Risk of Adverse Outcomes in Asthma Patients following Total Shoulder Arthroplasty

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Background: Asthma is a common condition, and as its incidence increases, the number of patients undergoing total shoulder arthroplasty (TSA) with this condition will also increase.

Purpose: To investigate the relationship of asthma with adverse outcomes after TSA, allowing better risk stratification of patients who may be eligible for single-day surgery.

Hypothesis: Asthma is an independent risk factor for increased postoperative adverse events, with greater asthma severity correlating with worse outcomes.

Methods: Using a national claims database (2015 to 2021), patients aged 18 years and older who underwent primary anatomic or reverse TSA for osteoarthritis, with and without asthma, were identified using diagnosis and procedure codes. Asthma severity (mild intermittent, mild persistent, moderate, severe) was assigned from ICD-10 codes. Cohorts were matched 1:4 on age, sex, Charlson Comorbidity Index, obesity, smoking, and rheumatoid arthritis. Multivariate logistic regression compared 90-day adverse events and 5-year aseptic revision.

Results: The matched cohort comprised 173,071 patients, 35,148 (20.3%) with asthma. Asthma was associated with higher odds of deep vein thrombosis (odds ratio [OR] = 1.23), atelectasis (OR = 1.23), and emergency department visits (OR = 1.1), and lower odds of respiratory failure (OR = 0.83). By severity, every group had higher odds of atelectasis, emergency department visits, all adverse events (OR = 1.18 to 1.44), and severe adverse events (OR = 1.19 to 1.31). Respiratory failure odds rose with severity (mild persistent OR = 1.28, moderate OR = 1.55, severe OR = 2.34). Severe asthma was also associated with pneumonia (OR = 2.10), sepsis (OR = 1.68), and readmission (OR = 1.38). Moderate and severe asthma had higher odds of minor adverse events. Aseptic revision at 5 years did not differ (OR = 1.05).

Conclusion: Asthma, regardless of severity, was associated with higher odds of 90-day all-cause and severe adverse events, atelectasis, and emergency department visits after total shoulder arthroplasty, and respiratory failure odds increased with severity. Effect sizes were modest, and causality cannot be inferred. Orthopedic surgeons should consider asthma and its severity in preoperative counseling and perioperative planning.

What this study adds: Asthma of any severity modestly raised early complication risk after TSA, with respiratory failure risk rising with severity but no difference in 5-year revision.

How this study might affect research, practice or policy: Surgeons should assess asthma severity when counseling patients and selecting candidates for single-day TSA, and prospective studies should test whether preoperative optimization reduces risk.

Study Design: Retrospective cohort study

Level of Evidence: III

Keywords: Arthroplasty; Joint; Orthopedics; Shoulder; Sport medicine

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INTRODUCTION

Total shoulder arthroplasty (TSA) is an increasingly popular surgery performed for end-stage shoulder joint pathology, including osteoarthritis, and has demonstrated reproducible effectiveness in providing pain relief in a cost-effective manner [1][2][3]. Indeed, the number of TSA performed each year has grown exponentially, and is expected to continue rising [4][5]. With the increased incidence of TSA, and in light

of bundled payment initiatives, there is a growing focus on risk stratification to enhance outcomes, prevent readmissions, and ensure high-quality care [6]. In this context, critical evaluation of a patient's perioperative risk is an emerging area of interest.

Risk stratification can aid in preoperative optimization by addressing modifiable risk factors that could portend negative outcomes such as obesity, diabetes, and smoking status [7][8][9][10]. An understanding of non-modifiable risk factors is useful when discussing the risks and benefits of elective procedures with patients for informed consent. Moreover, it could play a role in decision-making regarding discharge disposition - especially as outpatient TSA becomes more common [11]. That is, risk stratification could be used to decide which patients are appropriate for outpatient surgery.

One risk factor to consider during stratification is asthma. Asthma is a common chronic condition worldwide and frequently overlaps with the TSA patient demographic [12]. It has been shown to be a risk factor for postoperative pulmonary complications across various surgeries [13]. Moreover, in the total joint arthroplasty literature, it has been included in risk-stratification tools - and shown to be associated with pulmonary and non-pulmonary adverse events [14][15]. Nevertheless, there is a paucity of research investigating asthma as a potential risk factor for adverse events specifically in TSA. Thus, in our study, we sought to highlight the relationship of asthma with adverse outcomes in patients undergoing TSA with the goal of better risk stratifying patients who are eligible for single day surgery and to optimize postoperative care protocols. We hypothesized that asthma would be an independent risk factor for poor 90-day postoperative adverse events.

