial incisional SSI, organ/space SSI, wound dehiscence, readmission, reoperation, non-home discharge, mortality, and any complication. These variables were chosen based on previous NSQIP studies.⁹

The patients were divided into two groups: those with no hypertension and those with hypertension. Hypertension was defined as BP greater than 140/90, hypertension status documented in the patient's medical record, and the use of antihypertensive medication within 30 days prior to the operative procedure. The patient must have been receiving long-term antihypertensive medication, including but not limited to diuretics, beta blockers, angiotensin-converting enzyme inhibitors, and calcium channel blockers, for more than two weeks.

There were 26,633 patients remaining after exclusion criteria; 17,706 (66.5%) patients were included in the hypertension cohort, and 8927 (33.5%) patients were included in the no hypertension

cohort (Fig. 1). A total of 27,050 patients underwent TSA in NSQIP from 2015 to 2020. Cases were excluded as follows: 152 for missing BMI, 29 for unknown ASA classification, 2 for unknown readmission status, 227 for missing functional health status prior to surgery, and 7 for unknown discharge status.

Statistical analyses were performed with SPSS Software version 28.0 (IBM Corp., Armonk, NY, USA). Patient demographics and comorbidities were compared between cohorts through bivariate analysis. To identify relationships between hypertension and postoperative complications, multivariate logistic regression was employed, adjusting for all significantly associated patient demographics and comorbidities. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported, and the threshold for statistical significance was set at $P < .05$.

Results

Female gender ($P < .001$), older age ($P < .001$), greater BMI ($P < .001$), dependent functional status ($P < .001$), ASA classification ≥ 3 ($P < .001$), and nonsmoking status ($P < .001$) were demographics significantly associated with hypertension (Table I). Additionally, comorbidities significantly associated with hypertension included CHF ($P < .001$), diabetes requiring insulin ($P < .001$), COPD ($P < .001$), bleeding disorder ($P < .001$), and shorter operation time ($P < .001$).

Bivariate analysis was used to identify postoperative complications associated with hypertension. Compared to no hypertension, hypertension was significantly associated with an increased likelihood of experiencing sepsis ($P = .021$), pneumonia ($P = .019$), myocardial infarction ($P = .038$), blood transfusions ($P = .006$), readmission ($P < .001$), reoperation ($P < .001$), non-home discharge ($P < .001$), and any complication ($P < .001$) (Table II).

Multivariate analysis was used to account for patient demographics significantly associated with hypertension. Compared to no hypertension, hypertension was independently significantly associated with an increased likelihood of experiencing reoperation (OR 1.48; 95% CI, 1.142–1.905; $P = .003$) and any complication (OR 1.10; 95% CI, 1.008–1.205; $P = .033$) (Table III). The most common reasons specified for reoperation included hematoma, infection, and dislocation (Table IV).

Discussion

In the present study, we investigated the relationship of hypertension on early postoperative outcomes following TSA. Hypertension was significantly associated with an increased likelihood of experiencing postoperative sepsis, pneumonia, myocardial infarction, blood transfusions, readmission, reoperation, non-home discharge, and any complication. Following adjustment for significantly associated patient demographics and comorbidities, hypertension was independently significantly associated with an increased likelihood of experiencing reoperation and any complication. To our knowledge, this is the first report that establishes hypertension as a risk factor for these complications following TSA.

We found that hypertension was significantly associated with female gender, older age, greater BMI, dependent functional status, ASA classification ≥ 3 , and nonsmoking status. In addition, we found that hypertension was significantly associated with comorbidities including CHF, insulin-dependent diabetes, COPD, bleeding disorder, and shorter operation time. Among these significant patient factors, BMI has previously been identified as a modifiable risk factor for hypertension.¹⁵ The modifiability of both BMI and hypertension underscores their significance as key areas for intervention in prevention of hypertension. The association between

