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Preoperative opioid use is an independent risk factor for complication, revision, and increased health care utilization following primary total shoulder arthroplasty

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Introduction: The incidence of total shoulder arthroplasty (TSA) in increasing. Evidence in primary hip and knee arthroplasty suggest that preoperative opioid use is a risk factor for postoperative complication. This relationship in TSA is unknown. The purpose of this study was to investigate this relationship.

Methods: The Truven Marketscan claims database was used to identify patients who underwent primary, unilateral TSA. Preoperative opioid use status was then used to divide patients into cohorts based on the average daily oral morphine equivalents (OMEs) received in the 6-month preoperative period. This included the following cohorts: opioid naïve and <1, 1-5, 5-10, and >10 average daily OMEs. In total, 29,454 patients with 90-day postoperative follow-up were included. Of these, 21,580 patients and 8959 patients had 1- and 3-year follow-up, respectively. Patient information and complication data were collected. Univariate and multivariate logistic regression were then performed to assess the association of preoperative opioid use with postoperative outcomes. A subgroup analysis was performed to examine revision surgery at 1 and 3 years postoperatively.

Results: Forty-four percent of identified patients received preoperative opioids, but the preoperative opioid-naïve patient became more common over the study period. Multivariate analysis demonstrated that patients receiving >10 average daily OMEs (compared with opioid naïve) had higher odds of opioid overdose (odds ratio [OR] 4.17, 95% confidence interval [CI] 1.57-11.08, $P = .004$), wound complication (OR 2.04, 95% CI 1.44-2.89, $P < .001$), superficial surgical site infection (OR 2.33, 95% CI 1.63-3.34, $P < .001$), prosthetic joint infection (OR 3.41, 95% CI 2.50-4.67, $P < .001$), pneumonia (OR 1.95, 95% CI 1.39-2.75, $P < .001$), and thromboembolic event (OR 1.42, 95% CI 1.18-1.72, $P < .001$). The same group had higher health care utilization, including extended length of stay, nonhome discharge, readmission, and emergency department visits ($P \leq .001$). Total perioperative adjusted costs were more than $7000 higher in the >10-OME group when compared to preoperative opioid-naïve patients.

Discussion: Opioid use prior to TSA is common and is associated with increased complications, health care utilization, revision surgery, and costs. This risk is dose dependent, and efforts should be made at cessation prior to surgery.

Level of evidence: Level III; Retrospective Case-Control Design; Prognosis Study

Keywords: Opioids; complications; outcomes; preoperative; total shoulder; arthroplasty

The incidence of total shoulder arthroplasty (TSA) is increasing exponentially.[10,11,15,18,22,40] Consequently, the prevalence of shoulder arthroplasty in the United States is higher now than ever before and is anticipated to continue to rise.[12] Given this increase in the number of procedures being

As a review of publicly available, deidentified data, this study did not require review by the Emory Institutional Review Board.

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performed, identification of risk factors, particularly modifiable ones, for postoperative complications is paramount. One potential modifiable risk factor is preoperative opioid use.

The opioid epidemic is well established and expected to continue.[1,32,39,45] Opioid pain medication for the treatment of pain—both acute and chronic—has become common, and this is associated with an approximately 25% rate of opioid misuse and 10% rate of opioid addiction.[39] Therefore, it is not surprising that the number of patients undergoing procedures with pain-driven indications (such as arthroplasty) on preoperative narcotics is increasing.[43] However, this is potentially problematic as multiple studies in total hip and knee arthroplasty have identified preoperative opioid use as a risk factor for postoperative complications,[2,4,20,27,30] postoperative narcotic consumption,[30] readmission,[4,20,42] revision,[3,20,36,42] increased costs,[4] and dissatisfaction.[13,36]

The data regarding the same relationship in TSA, however, is primarily limited to small, single-institution investigations.[8,24,25] These studies have demonstrated that preoperative opioid use is associated with increased postoperative opioid consumption,[8] as well as inferior clinical outcomes and satisfaction when compared to the opioid-naïve patients.[7,24,25,37] However, in one small series, there was no difference in readmission or length of stay in those using or not using preoperative opioids.[8] One study using a national database included total shoulder arthroplasty, but TSA patients constituted just 4% of the included population, making interpretation of these data difficult.[4] Therefore, there is a need for further investigation into the impact of preoperative opioid use in patients undergoing primary TSA.

