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Components of metabolic syndrome as significant risk factors for postoperative complications following total shoulder arthroplasty: hypertension, diabetes, and obesity

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Background: Metabolic syndrome (MetS) is a known risk factor for adverse postoperative outcomes. However, the literature surrounding the effects of MetS on orthopedic surgery outcomes following total shoulder arthroplasty (TSA) remains understudied. The purpose of this study is to investigate the effect of MetS on postoperative 30-day adverse outcomes following TSA.

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried for all patients who underwent TSA between 2015 and 2020. After exclusion criteria, patients were divided into MetS and no MetS cohorts. MetS patients were defined as presence of hypertension, diabetes, and body mass index > 30 kg/m^2. Bivariate logistic regression was used to compare patient demographics, comorbidities, and complications. Multivariate logistic regression, adjusted for all significant patient demographics and comorbidities, was used to identify the complications independently associated with MetS.

Results: A total of 26,613 patients remained after exclusion criteria, with 23,717 (89.1%) in the no MetS cohort and 2896 (10.9%) in the MetS cohort. On multivariate analysis, MetS was found to be an independent predictor of postoperative pneumonia (odds ratio [OR] 1.61, 95% confidence interval [CI] 1.02-2.55; $P = .042$), renal insufficiency (OR 4.09, 95% CI 1.67-10.00; $P = .002$), acute renal failure (OR 4.17, 95% CI 1.13-15.31; $P = .032$), myocardial infarction (OR 2.11, 95% CI 1.21-3.69; $P = .009$), nonhome discharge (OR 1.41, 95% CI 1.24-1.60; $P < .001$), and prolonged hospital stay > 3 days (OR 1.44, 95% CI 1.25-1.66; $P < .001$).

Conclusion: MetS was identified as an independent risk factor for postoperative pneumonia, renal insufficiency, acute renal failure, myocardial infarction, nonhome discharge, and prolonged hospital stay following TSA. These findings encourage physicians to medically optimize MetS patients prior to surgery to limit adverse outcomes.

Total shoulder arthroplasty (TSA) is an effective surgical procedure for multiple shoulder disorders, with the potential to improve pain, shoulder function, and overall wellbeing.[24] Indications for TSA include glenohumeral arthritis, rotator cuff tear, and proximal humerus fracture.[21] Over the recent years, the incidence of TSA has rapidly increased, with a 103.7% rise in procedures between 2011 and 2017 and a predicted increase of 235.2% by 2025.[26]

Similarly, the number of people with metabolic syndrome (MetS) has grown.[20] The global prevalence of MetS is 20%-25%, with 35% of all adults and 50% of adults aged more than 60 years in the United States having MetS.[1,20] MetS is defined by the World Health Organization as a pathologic condition that places patients at risk for cardiovascular disease and type 2 diabetes mellitus due to the combination of insulin resistance, hypertension, central obesity, and hyperlipidemia.[2,23] Patients typically have insulin resistance with at least 2 of these other additional risk factors to diagnose MetS. The presence of these health conditions arises from multiple factors, such as genetics, sedentary lifestyles, diet composition, and higher calorie intake compared to energy expenditure.[23]

Institutional review board approval was not required for this study.

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Previous literature has shown that MetS is associated with adverse outcomes following orthopedic surgeries, specifically following total hip arthroplasty (THA) and total knee arthroplasty (TKA).[7] For these surgeries, MetS placed patients at greater risk for cardiovascular complications, endocrine dysfunction, urinary tract infections, surgical site infections (SSIs), thromboembolic events, and osteoarthritis.[7] Additionally, prior research demonstrates that certain patient population groups face greater postoperative complications because MetS is disproportionately prevalent in racial minority groups, females undergoing TKA, and males undergoing THA.[6] Due to TSA's faster rate of increase compared to THA and TKA, it is important to investigate the relationship between MetS and postoperative complications following TSA.[26]

Given the increasing demand for TSA and the rising prevalence of MetS with the United States' aging population, it is important to understand how MetS impacts postoperative complications following TSA. The purpose of this study was to analyze the relationship between MetS and adverse postoperative outcomes following TSA.

Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried for all patients who underwent TSA between 2015 and 2020. The data available through the NSQIP database are collected by trained surgical clinical reviewers and are obtained from more than 600 hospitals in the United States. The data are periodically audited to maintain its accuracy and validity. The ACS-NSQIP database is fully deidentified, therefore rendering this study exempt from approval by our University's Institutional Review Board.

Current Procedural Terminology code 23472 was used to identify patients who underwent both anatomic and reverse TSA between 2015 and 2020. Patients aged less than 18 years are automatically excluded from the database. Cases for TSA due to trauma were also excluded. Patient cases were additionally excluded for missing information in any of the following variables: height, weight, total operative time, discharge destination, American Society of Anesthesiologists (ASA) classification, length of hospital stay, and readmission status.

MetS was defined as the presence of the following 3 characteristics: body mass index (BMI) > 30 kg/m^2, diabetes mellitus, and hypertension. Both noninsulin and insulin-dependent diabetic patients were included. Patients with hypertension included those requiring antihypertensive medication for chronic hypertension for > 2 weeks preoperatively.

Patient demographics collected in this study include age, gender, BMI, ASA classification, functional status, smoking status, and chronic steroid use. Patient comorbidities including diabetes, dyspnea, chronic obstructive pulmonary disease, ascites, congestive heart failure, hypertension, dialysis, disseminated cancer, open wound/wound infection, unintentional weight loss, and bleeding disorders were collected. Surgical characteristics including preoperative transfusion and total operative time were also collected.

Postoperative complications that occurred within 30 days of surgery included superficial SSI, deep SSI, organ/space SSI, wound dehiscence, deep vein thrombosis/thrombophlebitis, pulmonary embolism, stroke/cerebrovascular accident, pneumonia, renal insufficiency, acute renal failure, myocardial infarction, cardiac arrest, sepsis, septic shock, bleeding transfusions, failure to wean, reintubation, reoperation, and readmission. Discharge destination, home vs. nonhome, and prolonged hospital stay > 3 days were also included in this analysis.

A total of 27,050 patients who underwent TSA between 2015 and 2020 were included in this study. Cases were excluded as follows: 152 for missing height/weight, 227 for unknown functional status, 11 for unknown discharge destination, 29 for missing ASA classification, 16 for missing length of hospital stay, and 2 for missing readmission status. The remaining 26,613 patients were divided into cohorts, with 23,717 (89.1%) in the no MetS cohort and 2896 (10.9%) in the MetS cohort (Fig. 1).

All statistical analyses were completed using SPSS Software version 29.0 (IBM Corp., Armonk, NY, USA). Patient demographics and comorbidities were compared between cohorts using bivariate logistic regression analysis. Multivariate binomial logistic regression, adjusted for all significant demographics and comorbidities, was then used to identify the postoperative outcomes independently associated with MetS. Odds ratios (ORs) were reported for 95% confidence intervals (CIs). Significance was set to $P < .05$.

Results

Bivariate analysis was used to identify patient demographics and comorbidities significantly associated with MetS patients undergoing TSA, shown in Table I. The characteristics significantly associated with the MetS cohort were age < 65 years ($P < .001$), female gender ($P = .017$), ASA ≥ 3 ($P < .001$), dependent functional status ($P < .001$), current nonsmoker ($P < .001$), dyspnea on exertion ($P = .048$), dyspnea at rest ($P < .001$), chronic obstructive pulmonary disease ($P < .001$), congestive heart failure ($P < .001$), open wound/wound infection ($P = .013$), and bleeding disorders ($P = .004$). In contrast, patients with MetS were less likely to be aged ≥ 75 years ($P < .001$).

Bivariate analysis was also used to identify postoperative outcomes significantly associated with MetS, shown in Table II. The outcomes significantly associated with the MetS cohort were pneumonia ($P = .003$), renal insufficiency ($P < .001$), acute renal failure ($P = .009$), myocardial infarction ($P < .001$), sepsis ($P = .018$), bleeding transfusions ($P = .027$), reoperation ($P = .012$), readmission ($P < .001$), nonhome discharge ($P < .001$), and prolonged hospital stay > 3 days ($P < .001$).