MATERIALS AND METHODS

Study design and population

A retrospective cohort analysis of the Mariner dataset within the PearlDiver (PearlDiver Inc, Colorado Springs, CO) database was performed for patients treated from January 2015 through December 2021. This database is a Health Insurance Portability and Accountability Act (HIPAA)-compliant national claims database which allows for cohort analysis based on International Classification of Disease (ICD) 9 and 10 codes as well as Current Procedure Terminology (CPT) codes. The Mariner dataset contains claims information on over 160 million de-identified patients in the United States. Each patient is assigned a unique identifier which allows for longitudinal tracking even after changes in insurance type. The study is reported in accordance with the STROBE guideline for cohort studies.

Ethics approval and patient consent

The database provides only de-identified and aggregated patient data, ensuring compliance with privacy standards and exempting this research from review by the Johns Hopkins Institutional Review Board (**IRB #NCR213330**). The study was conducted in accordance with the Declaration of Helsinki.

Patient selection and asthma classification

Patients aged 18 and older undergoing primary TSA for osteoarthritis with and without asthma were identified using ICD 9 and 10 codes and CPT codes. Primary TSA, including both anatomic and reverse prostheses, was identified using CPT code 23472. Asthma patients were then further divided based on asthma severity: mild intermittent, mild persistent, moderate, and severe asthma. Severity was assigned from the ICD-10 diagnosis codes recorded in the claims (J45.2x, mild intermittent; J45.3x, mild persistent; J45.4x, moderate persistent; J45.5x, severe persistent), not from medication use or a clinical severity scale, and these code-based definitions were not validated against clinical records. The overall asthma cohort comprised patients with any asthma diagnosis code. Patients undergoing TSA for fracture, infection or malignancy were excluded. Demographic information including age, sex, and Charlson Comorbidity Index Score (CCI), were recorded.

Primary and secondary outcomes

The primary outcome was 90-day post-operative adverse events after TSA. All adverse events were subdivided into severe and minor adverse events. Severe adverse events included respiratory failure, failure to wean off ventilator, reintubation, pulmonary embolism (PE), sepsis, cardiac arrest, myocardial infarction, deep vein thrombosis (DVT), and superficial surgical site infection (SSI). Minor adverse events included pneumonia, atelectasis, wound dehiscence, urinary tract infection (UTI), acute kidney injury (AKI), pleural effusion, hematoma, and transfusion. Secondary outcomes included 5-year aseptic revision rates.

Sample size calculation

No a priori sample size or power calculation was performed; all eligible patients in the database during the study period were included.

Reporting equity, diversity, and inclusion in research

The study includes women and men aged 18 years and older across a wide range of ages and comorbidity profiles. Sex refers to the sex recorded in the claims data (male or female); gender identity is not recorded, so gender-based analyses were not possible. Before matching, the asthma cohort was

predominantly female (68.8% vs. 51.9% in the non-asthma cohort), and sex was therefore included as a matching variable (61.9% and 61.7% female in the matched asthma and non-asthma cohorts, respectively). Race, ethnicity, socioeconomic status, and other social determinants of health are not available in the database and are not reported, which limits conclusions about equity and generalizability.

Statistical analysis

All statistical analysis was performed using analytical tools within the database. Univariate analysis was performed using student t-test and chi-squared tests to compare patient demographics and characteristics between cohorts. A 1:4 match was then performed between the asthma and non-asthma patient cohorts based on age, sex, CCI score, obesity, smoking, and rheumatoid arthritis. Balance after matching was assessed by comparing demographics and comorbidities between the matched cohorts with the same tests (**Supplementary Table 2**). Multivariate logistic regression was conducted to control for confounding variables and to compare the incidence of 90-day adverse events and 5-year aseptic revision rates. Any comorbidities that remained significantly different ($p < 0.05$) between the matched cohorts (**Supplementary Table 2**) were included as covariates in the logistic regression models. Odds ratio (OR) and 95% confidence intervals were collected for adverse events. The asthma severity sub cohorts were evaluated similarly. P-values less than 0.05 were considered statistically significant and exact p-values are reported unless less than 0.001. No adjustment for multiple comparisons was applied; findings close to the significance threshold should therefore be interpreted cautiously. Odds ratios are reported as odds ratios and were not interpreted as relative risks.