In this study, we sought to investigate the relationship between preoperative opioid use and complications, health care utilization, and revision surgery following TSA. As a secondary outcome, we sought to determine preoperative opioid prescribing trends. We hypothesized that preoperative opioid use would be associated with higher rates of complications, increased health care utilization, and higher revision rates. We additionally hypothesized that preoperative opioid prescriptions would become less common over the study period.

Methods

Data acquisition

This is a retrospective cohort study performed using the Truven Health MarketScan Commercial Claims and Encounters and Medicare Supplemental and Coordination of Benefit databases (Truven Health, Ann Arbor, MI, USA). The database includes deidentified patient data. Since 1995 the database has amassed data on 240 million patients. Information on all facets of care is included, including inpatient hospital stays, outpatient clinical visits, and pharmaceutical information.[38] The database also includes information regarding filled prescriptions and codes these medications using National Drug Codes (NDCs). In the present study, we used NDCs to identify opioid medications prescribed to patients. There is precedence for using these codes for identification of opioids in large databases.[4]

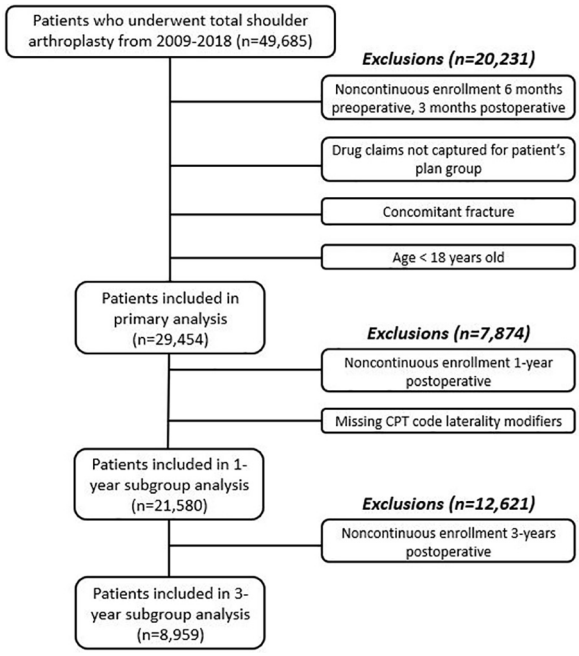

Figure 1 Flow diagram of study inclusion and exclusion criteria.

Patient population

We identified patients included in this study by using Current Procedural Terminology (CPT) codes for primary total shoulder arthroplasty (CPT 23472). Those undergoing hemiarthroplasty and revision shoulder arthroplasty were not included. Additionally, we identified and excluded patients undergoing replacement for fracture using International Classification of Diseases (ICD) diagnosis codes. We queried the years 2009-2018 and initially included all adult patients ($\geq$18 years old) undergoing a total shoulder arthroplasty (anatomic or reverse prosthesis). However, to be ultimately included in the study, patients needed to have continual enrollment in the database for 6 months prior to and 90 days after surgery. Those without this minimal follow-up were excluded. This constituted our final cohort. Figure 1.