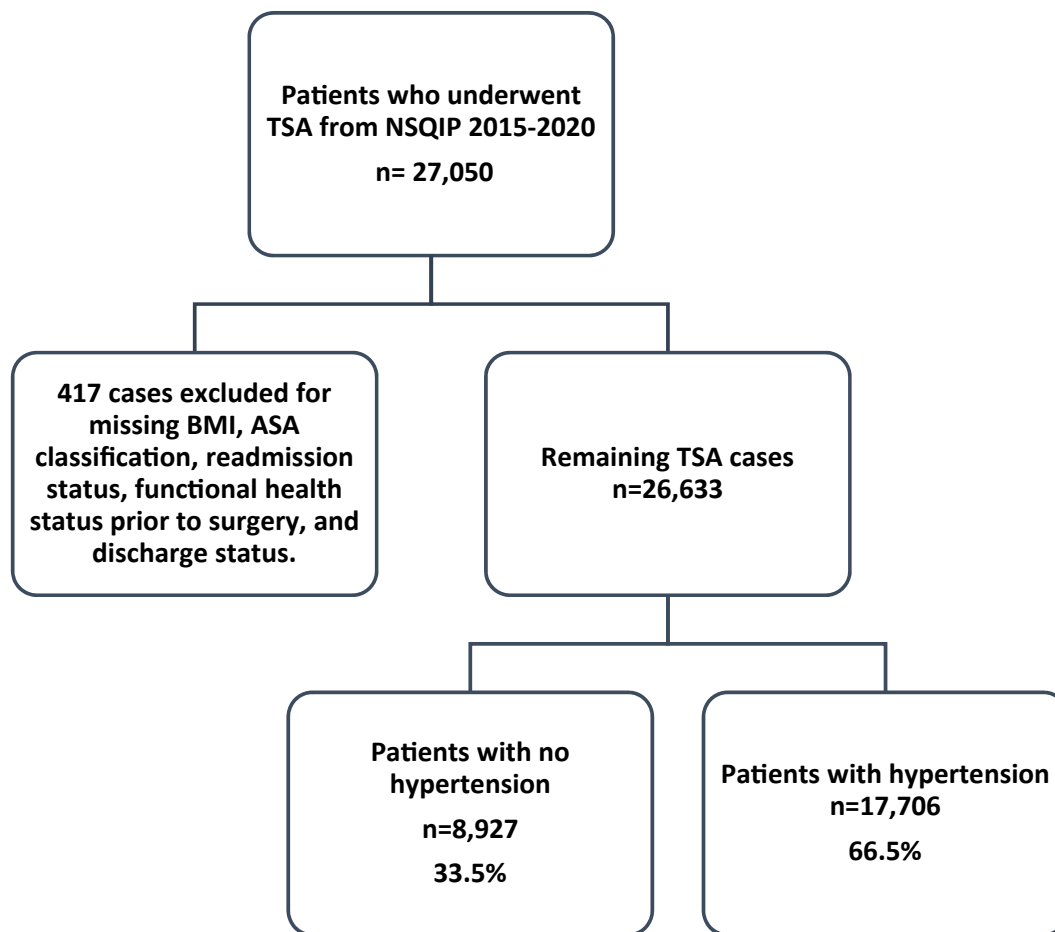


Figure 1 Strengthening the reporting of observational studies in epidemiology diagram describing inclusion and exclusion criteria prior to statistical analysis. TSA, total shoulder arthroplasty; NSQIP, national surgical quality improvement program; ASA, American Society of Anesthesiologists; BMI, body mass index.

hypertension and several of these demographics and comorbidities can be better understood when reviewing hypertension from a fundamental level.