RESULTS

Unmatched demographics and characteristics

Of the 266,553 patients with osteoarthritis undergoing TSA, 49,009 (18.4%) had asthma (**Supplementary Table 1**). Patient selection and flow are shown in **Figure 1**. Patients with asthma were significantly younger than those without asthma (67.8 ± 8.5 years vs. 69.1 ± 8.2 years, $p < 0.001$). The asthma cohort comprised of 33,724 (68.8%) females whereas the cohort without asthma comprised of 112,788 (51.85%) females ($p < 0.001$). The average CCI in patients with asthma was 2.67 ± 2.39, and the average CCI in those without asthma was 1.8 ± 2.1 ($p < 0.001$). Length of stay in the asthma group was 1.9 ± 1.53 days whereas the length of stay in the non-asthma group was 1.8 ± 1.5 days ($p < 0.001$). Smoking was more prevalent in the asthma group than in the non-asthma group (17,114 [34.9%] and 58,328 [26.8%], respectively; $p < 0.001$).

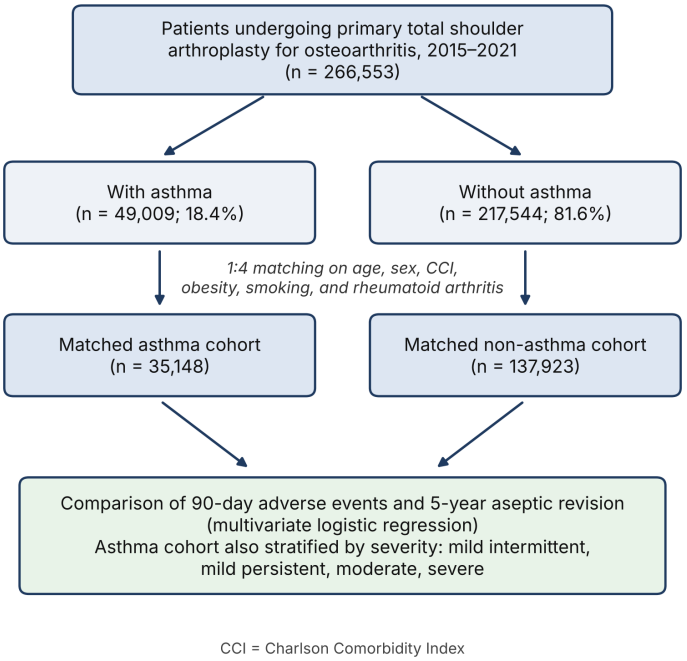


Figure 1. Patient flow. Patients undergoing primary total shoulder arthroplasty for osteoarthritis were divided by asthma status, matched 1:4, and compared for 90-day adverse events and 5-year aseptic revision; the asthma cohort was also stratified by severity.

Unmatched incidence rates

Supplementary Table 1 depicts comorbidities in the unmatched cohorts. A number of comorbidities such as congestive heart failure (4,826 [9.85%] vs. 14,592 [6.71%]), arrhythmias (11,909 [24.30%] vs. 43,732 [20.10%]), chronic pulmonary disease (37,480 [76.48%] vs. 43,634 [20.06%]), and obesity (21,431 [43.73%] vs. 60,383 [27.76%]) were significantly more prevalent in the group with asthma (p <0.001 for all).

Matched demographics

After matching, a total of 173,071 patients were included with 35,148 (20.3%) patients in the asthma cohort and 137,923 (79.7%) patients in the cohort without asthma (**Supplementary Table 2**). The average age in the asthma group was 68.83 ± 8.0 years vs. 68.88 ± 7.9 years in the non-asthma group (p = 0.26). CCI was significantly higher in the cohort with asthma than the cohort without asthma (2.08 ± 1.90 and 2.03 ± 1.85, respectively; p < 0.001). The cohort with asthma comprised of 21,753 (61.89%) females whereas the cohort without asthma comprised of 85,133 (61.73%) females. The average length of stay in patients with asthma was 1.81 ± 1.37 days whereas average length of stay in patients without asthma was 1.83 ± 1.58 days (p = 0.78).

Matched incidence rates

Supplementary Table 2 depicts comorbidities in the matched cohorts. Congestive heart failure was significantly more prevalent in the cohort with asthma than the cohort without asthma (2,739 [7.79%] and 10,247 [7.43%], respectively; p = 0.022). Similarly, other comorbidities such as arrhythmias (7,773 [22.12%] vs. 28,704 [20.81%]), and chronic pulmonary disease (25,262 [71.87%] vs. 31,541 [22.87%]), were significantly more common in the cohort with asthma (p <0.001 for all). Peripheral vascular disease (6,375 [18.14%] vs. 26,521 [19.23%]) and chronic kidney disease (4,565 [12.99%] vs. 19,980 [14.49%]) were more prevalent in the cohort without asthma (p <0.001 for both).