Multivariate logistic regression, including all significant demographics and comorbidities, was used to identify which postoperative outcomes were independently associated with MetS, shown in Table III. MetS was found to be an independent predictor of pneumonia (OR 1.61, 95% CI 1.02-2.55; $P = .042$), renal insufficiency (OR 4.09, 95% CI 1.67-10.00; $P = .002$), acute renal failure (OR 4.17, 95% CI 1.13-15.31; $P = .032$), myocardial infarction (OR 2.11, 95% CI 1.21-3.69; $P = .009$), nonhome discharge (OR 1.41, 95% CI 1.24-1.60; $P < .001$), and prolonged hospital stay > 3 days (OR 1.44, 95% CI 1.25-1.66; $P < .001$).

Discussion

In our study, we investigated 30-day postoperative outcomes associated with MetS in patients undergoing TSA between 2015 and 2020 using a large national database. We followed the precedent set by other large database studies, defining MetS as having a BMI > 30, hypertension, and diabetes mellitus.[5,11] After adjusting for significant demographics and comorbidities, we identified MetS to be an independent risk factor for pneumonia, renal insufficiency, acute renal failure, myocardial infarction, nonhome discharge, and prolonged length of stay following TSA.

The term MetS encompasses multiple characteristics, including insulin resistance, central obesity, hypertension, and dyslipidemia, that impact the overall health of an individual.[7] Potential negative health outcomes associated with MetS include increased cardiovascular and thromboembolic risk, endocrine dysfunction, and development of osteoarthritis.[7] Furthermore, the presence of abdominal obesity has also been shown to significantly increase

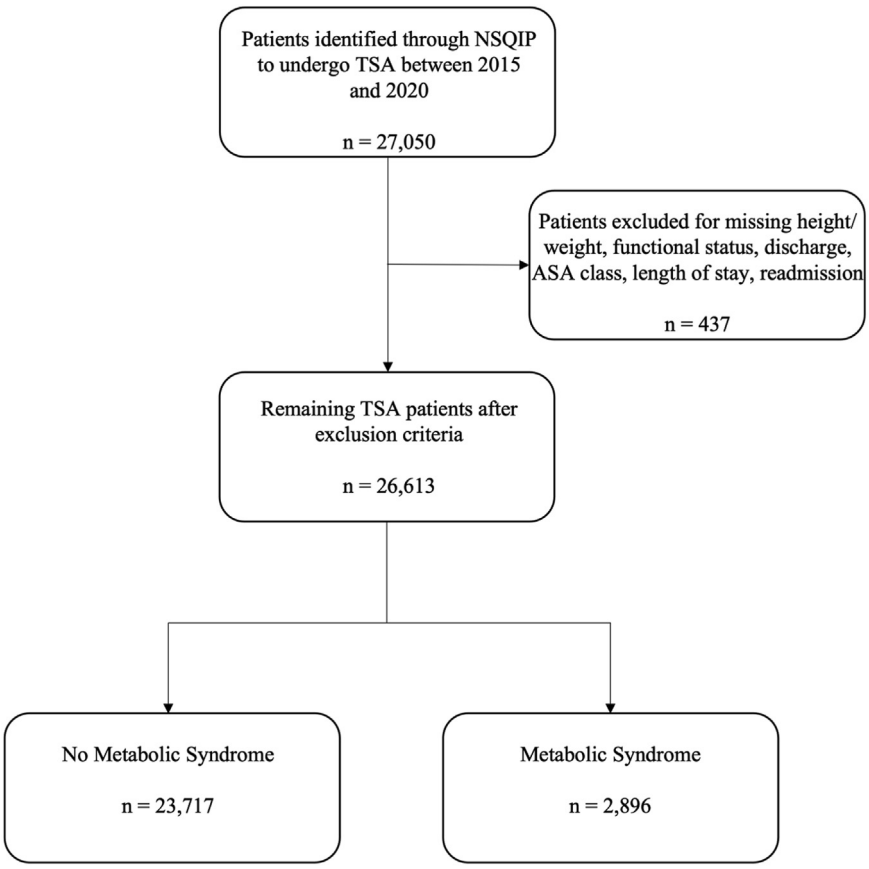

Figure 1 Inclusion and exclusion criteria for no MetS and MetS cohorts. *NSQIP,* National Surgical Quality Improvement Program; *TSA,* total shoulder arthroplasty; *ASA,* American Society of Anesthesiologists.