Preoperative patient data

We then queried the database for opioid prescriptions (hydrocodone, oxycodone, oxymorphone, dihydrocodeine morphine, hydromorphone, fentanyl, methadone, meperidine, and codeine) preoperatively for each patient. Tramadol was not included as a preoperative opioid for the purposes of this study. We used opioid conversion tables to convert prescription data into oral morphine equivalent (OME) doses. We then calculated average daily OMEs for each patient by dividing the total OMEs prescribed by the duration (in days) of the prescription and labeled this average daily OMEs. Based on these data, we divided patients into the following cohorts: (1) opioid-naïve (no opioid prescriptions for the 6-month preoperative period), (2) <1 OME (received an opioid prescription, but on average this was <1 OME per day), (3) 1-5

Table I Patient demographics and comorbidities

Characteristic	Opioid use group					*P* value*
	Opioid naïve, n (%) (N = 16,529; 56.12%)	<1 OME, n (%) (n = 1637; 5.56%)	1-5 OME, n (%) (n = 4227; 14.35%)	5-10 OME, n (%) (n = 1958; 6.65%)	>10 OME, n (%) (n = 5103; 17.33%)	
Demographic						
Age group, yr						
<55	1397 (8.45)	159 (9.71)	387 (9.16)	194 (9.91)	619 (12.13)	<.001
55-64	5774 (34.93)	567 (34.64)	1583 (37.45)	727 (37.13)	2061 (40.39)	
65-74	4919 (29.76)	460 (28.10)	1164 (27.54)	546 (27.89)	1417 (27.77)	
75-84	3895 (23.56)	390 (23.82)	960 (22.71)	421 (21.50)	874 (17.13)	
≥85	544 (3.29)	61 (3.73)	133 (3.15)	70 (3.58)	132 (2.59)	
Sex						
Male	8599 (52.02)	833 (50.89)	2041 (48.28)	853 (43.56)	2185 (42.82)	<.001
Female	7930 (47.98)	804 (49.11)	2186 (51.72)	1105 (56.44)	2918 (57.18)	
Comorbidities						
Obesity	1760 (10.65)	194 (11.85)	544 (12.87)	236 (12.05)	716 (14.03)	<.001
Chronic kidney disease	739 (4.47)	100 (6.11)	261 (6.17)	116 (5.92)	349 (6.84)	<.001
Alcohol use disorders	105 (0.64)	14 (0.86)	45 (1.06)	27 (1.38)	81 (1.59)	<.001
Tobacco use	463 (2.80)	71 (4.34)	195 (4.61)	65 (3.32)	324 (6.35)	<.001
Hypertension	9583 (57.98)	1009 (61.64)	2670 (63.17)	1264 (64.56)	3310 (64.86)	<.001
Coronary artery disease	2618 (15.84)	273 (16.68)	755 (17.86)	358 (18.28)	978 (19.17)	<.001
Congestive heart failure	575 (3.48)	73 (4.46)	212 (5.02)	105 (5.36)	356 (6.98)	<.001
Hyperlipidemia	7402 (44.78)	761 (46.49)	1949 (46.11)	881 (44.99)	2148 (42.09)	<.001
Rheumatoid arthritis	711 (4.30)	71 (4.34)	210 (4.97)	124 (6.33)	480 (9.41)	<.001
Diabetes	3097 (18.74)	363 (5.56)	920 (21.76)	462 (23.60)	1220 (23.91)	<.001
Depression	1280 (7.74)	158 (9.65)	465 (11.00)	256 (13.07)	995 (10.71)	<.001

OME, oral morphine equivalent.

* *P* value indicates any statistically significant differences in any of the groups.

OMEs (ie, daily average OMEs prescribed ≥1 but <5 OMEs), (4) 5-10 OMEs (ie, daily average OMEs ≥5 OMEs but <10), and (5) ≥10 OMEs (ie, average daily OMEs were equal to or greater than 10 OMEs) (Table I).

After patients were identified and separated into cohorts, we collected baseline demographic and comorbid data. We collected the following variables: age, sex, and medical comorbidities. We collected and controlled for the following comorbidities: obesity (defined as BMI ≥ 30), chronic kidney disease, hypertension, coronary artery disease, congestive heart failure, hyperlipidemia, rheumatoid arthritis, diabetes, depression, tobacco use, and alcohol use disorder. These characteristics were then compared between cohorts using chi-square analysis.