90-day Multivariate Analysis in Asthma vs. No Asthma Cohorts

Patients with asthma undergoing TSA had significantly higher odds of having deep vein thrombosis (DVT) (OR = 1.23 [1.04-1.45], p = 0.02), emergency department (ED) visits (OR = 1.1 [1.05-1.14], p < 0.001), and atelectasis (OR = 1.23 [1.07-1.41], p = 0.004) within 90 days of their procedure. The cohort with asthma had significantly lower odds of having cardiac arrest (OR = 0.47 [0.3-0.72], p < 0.001), respiratory failure (OR = 0.83 [0.74-0.92], p < 0.001), pleural effusion (OR = 0.70 [0.59-0.83], p < 0.001), and transfusion (OR = 0.65 [0.53-0.78], p < 0.001) within 90 days of their procedure.

90-day Multivariate Analysis in Asthma by Severity vs. No Asthma Cohorts

The overall and severity-specific analyses were modeled separately, so the overall odds ratios above are not averages of the severity-specific estimates; the precision of each severity-specific estimate is shown by its 95% confidence interval (**Tables 1-4**). Patients in all severity groups had significantly higher odds of developing atelectasis (Mild intermittent OR = 1.84 [1.54-2.21], Mild persistent OR = 2.10 [1.66-2.67], Moderate OR= 1.97 [1.59-2.44], Severe OR = 2.35 [1.62-3.41], respectively) and visiting the emergency department (OR = 1.49 [1.41-1.57], OR= 1.38 [1.27-1.50], OR= 1.43 [1.33- 1.53], OR = 1.47 [1.28-1.69], respectively; p < 0.001 for all) (**Tables 1-4**).

Patients with mild intermittent, mild persistent, and moderate asthma had significantly higher odds of developing urinary tract infections (OR = 1.27 [1.14-1.41], OR = 1.33 [1.14-1.54], OR = 1.24 [1.08-1.41], respectively; p < 0.001 for mild intermittent and mild persistent, p = 0.002 for moderate) and deep vein thrombosis (OR = 1.72 [1.38-2.15], OR = 1.63 [1.29-2.43], OR = 1.92 [1.49-2.49], respectively; p < 0.001 for all). The odds of developing these outcomes did not appear to increase with asthma severity.

Patients with mild persistent, moderate, and severe asthma had significantly higher odds of respiratory failure with odds incrementally increasing with degree of asthma severity (OR = 1.28 [1.05-1.56], OR = 1.55 [1.32-1.81], OR = 2.34 [1.83-3.00], respectively; p = 0.014 for mild persistent and p < 0.001 for moderate and severe). Furthermore, patients with moderate and severe asthma had significantly higher odds of developing pneumonia (OR = 1.44 [1.23-1.68] and OR = 2.10 [1.62-2.70], respectively; p < 0.001), while patients with severe asthma had significantly higher odds of developing sepsis (OR = 1.68 [1.10-2.56], p = 0.016) and readmission (OR = 1.38 [1.06-1.80], p = 0.016) within 90 days.

Table 1. 90-Day Matched Multivariate Logistic Regression Outcomes (Mild Intermittent Asthma vs. No Asthma).

	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Deep Vein Thrombosis	1.72	1.38	2.15	**<.001**
Cardiac Arrest	0.53	0.27	1.05	0.070
Myocardial Infarction	0.76	0.53	1.07	0.116
Acute Kidney Injury	1.01	0.87	1.19	0.857
Pneumonia	1.02	0.88	1.18	0.822
Pulmonary Embolism	0.90	0.64	1.28	0.559
Urinary Tract Infection	1.27	1.14	1.41	**<.001**
Sepsis	1.14	0.92	1.41	0.221
Surgical Site Infection	1.20	0.87	1.65	0.270
Readmission	0.97	0.85	1.10	0.664
Emergency Room Visits	1.49	1.41	1.57	**<.001**
Respiratory Failure	1.05	0.90	1.22	0.542
Failure to wean of Ventilator	1.75	0.77	4.02	0.184
Reintubation	*	0.00	*	0.977
Atelectasis	1.84	1.54	2.21	**<.001**
Wound Dehiscence	1.24	0.84	1.83	0.271
Pleural Effusion	0.85	0.66	1.08	0.183
Hematoma	0.96	0.67	1.36	0.821
Transfusion	0.61	0.45	0.83	0.001

* no data due to one of the groups having an incidence of 0 for this outcome. CI: Confidence Interval

Table 2. 90-Day Matched Multivariate Logistic Regression Outcomes (Mild Persistent Asthma vs. No Asthma).