risk of insulin resistance and diabetes.[2,18] The mechanism of the many medical complications seen among MetS patients is overall complex and multifactorial. For example, it has been suggested that obesity and insulin resistance lead to oxidative stress that increases atherogenesis and fibrosis.[22]

As rates of obesity continue to rise across the United States, the demand for orthopedic surgery is increasing.[18] Along with these increasing obesity rates, MetS has also been on the rise. A study by Murphy et al reported overall increasing trends in MetS diagnosis, with a 257% increase from 2002 to 2011.[20] Moreover, MetS has been reported to affect up to 40% of adults, and the amount of individuals affected markedly increases with age.[7] The management of this condition greatly contributes to increased hospital costs and potentially burdens the healthcare system. Previous studies have shown that obesity and diabetes as independent factors place patients at higher risks for poor postoperative outcomes such as readmission and pulmonary complications in orthopedic surgeries.[9,14] Therefore, the adverse outcomes associated with MetS patients following orthopedic surgery is an important area of investigation to improve overall patient management and outcomes.

Prior research on MetS in TSA patients has been limited, but overall shows increased risk of complications following orthopedic surgery. A study by Murphy et al that looked at TSA patients from 2002-2011 found overall increasing trends of MetS patients undergoing TSA and reported MetS to be an independent risk factor for multiple medical and surgical complications.[20] Marigi et al reported rates of deep infection, joint instability, venous thrombosis, and pulmonary embolism to be significantly higher in the MetS group following TSA.[17] However, a study by Garcia et al on TSA patients from 2005-2013 did not find MetS to be an independent predictor of adverse postoperative outcomes.[5] Therefore, along with the rise in TSA utilization, it is important to clarify this potential increased risk of the MetS patient population.

In our study, we identified MetS to be an independent risk factor for both renal insufficiency and acute renal failure following TSA. This is consistent with prior research on shoulder arthroplasty, as Murphy et al found acute renal failure to be a statistically significant outcome among MetS patients.[20] Moreover, BMI > 35 kg/m^2 can significantly increase risk of postoperative medical complications, including renal insufficiency and failure.[8] Patients with MetS are more likely to be at increased risk of adverse renal outcomes, as the oxidative stress and inflammation associated with increased adipose tissue may lead to endothelial dysfunction and hypertension.[27] Additionally, increased perirenal fat can cause high intrarenal pressures and has been shown to be an independent predictor of kidney dysfunction.[12] Kidney dysfunction itself has also been shown to lead to postoperative complications following TSA, including postoperative anemia requiring transfusion, nonhome discharge, and hospital readmission.[10]

We also identified MetS to be an independent predictor of pneumonia following TSA. Adverse pulmonary outcomes in MetS patients have been inconsistently reported in prior studies.[7] Interestingly, a study by Cichos et al found MetS to be associated with decreased odds of pulmonary outcomes, including pneumonia and pulmonary embolism following hip fractures.[4] However, it is well known that insulin-resistant states, such as those seen in MetS, can cause immune dysregulation, which may increase a

Table I
Patient demographics and comorbidities in patients with and without metabolic syndrome following TSA.