Postoperative outcomes, cost implications, and trends in preoperative prescribing

We collected the following 90-day complication data: emergency department (ED) visit, pain-related ED visit, extended length of stay (defined as length of stay ≥3 days), nonhome discharge, readmission, opioid overdose, wound complications, superficial surgical site infection (SSI), periprosthetic joint infection (PJI), pneumonia, thromboembolic event (deep vein thrombosis or pulmonary embolism), myocardial infarction, and stroke. We additionally examined 30-day readmission. Finally, we examined revision surgery at 1 and 3 years postoperatively. In order to be included in this analysis, patients needed to have 1- and 3-year continuous enrollment in the database, respectively. Revision procedures were identified using CPT codes.

Cost data was collected for the 6-month preoperative and 90-day postoperative period and compared between cohorts. Therefore, ''cost'' is defined as the sum of net costs plus any deductibles, copays, or coinsurance in the 6 months before and 3 months following TSA, similar to prior studies.[19] We calculated and recorded the median and interquartile range. We then performed multivariate analysis, controlling for variables listed in Table I, to isolate the financial impact of preoperative opioid use on total care costs. Additionally, we tracked and plotted preoperative opioid prescribing trends over the study period on an annual basis to assess prescribing trends over time in our study population.

Statistical analysis

All statistical analysis was performed using SAS, version 9.4 (SAS Institute, Cary, NC, USA). A *P* value of <.05 was considered significant. We compared baseline characteristics and comorbidities between cohorts using chi-square analysis. Complications were then compiled and compared between groups with chi-square analysis. We performed binomial logistic regression, controlling for baseline patient demographic and comorbid data (all factors listed in Table I). These comparisons were made between groups receiving opioids, with the opioid-naïve group used as a reference. Because of the right-skewed distribution of health care costs, a generalized linear model with gamma distribution

Table II Adjusted odds of 90-day resource utilization and complication data

Outcome	Opioid use group							
	<1 OME		1-5 OME		5-10 OME		>10 OME	
	OR (95% CI)*	*P* value	OR (95% CI)*	*P* value	OR (95% CI)*	*P* value	OR (95% CI)*	*P* value
Resource utilization								
ED visit	**1.40 (1.20-1.64)**	**<.001**	**1.18 (1.06-1.32)**	**.003**	**1.32 (1.14-1.53)**	**.002**	**1.51 (1.37-1.53)**	**<.001**
Pain-related ED visit	0.90 (0.36-2.26)	.826	1.11 (0.64-1.95)	.711	**2.60 (1.52-4.46)**	**<.001**	**2.14 (1.41-3.26)**	**<.001**
30-d readmission	0.83 (0.51-1.35)	.460	1.05 (0.78-1.41)	.723	1.35 (0.95-1.95)	.093	**1.57 (1.24-1.99)**	**<.001**
90-d readmission	1.02 (0.77-1.34)	.876	1.09 (0.91-1.31)	.331	**1.42 (1.13-1.76)**	**.002**	**1.82 (1.56-2.09)**	**<.001**
Extended LOS	**1.25 (1.08-1.43)**	**<.001**	**1.29 (1.17-1.41)**	**.002**	**1.52 (1.35-1.72)**	**<.001**	**1.98 (1.83-2.15)**	**<.001**
Nonhome discharge	1.17 (0.94-1.47)	.165	**1.26 (1.09-1.47)**	**.002**	**1.47 (1.21-1.78)**	**<.001**	**1.77 (1.55-2.03)**	**<.001**
Complications								
Opioid overdose	1.37 (0.17-11.2)	.767	1.56 (0.41-6.10)	.512	3.47 (0.89-13.5)	.0723	**4.17 (1.57-11.08)**	**.004**
Wound complication	1.06 (0.52-2.10)	.878	1.18 (0.76-1.84)	.455	1.30 (0.73-2.34)	.379	**2.04 (1.44-2.89)**	**<.001**
Superficial SSI	1.07 (0.52-2.38)	.843	1.42 (0.91-2.21)	.121	**2.55 (1.58-4.13)**	**<.001**	**2.33 (1.63-3.34)**	**<.001**
Prosthetic joint infection	1.36 (0.72-2.56)	.338	**1.88 (1.28-2.76)**	**.001**	**3.29 (2.17-2.76)**	**<.001**	**3.41 (2.50-4.67)**	**<.001**
Pneumonia	1.68 (0.98-2.87)	.058	1.06 (0.68-1.64)	.795	1.12 (0.62-2.01)	.715	**1.95 (1.39-2.75)**	**<.001**
Thromboembolic event	0.91 (0.64-1.29)	.594	1.08 (0.87-1.34)	.485	1.19 (0.88-1.56)	.245	**1.42 (1.18-1.72)**	**<.001**
Stroke	0.91 (0.65-1.46)	.923	1.01 (0.77-1.32)	.942	1.14 (0.80-1.62)	.458	1.20 (0.95-1.53)	.138
Myocardial infarction	1.21 (0.57-2.54)	.611	1.23 (0.75-2.03)	.410	0.98 (0.47-2.06)	.961	1.22 (0.75-1.97)	.421