	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Deep Vein Thrombosis	1.63	1.29	2.43	**<.001**
Cardiac Arrest	0.66	0.23	1.46	0.369
Myocardial Infarction	1.10	0.71	1.70	0.660
Acute Kidney Injury	1.16	0.93	1.45	0.177
Pneumonia	1.20	0.98	1.46	0.073
Pulmonary Embolism	1.08	0.68	1.72	0.743
Urinary Tract Infection	1.33	1.14	1.54	**<.001**
Sepsis	0.94	0.67	1.31	0.703
Surgical Site Infection	1.05	0.64	1.71	0.858
Readmission	0.95	0.79	1.15	0.584

	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
ED Visits	1.38	1.27	1.50	**<.001**
Respiratory Failure	1.28	1.05	1.56	**0.014**
Failure to wean of Ventilator	0.58	0.08	4.27	0.590
Reintubation	*	0.00	*	1.00
Atelectasis	2.10	1.66	2.67	**<.001**
Wound Dehiscence	0.82	0.42	1.62	0.570
Pleural Effusion	0.84	0.59	1.21	0.350
Hematoma	0.98	0.58	1.66	0.949
Transfusion	0.54	0.36	0.86	**0.010**

* no data due to one of the groups having an incidence of 0 for this outcome. CI: Confidence Interval

Table 3. 90-Day Matched Multivariate Logistic Regression Outcomes (Moderate Asthma vs. No Asthma).

	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Deep Vein Thrombosis	1.92	1.49	2.49	**<.001**
Cardiac Arrest	0.47	0.19	1.15	0.096
Myocardial Infarction	0.87	0.58	1.31	0.505
Acute Kidney Injury	1.05	0.86	1.27	0.650
Pneumonia	1.44	1.23	1.68	**<.001**
Pulmonary Embolism	1.06	0.71	1.58	0.770
Urinary Tract Infection	1.24	1.08	1.41	**0.002**
Sepsis	1.14	0.88	1.49	0.313
Surgical Site Infection	1.39	0.96	2.02	0.082
Readmission	1.10	0.94	1.27	0.239
ED Visits	1.43	1.33	1.53	**<.001**
Respiratory Failure	1.55	1.32	1.81	**<.001**
Failure to wean of Ventilator	0.87	0.20	3.66	0.844
Reintubation	*	0.00	*	1.000
Atelectasis	1.97	1.59	2.44	**<.001**
Wound Dehiscence	0.97	0.58	1.68	0.961
Pleural Effusion	0.97	0.73	1.29	0.830
Hematoma	0.93	0.59	1.47	0.755
Transfusion	0.66	0.46	0.95	**0.025**

* no data due to one of the groups having an incidence of 0 for this outcome. CI: Confidence Interval

Table 4. 90-Day Matched Multivariate Logistic Regression Outcomes (Severe Asthma vs. No Asthma).

	Odds Ratio	Lower 95% CI	Upper 95% CI	P-value
Deep Vein Thrombosis	1.2	0.66	2.20	0.551
Cardiac Arrest	*	*	N/A	0.959
Myocardial Infarction	1.28	0.66	2.50	0.460
Acute Kidney Injury	1.21	0.85	1.72	0.291
Pneumonia	2.10	1.62	2.70	**<.001**
Pulmonary Embolism	0.94	0.42	2.12	0.880
Urinary Tract Infection	1.07	0.81	1.41	0.625
Sepsis	1.68	1.10	2.56	**0.016**
Surgical Site Infection	1.11	0.49	2.51	0.794
Readmission	1.38	1.06	1.80	0.016
ED Visits	1.47	1.28	1.69	**<.001**
Respiratory Failure	2.34	1.83	3.00	**<.001**
Failure to wean of Ventilator	3.68	0.87	15.6	0.077
Reintubation	*	0.00	*	1.000
Atelectasis	2.35	1.62	3.41	**<.001**
Wound Dehiscence	1.07	0.39	2.88	0.810
Pleural Effusion	1.11	0.66	1.86	0.688
Hematoma	0.95	0.39	2.32	0.917
Transfusion	0.84	0.45	1.58	0.595

* no data due to one of the groups having an incidence of 0 for this outcome. CI: Confidence Interval

90-day Multivariate Analysis by Grouped Adverse Events in Asthma by Severity vs. No Asthma Cohorts