Characteristic	No metabolic syndrome		Metabolic syndrome		*P* value
	Number	Percent	Number	Percent	
Total	23,717	100.0%	2896	100.0%	
Age					
18-39	4	0.02%	140	4.8%	**.001**
40-64	6574	27.7%	744	25.7%	**<.001**
65-74	9703	40.9%	1420	49.0%	–
≥75	7300	30.8%	728	25.1%	**<.001**
Gender					**.017**
Female	13,147	55.4%	1673	57.8%	
Male	10,570	44.6%	1223	42.2%	
Body mass index (kg/m^2)					
>18.5	195	0.83%	0	0.00%	1.000
18.5-30.0	12,704	53.6%	0	0.00%	–
30.1-34.9	5878	24.8%	1224	42.3%	.956
35-39.9	2895	12.2%	891	30.8%	.955
≥40	2045	8.6%	781	26.9%	.955
ASA classification					**<.001**
1-2	10,867	45.8%	421	14.5%	
≥ 3	12,850	54.2%	2475	85.5%	
Functional status					**<.001**
Independent	23,248	98.0%	2798	96.6%	
Dependent	469	1.9%	98	3.4%	
Current smoker					**<.001**
No	21,201	89.4%	2663	92.0%	
Yes	2516	10.6%	233	8.0%	
Diabetes					
No	21,803	91.9%	0	0.0%	–
Noninsulin	1442	6.1%	1978	68.3%	.937
Insulin	472	1.9%	918	31.7%	.936
Dyspnea					
No	22,226	93.7%	2592	89.5%	–
Moderate exertion	1424	6.0%	290	10.0%	**<.001**
At rest	67	0.3%	14	0.5%	**.048**
COPD					**<.001**
No	22,192	93.6%	2650	91.5%	
Yes	1525	6.4%	246	8.5%	
Ascites					.999
No	23,713	99.9%	2896	100.0%	
Yes	4	0.02%	0	0.0%	
CHF					**<.001**
No	23,581	99.4%	2855	98.6%	
Yes	136	0.6%	41	1.4%	
Hypertension					.963
No	8921	37.6%	0	0.0%	
Yes	14,796	62.4%	2896	100.0%	
On dialysis					.824
No	23,641	99.7%	2886	99.7%	
Yes	76	0.3%	10	0.3%	
Disseminated cancer					.269
No	23,659	99.8%	2892	99.9%	
Yes	58	0.2%	4	0.1%	
Open wound/wound infection					**.013**
No	23,640	99.7%	2878	99.4%	
Yes	77	0.3%	18	0.6%	
10% weight loss					.995
No	23,668	99.8%	2890	99.8%	
Yes	49	0.2%	6	0.2%	
Bleeding disorders					**.004**
No	23,143	97.6%	2800	96.7%	
Yes	574	2.4%	96	3.3%	
Chronic steroid use					.228
No	22,556	95.1%	2769	95.6%	
Yes	1161	4.9%	127	4.4%	
Preoperative transfusion					.11
No	23,670	99.8%	2886	99.5%	
Yes	47	0.2%	10	0.5%	
Total operative time					
0-79	6072	25.6%	710	24.5%	.574
80-128	11,800	49.8%	1418	49.0%	–
≥129	5845	24.6%	768	26.5%	.060

TSA, total shoulder arthroplasty; *ASA*, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease; *CHF*, congestive heart failure.
Bold *P* value indicates statistical significance with *P* value set to <.05.

Table II
Thirty-day postoperative outcomes in patients with and without metabolic syndrome.

Postoperative complication	No metabolic syndrome		Metabolic syndrome		*P* value
	Number	Percent	Number	Percent	
Superficial SSI	60	0.25%	9	0.31%	.564
Deep SSI	14	0.06%	3	0.10%	.377
Organ space SSI	55	0.23%	3	0.10%	.174
Wound dehiscence	16	0.07%	1	0.03%	.516
DVT/Thrombophlebitis	74	0.31%	9	0.31%	.991
Pulmonary embolism	65	0.27%	9	0.31%	.723
Stroke/CVA	19	0.08%	3	0.10%	.679
Pneumonia	101	0.43%	24	0.83%	**.003**
Renal insufficiency	15	0.06%	8	0.28%	**<.001**
Acute renal failure	6	0.03%	4	0.14%	**.009**
Myocardial infarction	55	0.23%	17	0.59%	**<.001**
Cardiac arrest	12	0.05%	2	0.07%	.684
Sepsis	30	0.13%	9	0.31%	**.018**
Septic shock	12	0.05%	1	0.03%	.714
Bleeding transfusions	404	1.70%	66	2.28%	**.027**
Failure to wean	26	0.11%	0	0.00%	.998
Reintubation	39	0.16%	9	0.31%	.085
Reoperation	313	1.32%	55	1.90%	**.012**
Readmission	662	2.79%	113	3.90%	**<.001**
Mortality	36	0.15%	6	0.21%	.480
Nonhome discharge	1892	7.98%	377	13.02%	**<.001**
Prolonged hospital stay (>3 days)	1386	5.84%	295	10.19%	**<.001**

SSI, surgical site infection; *DVT*, deep vein thrombosis; *CVA*, cerebrovascular accident.
Bold *P* value indicates statistical significance with *P* value set to <.05.