ED, emergency department; *LOS*, length of stay; *SSI*, surgical site infection; *OR*, odds ratio; *CI*, confidence interval; *OME*, oral morphine equivalent.
* Opioid-naïve cohort was used as reference; items in bold are significant.

and a logarithmic link function was used to compare total health care costs between opioid-use cohorts. We used the same model to analyze 1-year and 3-year revision rates in a subgroup of patients with adequate follow-up.

Results

Baseline patient information

From 2009-2018, we identified 29,454 patients undergoing total shoulder arthroplasty who met the inclusion criteria. We separated patients into cohorts based on preoperative opioid use, and the specific breakdown of patients in each cohort can be seen in Table I. In the 6-month period preceding surgery, 44% of patients received opioid prescriptions and 56% were opioid-naïve. The largest opioid cohort was those receiving >10 average daily OMEs. There were multiple significant differences between the cohorts. The >10-OMEs group contained significantly more young (<64-year-old) patients, had a female predominance, and more commonly had nearly every medical comorbidity ($P < .001$; Table I).

Preoperative opioid use and postoperative complication

Univariate analysis revealed that those with preoperative opioid use had higher rates of every examined outcome ($P \leq .013$) except for myocardial infarction and stroke (p-value = 0.793 and 0.724, respectively). Full univariate analysis results can be seen in Table II. Subsequent multivariate analysis, controlling for all variables listed in Table I, found that receiving >10 preoperative average daily OMEs is associated with increased odds of the following: opioid overdose (>10 OMEs vs. opioid-naïve, odds ratio [OR] 4.17, 95% confidence interval [CI] 1.57-11.08, $P = .004$), wound complication (OR 2.04, 95% CI 1.44-2.89, $P < .001$), superficial SSI (OR 2.33, 95% CI 1.63-3.34, $P < .001$), PJI (OR 3.41, OR 2.50-4.67, $P < .001$), pneumonia (OR 1.95, 95% CI 1.39-2.75, $P < .001$), and thromboembolic event (OR 1.42, 95% CI 1.18-1.72, $P < .001$). Furthermore, there was a dose effect of preoperative opioid use as we found increasing postoperative odds of examined outcomes with increasing preoperative average daily OMEs. It should also be noted that patients receiving ≥1 average daily OME had increased odds of PJI (Table II).