Patients with mild intermittent, mild persistent, moderate, and severe asthma had significantly higher odds of all (OR = 1.18 [1.11,1.26], OR = 1.24 [1.13,1.36], OR = 1.33 [1.23, 1.43], OR = 1.44 [1.25,1.66], respectively; p < 0.001) and severe adverse events (OR= 1.19 [1.10, 1.28], OR = 1.26 [1.14,1.40], OR = 1.28 [1.17, 1.40], OR = 1.31 [1.11,1.57], respectively; p < 0.001 for all) (**Table 5**). Patients with moderate and severe asthma had significantly higher odds of minor adverse events (OR = 1.27 [1.14, 1.40] and OR = 1.65 [1.38, 1.97], respectively; p < 0.001).

5-year Multivariate Analysis in Asthma vs. No Asthma Cohorts

The cohort with asthma was not at significantly greater odds of having a revision procedure at 5-years (OR = 1.05 [0.95-1.17]; p = 0.29).

DISCUSSION

Principal findings

This study was conducted to ascertain the risks associated with TSA in asthmatic patients. A_s the prevalence of asthma continues to rise worldwide, it becomes increasingly important to evaluate how this condition may impact surgical outcomes, informing clinical risk stratification strategies [16] [17]. Such strategies may aid in identifying patients who would benefit from extended postoperative observation, particularly if their asthma is associated with a higher risk of complications. In conjunction with the rapidly increasing incidence of total shoulder arthroplasty, developing a thorough understanding of the interplay between asthma and outcomes following total shoulder arthroplasty allows for orthopaedic surgeons to optimize patient care for this

expanding subset of patients [4][5]. The key results of this study indicate that asthma is associated with modestly higher odds of several adverse outcomes following TSA, suggesting a role for tailored preoperative assessment and postoperative management to enhance patient safety and optimize care for this growing patient population. Our hypothesis was only partially confirmed: asthma was associated with higher odds of deep vein thrombosis, atelectasis, and emergency department visits, every severity group had higher odds of the grouped adverse events, and the odds of respiratory failure rose with asthma severity; however, the overall asthma cohort had lower odds of several other outcomes (cardiac arrest, respiratory failure, pleural effusion, and transfusion), and there was no association with 5-year aseptic revision.

Table 5. Multivariable analysis of 90-day postoperative outcomes of total shoulder arthroplasty patients with varying severities of asthma compared to no asthma.

	Mild Intermittent OR (95% CI)	P-value	Mild Persistent OR (95% CI)	P-value	Moderate Asthma OR (95% CI)	P-value	Severe Asthma OR (95% CI)	P-Value
All adverse events	1.18 (1.11,1.26)	<0.001	1.24 (1.13,1.36)	<0.001	1.33 (1.23, 1.43)	<0.001	1.44 (1.25,1.66)	**<0.001**
Severe adverse events	1.19 (1.10, 1.28)	<0.001	1.26 (1.14,1.40)	<0.001	1.28 (1.17, 1.40)	<0.001	1.31 (1.11,1.57)	**<0.001**
Minor adverse events	1.07 (0.98, 1.17)	0.116	1.13 (1.00, 1.28)	0.050	1.27 (1.14,1.40)	<0.001	1.65 (1.38, 1.97)	**<0.001**

OR: Odds ratio CI; Confidence interval

Comparison with prior research

Previous literature regarding TSA outcomes have reported the incidence of complication such as venous thromboembolism (VTE) to be between 0.2 to 16% [18][19]. Interestingly, several studies included within a systematic review from Saleh et al. found asthma to be a risk factor for VTE following TSA, while others found no significant risk of VTE with asthma [19]. Furthermore, development of atelectasis within 90 days of TSA is underrepresented in orthopaedic literature. In our review, we found a single retrospective review of 119 patients undergoing reverse TSA mentioning atelectasis specifically occurring within the first 90 days postoperatively. In their analysis of TSA patients stratified by body mass index, 2.5% of patients developed atelectasis, which is higher in comparison to the incidence we found in our investigation [20]. Emergency department visits within 90 days of TSA have been shown to be associated with anxiety, post-operative surgical complications, and presentation to the emergency department within 1-year prior to surgery [21].