Though management of hypertension has been extensively studied, its negative impact on surgical outcomes remains a subject of investigation. Evidence has consistently suggested that hypertension plays a significant role in perioperative and postoperative cardiovascular instability and morbidity. A large, prospective analysis of 17,201 patients undergoing general anesthesia for surgery suggested that elevated preoperative BP is linked to perioperative hypertension, bradycardia, and tachycardia, all of which are classified as adverse events under anesthesia.³ Similar conclusions were also reached by a study with 140 patients undergoing both general and vascular surgery, which found that a prior history of hypertension, along with a higher admission systolic BP, were significant risk factors for postoperative silent myocardial ischemia.⁸ Additionally, elevated diastolic BP is significantly associated with greater postoperative mortality in elective noncardiac surgery.¹⁶ Altogether, these findings highlight the complexity of the relationship between hypertension and surgical outcomes, stressing the need for management of the dynamic in practice, including in the field of orthopedic surgery. The present study, along with previous studies reviewing preoperative TSA comorbidities including chronic steroid use and CHF, supports the need for medical optimization prior to undergoing TSA.²

Outside of cardiovascular complications, hypertensive patients undergoing primary total hip arthroplasty have been found to take

two additional days to cease wound discharge compared to those who are normotensive.¹ Extended periods of “non-dry” wounds are associated with greater chance of infection, which can result in prolonged hospitalization and an increased risk of more severe complications.¹ Another study examining 14 common orthopedic procedures including TSA, found that hypertension, along with other comorbidities, were individually associated with a significantly increased postoperative length of stay.⁵ These findings are further supported by a study demonstrating that hypertensive octogenarians undergoing total knee arthroplasty were at risk for greater length of hospitalization, among other complications.⁷ In general, hypertensive patients are predisposed to a greater amount of surgical complications, which may be attributed to the role of increased BP in promoting organ damage, hemodynamic instability, and delayed wound healing.¹⁰ Our study did not exclusively find a relationship with prolonged hospital stay nor wound complications. However, we were able to identify hypertension as an independent risk factor for experiencing any complication in TSA.

Along with a significant risk of any complication, our study revealed that hypertension was an independent predictor of reoperation, with the hypertensive cohort experiencing a reoperation rate of 1.6%. The most common reasons for returning to the operating room in the present study included hematoma, infection, and dislocation. In a study of reverse TSA, a reoperation rate of 3.5% was reported, most commonly to manage hematoma-related complications.¹⁹ Even after accounting for significant patient aspects that could contribute to the need for reoperation, including

Table I
Patient demographics and comorbidities for patients who do not have hypertension and those with hypertension.

	No hypertension		Hypertension		P value
	Number	%	Number	%	
Overall	8927	100	17,706	100	
Sex					<.001
Female	4801	53.8	10,032	56.7	
Male	4126	46.2	7674	43.3	
Age					<.001
18–39	116	1.3	28	0.2	
40–64	3304	37.0	4018	22.7	
65–74	3558	39.9	7574	42.8	
≥75	1949	21.8	6086	34.4	
BMI (kg/m ²)					<.001
<18.5	112	1.3	76	0.4	
18.5–29.9	5126	57.4	7483	42.3	
30–34.9	2138	23.9	5024	28.4	
35–39.9	958	10.7	2864	16.2	
≥40	593	6.6	2259	12.8	
Functional status prior to surgery					<.001
Dependent	149	1.7	419	2.4	
Independent	8778	98.3	17,287	97.6	
ASA classification					<.001
≤2	5450	61.1	5844	33.0	
≥3	3477	38.9	11,862	67.0	
Smoker					<.001
No	7852	88.0	16,028	90.5	
Yes	1075	12.0	1678	9.5	
Comorbidities					
CHF	24	0.3	153	0.9	<.001
DM requiring insulin	637	7.1	4176	23.6	<.001
COPD	412	4.6	1360	7.7	<.001
Bleeding disorder	116	1.3	555	3.1	<.001
Disseminated cancer	22	0.2	40	0.2	.743
Operation time					<.001
0–79	2140	24	4645	26.2	
80–128	4441	49.7	8786	49.6	
≥129	2346	26.3	4275	24.1	

BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease. Bold P values indicate statistical significance with *P* < .05.

advanced age and bleeding disorders, hypertension was still found to be an independent risk factor for reoperation in the present study.