Table III
Multivariate analysis of 30-day postoperative outcomes in patients with and without metabolic syndrome following TSA, adjusted for significant demographics and comorbidities.

Postoperative complication	Odds ratio	95% CI	*P* value
Pneumonia	1.61	1.02-2.55	**.042**
Renal insufficiency	4.09	1.67-10.00	**.002**
Acute renal failure	4.17	1.13-15.31	**.032**
Myocardial infarction	2.11	1.21-3.69	**.009**
Sepsis	1.74	0.80-3.78	.159
Bleeding transfusions	1.11	0.85-1.46	.438
Reoperation	1.28	0.95-1.72	.109
Readmission	1.19	0.97-1.47	.098
Nonhome discharge	1.41	1.24-1.60	**<.001**
Prolonged hospital stay > 3 days	1.44	1.25-1.66	**<.001**

TSA, total shoulder arthroplasty; *CI*, confidence interval.
Bold *P* value indicates statistical significance with *P* value set to <.05.

patient's likelihood of infectious complications.[3] Furthermore, immune dysregulation may impact leukocyte counts, and preoperative leukocytosis has been identified as an independent predictor of additional postoperative complications following TSA, such as bleeding transfusions and nonhome discharge.[13]

MetS is a well-known risk factor for cardiovascular disease, and increased risk of postoperative myocardial infarction and other adverse cardiovascular events have previously been reported.[4,7,20] Similarly, we identified MetS to be an independent predictor for postoperative myocardial infarction. Cardiovascular disease is a common comorbidity among obese individuals and has been found to be twice as likely among MetS patients.[2,18] The chronic inflammation in MetS has been suggested to lead to this increased prevalence due to endothelial cell dysfunction and activation of monocytes.[22] Of note, patients with MetS are at increased risk of death from cardiovascular disease compared to the general population.[25] Furthermore, having a greater number of MetS characteristics has been associated with increased risk of adverse cardiovascular outcomes, and the stress of surgery could further exacerbate these risk factors.[7]

Finally, we identified MetS to be an independent risk factor for prolonged hospital stay and nonhome discharge. This finding is similar to prior studies on MetS patients undergoing TSA.[20] A study by Mahure et al reported that patients with diabetes, a component of MetS, are at increased risk of nonhome discharge and prolonged length of stay following elective TSA.[16] Nonhome discharge and longer length of stay among diabetic patients have both been shown to lead to increased hospital costs, decreased bone strength, and impaired return to independent functional status.[14,15] Therefore, the negative impact of MetS on these outcomes may be important to consider to minimize both hospital costs and negative long-term patient outcomes.

Our study is limited to the information available on the ACS-NSQIP database. Therefore, we are not able to analyze outcomes outside of a 30-day postoperative window. Furthermore, the broad categorical format of the NSQIP database restricted our ability to analyze other potential contributing factors including severity of each comorbidity, specific indications for surgery, and individual physician skill. Additionally, our definition of MetS was limited to the characteristics available through the NSQIP database, with factors such as abdominal waist circumference and hyperlipidemia unable to be assessed. Additionally, socioeconomic status and educational level, identified in prior studies to affect the development of MetS, were unable to be investigated.[19] Further research should be directed at better understanding how the management of individual MetS components could improve outcomes.[28] Overall, we were able to use a large national database to investigate the postoperative outcomes associated with MetS following TSA. This contributes to upper extremity literature regarding the postoperative outcomes in MetS patients.

Conclusion

MetS was identified as an independent predictor of postoperative pneumonia, renal insufficiency, acute renal failure, myocardial infarction, nonhome discharge, and prolonged hospital stay > 3 days within 30 days following TSA. As the demand for TSA continues to rise, along with the increase in obesity and

MetS patients, it is important to understand the risk factors and outcomes in this patient population to minimize adverse outcomes.

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