Overall asthma and asthma severity

Our analysis of adverse events within 90 days following TSA reveals significant associations between asthma and postoperative outcomes. Asthmatic patients, regardless of the severity of their condition, exhibit increased odds of all-cause and severe adverse events. They are more likely to develop specific complications such as atelectasis, DVT, and ED visits within the postoperative period. However, while these patients face higher odds of certain adverse events, the odds of cardiac arrest and respiratory failure (severe adverse events) and of pleural effusion and transfusion (minor adverse events) were significantly lower compared to non-asthmatic patients. The reasons for this pattern are unclear. It has been hypothesized that heightened perioperative vigilance for patients with known asthma could reduce some severe complications, but this study contains no information on monitoring intensity, perioperative management, or medication use, so this explanation is speculative. Residual confounding, selective coding of comorbidities, and chance may also contribute. However, it is important to note that as asthma severity increased, the statistical significance of differences in the rates of cardiac arrest, respiratory failure, and pleural effusion between asthmatic and non-asthmatic patients diminished. In fact, patients with more severe asthma demonstrated increased odds of experiencing respiratory failure. The magnitude of the associations was modest for the overall asthma cohort and the grouped outcomes (odds ratios of approximately 1.1 to 1.4) and larger only for selected outcomes in severe asthma (approximately 2.1 to 2.4 for pneumonia, respiratory failure, and atelectasis). Absolute risk differences were not assessed, so the clinical importance for an individual patient is uncertain.

The overall and severity-specific results are not additive. The overall estimates for respiratory failure (OR = 0.83),

atelectasis, DVT, and ED visits were lower than the corresponding severity-specific estimates, and the overall estimate for respiratory failure was below that of all four severity groups (OR = 1.05 to 2.34). The overall estimate is not a weighted average of the severity-specific estimates because the two sets of analyses were fit separately, each with its own comparison group and covariates, and because patients whose asthma severity was not specified contribute only to the overall analysis. We therefore regard the severity-specific estimates as more informative for risk stratification and interpret the lower overall odds of respiratory failure with caution.

Further analysis, stratified by asthma severity, revealed that patients with mild intermittent, mild persistent, and moderate asthma have elevated odds of urinary tract infections and DVTs but lower odds of requiring transfusions. These complications may be related to the increased odds of ED visits, although this study cannot establish that link; such patients may warrant closer postoperative monitoring. In contrast, those with severe asthma face significantly higher odds of severe complications, including respiratory failure, sepsis, and readmission. While all levels of asthma are associated with increased odds of experiencing both all-measured adverse and severe adverse events following TSA, more severe asthma was associated with progressively higher point estimates for these outcomes (the confidence intervals of adjacent severity groups overlapped, and no formal test for trend was performed). Severe asthma may be associated with a compromised ability to manage postoperative stress and potential infections, leading to more adverse outcomes following TSA [22]. This is consistent with prior studies that have suggested that inhaled corticosteroid use is associated with increased risk of developing periprosthetic joint infection following total hip arthroplasty [23]. Additionally, increasing asthma severity has been associated with greater odds of experiencing severe adverse events such as respiratory failure, pulmonary embolism, and reintubation following total knee arthroplasty [14]. These findings suggest that postoperative management strategies tailored to asthma severity merit consideration. Notably, although our results indicate that asthma is associated with increased odds of experiencing adverse events following TSA, there was no significant difference in the odds of aseptic revision. This lack of significant difference may be attributed to aseptic revisions being primarily driven by mechanical and technical aspects of the implant, such as implant wear, loosening, or surgical technique [24]. Consequently, while asthma may heighten the risk of complications related to infections or postoperative recovery, it does not appear to directly affect the risk of aseptic revision.

Clinical implications

Our findings support thorough consultation between orthopaedic surgeons and asthmatic patients when considering TSA. The significance of these results lies in their potential to enhance preoperative risk assessment and postoperative care. By incorporating asthma severity into risk stratification, clinicians can better identify patients who may require extended observation or intensified postoperative care. Patients should also be made aware of the modestly increased odds of some complications, particularly with more severe asthma. Orthopaedic surgeons may further consider collaborative efforts to optimize asthmatic patients' respiratory status with other physicians prior to and following TSA in efforts to prevent severe post-operative complications. Whether optimizing asthma control before surgery (for example, ensuring adequate controller therapy and the absence of active symptoms, in coordination with the patient’s pulmonologist or primary care physician) reduces these risks cannot be determined from this study, because medication use, symptom control, and lung function were not available. Given the modest effect sizes, these findings are better suited to informing counseling and perioperative planning than to excluding patients from TSA or from outpatient pathways on their own.