The findings of this study were limited by several factors, many of which are intrinsic to the database used. Although NSQIP provides a robust and diverse set of patient information, there are several characteristics not available that may influence this study, such as outpatient procedures. Additionally, patient information regarding hypertension severity, as well as its treatment and management is not available. Furthermore, NSQIP does not monitor complications beyond the 30-day postoperative period. This excludes long-term complications, such as poor functional outcomes, implant instability, neural injury, and potential periprosthetic fractures. Also, the present study was unable to distinguish between anatomic and reverse TSA, which have differences in risks of complications, an inherent limitation of the NSQIP database. Lastly, in NSQIP database, the majority of cases of reoperation did not specify the reasoning behind return to the operating room. While hematoma and infection were able to be included, other reasons for return to the operating room, such as osteoporosis or prior history of proximal humerus fracture malunion, were not able to be incorporated. Barring these limitations, the NSQIP database allowed us to analyze a sizable amount of data and correlate hypertension with both reoperation and greater chance of any postoperative complication. This study is the first to report this relationship, contributing to the growing body of evidence in

Table II
Bivariate analysis of 30-day postoperative complications in patients without hypertension and with hypertension.

	No hypertension		Hypertension		P value
	Number (%)	Number (%)	Number (%)	Number (%)	
Sepsis	6 (0.1)	33 (0.2)			.021
Septic shock	2 (0.0)	11 (0.1)			.184
Pneumonia	30 (0.3)	97 (0.5)			.019
Stroke	3 (0.0)	19 (0.1)			.062
Cardiac arrest	2 (0.0)	13 (0.1)			.118
Myocardial infarction	16 (0.2)	57 (0.3)			.038
Blood transfusions	131 (1.5)	343 (1.9)			.006
Deep vein thrombosis	33 (0.4)	50 (0.3)			.229
Pulmonary embolism	25 (0.3)	49 (0.3)			.961
Failure to wean off ventilator	11 (0.1)	17 (0.1)			.519
Deep incisional SSI	7 (0.1)	10 (0.1)			.505
Superficial incisional SSI	19 (0.2)	50 (0.3)			.293
Organ/space SSI	19 (0.2)	39 (0.2)			.902
Wound dehiscence	5 (0.1)	12 (0.1)			.720
Readmission	194 (2.2)	577 (3.3)			<.001
Reoperation	89 (1.0)	281 (1.6)			<.001
Non-home discharge	509 (5.7)	1774 (10.0)			<.001
Mortality	10 (0.1)	32 (0.2)			.186
Any complication	873 (9.8)	2712 (15.3)			<.001

SSI, surgical site infection.

Bold P values indicate statistical significance with *P* < .05.

Table III
Multivariate analysis of 30-day postoperative complications in patients with hypertension, adjusted for significantly associated patient demographics/comorbidities.

	Hypertension	
	OR	P value (95% CI)
Sepsis	1.99	.139 (0.799–4.939)
Pneumonia	0.99	.952 (0.642–1.518)
Myocardial infarction	0.94	.844 (0.526–1.690)
Blood transfusions	0.94	.558 (0.752–1.166)
Readmission	1.13	.162 (0.951–1.352)
Reoperation	1.48	.003 (1.142–1.905)
Non-home discharge	1.09	.151 (0.970–1.215)
Mortality	1.21	.628 (0.566–2.566)
Any complication	1.10	.033 (1.008–1.205)

OR, odds ratio; CI, confidence interval.

Bold P values indicate statistical significance with *P* < .05.

Table IV
Most common reasons for reoperation.

Reason for reoperation	Number	%
Hematoma	44	0.2
Wound infection	38	0.1
Dislocation	79	0.3

support of optimizing the preoperative process towards addressing manageable comorbidities that may be associated with adverse outcomes.

Conclusion

In this study, we identified hypertension as an independent significant predictor for both reoperation and any complication in TSA. To our knowledge, this is the first report that establishes hypertension as a risk factor for these complications. This study provides support in favor of utilizing a patient’s hypertensive status into preoperative screening, aiming to optimize surgical candidate selection and improve surgical outcomes following TSA. Future work is needed to further understand and control hypertension as a preoperative risk factor.

Disclaimers:

Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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