Limitations

Consideration should be given to the limitations present in our study. The retrospective design introduces potential selection bias and limits the ability to establish causal relationships [25]. Reliance on the accuracy of CPT and ICD codes may introduce biases or confounding variables associated with the use of national databases. Asthma and its severity were defined from diagnosis codes alone, without medication data, spirometry, or validation against clinical records, so misclassification of both asthma status and severity is possible, and the severity analyses should be considered hypothesis-generating. The data derive from an insured population in a single country, which may limit generalizability to other health care systems. Sex was balanced by matching, but sex-stratified analyses were not performed, so potential sex differences in the association between asthma and outcomes could not be evaluated; gender identity is not recorded in claims data. Additionally, the timeline in which patients were diagnosed with asthma and classification according to severity could not be established, potentially leading to under- or over-reporting of asthma severity in the patients included in our analyses. Another significant limitation is the lack of control for the intensity of medical therapy associated with asthma severity. Patients with severe asthma typically receive more intensive treatment, including higher doses of steroids, which were not

accounted for in our analysis. Furthermore, we were unable to ascertain whether patients were adhering to their prescribed asthma treatments, leaving it unclear if complications were more prevalent among those with poor management or if properly medicated patients with severe asthma had similar complication rates to those with less severe forms. Although age and sex were matched and length of stay was similar between the cohorts after matching, significant differences persisted in a number of variables, including the Charlson Comorbidity Index and comorbidities such as congestive heart failure, chronic pulmonary disease, and diabetes. We aimed to account for these differences by controlling for them in our multivariate logistic regression, adjusting the analysis to mitigate potential confounding effects. This approach mitigates but cannot fully eliminate confounding, and unmeasured factors (for example, asthma control, medication use, and socioeconomic status) may remain. In addition, chronic pulmonary disease, which remained far more prevalent in the asthma cohort after matching, overlaps conceptually with asthma itself, so adjusting for it may have attenuated or distorted the estimated associations. Finally, the severity subgroups were smaller than the overall cohort and the confidence intervals were widest for severe asthma, particularly for rare outcomes (for example, failure to wean from the ventilator); no power calculation or correction for multiple comparisons was performed, and isolated findings with p-values close to 0.05 should be interpreted cautiously.

Future directions

Despite these limitations, our study provided insight into the postoperative risks present for asthmatic patients following TSA. These findings highlight the importance of further research to address the identified limitations and refine risk stratification strategies to improve patient outcomes.

Several mechanisms could be tested in future work. Airway hyperresponsiveness and impaired mucociliary clearance during anesthesia and mechanical ventilation may predispose patients with more severe asthma to atelectasis, pneumonia, and respiratory failure, and chronic airway inflammation or systemic corticosteroid exposure may contribute to infection and thromboembolic events. Studies that capture spirometry, asthma control, controller and rescue medication use, and perioperative anesthetic and airway management could test these theories, and prospective or registry-based designs could evaluate whether preoperative optimization of asthma control reduces postoperative events.

CONCLUSION

Asthma, regardless of severity, was associated with higher odds of 90-day all-cause and severe adverse events, atelectasis, and emergency department visits after total shoulder arthroplasty, and the odds of respiratory failure increased with severity. Effect sizes were modest and causality cannot be inferred. Asthma and its severity merit consideration in preoperative counseling and perioperative planning.

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Conflict of interest

Dr. Srikumaran serves as a board or committee member for AAOS, American Shoulder and Elbow Surgeons, and IASES; reports stock or stock options from ROM3, Sonogen, and Tigon Medical; is a paid consultant for, and receives intellectual property royalties from, Fx Shoulder and Tigon Medical; receives other financial or material support from Arthrex, DePuy–a Johnson & Johnson Company, and Thieme; and has been a paid presenter or speaker for, and received research support from, Fx Shoulder. The remaining authors declare no conflicts of interest.

Authors' contributions

Prasenjit Saha contributed to the conception and design of the study, and data acquisition. Ethan R. Harris, Seyedeh Zahra Mousavi, Jean Fleuriscar, Anthony Bishara, Henry Fox, and Miriam D. Weisberg contributed to the interpretation of the findings, data analysis, and manuscript preparation. Murad Razzak contributed to data analysis, manuscript preparation, revision, and submission. Dr. Umasuthan Srikumaran, MD supervised the study, provided methodological and clinical guidance, and critically revised the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Ethics statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was reviewed by the authors' institutional review board and deemed exempt from full review. The study utilized de-

identified patient data from the PearlDiver Mariner database; therefore, informed consent was not required.

Use of generative AI / large language models

Claude (Anthropic) was used to assist with language editing and revision of this manuscript, to enhance readability and language. The authors reviewed and edited all output and took full responsibility for the content.

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