Preoperative opioid use, health care utilization, and revision surgery

In order to determine the impact of preoperative opioid use on health care utilization, we examined the rates of extended length of stay (≥3 day), nonhome discharge, 30-day readmission, 90-day readmission, and 90-day ED visits (all-cause and pain-related). These were all significantly more common in preoperative opioid users when compared to those who were opioid-naïve (univariate analysis, $P \leq .002$; Table III.

Table III Univariate analysis of resource utilization and complication data

Outcome	Opioid use group					*P* value*
	Opioid naïve, n (%)	<2 OME, n (%)	1-5 OME, n (%)	5-10 OME, n (%)	>10 OME, n (%)	
Resource utilization						
ED presentation	1523 (9.21)	211 (12.89)	475 (11.24)	246 (12.56)	741 (14.52)	<.001
Pain-related ED presentation	54 (0.33)	5 (0.31)	16 (0.38)	18 (0.92)	41 (0.80)	.002
30-d readmission	208 (1.26)	18 (1.10)	60 (1.42)	36 (1.84)	115 (2.25)	<.001
90-d readmission	559 (3.38)	59 (3.60)	166 (3.93)	99 (5.06)	348 (6.82)	<.001
Nonhome discharge	761 (4.60)	80 (4.89)	4014 (5.04)	107 (5.46)	326 (6.39)	<.001
Extended LOS	2539 (15.36)	307 (18.75)	806 (19.07)	434 (22.17)	1323 (25.93)	<.001
Complications						
Opioid overdose	7 (0.04)	1 (0.06)	3 (0.07)	3 (0.15)	10 (0.20)	.013
Wound complication	84 (0.51)	9 (0.55)	26 (0.62)	13 (0.66)	54 (1.06)	<.001
Superficial SSI	74 (0.45)	8 (0.49)	27 (0.64)	22 (1.12)	55 (1.08)	<.001
Prosthetic joint infection	81 (0.49)	11 (0.67)	39 (0.92)	31 (1.58)	88 (1.72)	<.001
Pneumonia	91 (0.55)	16 (0.98)	26 (0.62)	13 (0.66)	59 (1.16)	<.001
Thromboembolic event	379 (2.29)	35 (2.14)	107 (2.53)	54 (2.76)	168 (3.29)	<.001
Myocardial infarction	63 (0.38)	8 (0.49)	21 (0.50)	8 (0.41)	24 (0.47)	.793
Stroke	268 (1.62)	27 (1.65)	71 (1.68)	37 (1.89)	96 (1.88)	.724

ED, emergency department; *LOS*, length of stay; *SSI*, surgical site infection; *OME*, oral morphine equivalent.
* *P* value indicates any statistically significant differences in any of the groups; OMEs defined as the average daily opioid usage in the year prior to surgery.

On multivariate analysis, every examined preoperative opioid use group had increased odds of extended length of stay and postoperative ED visits even when controlling for patient comorbidities and demographic information ($P \leq .001$). Additionally, those receiving >10 preoperative average daily OMEs had increased odds of all utilization parameters, including extended length of stay (OR 1.98, 95% CI 1.83-2.15, $P < .001$), nonhome discharge (OR 1.77, 95% CI 1.55-2.03, $P < .001$), 90-day readmission (OR 1.82, 95% CI 1.56-2.09, $P < .001$), pain-related ED visits (OR 2.14, 95% CI 1.41-3.26, $P < .001$), and all-cause ED visits (OR 1.51, 95% CI 1.37-1.53, $P < .001$). It is important to note that, similar to postoperative complications, there was an observed dose effect with increasing preoperative opioid dose leading to higher odds of increased resource utilization (Table III).

We analyzed revision surgery at 1 and 3 years postoperatively. Revision rates at 1 and 3 years were similar between patients who were preoperative opioid-naïve and those receiving <10 average daily OMEs. However, the >10-OME group had significantly greater odds of revision at 1 year (OR 2.16, 95% CI 1.64-2.88, $P < .001$) and 3 years (OR 2.15, 95% CI 1.56-2.96, $P < .001$) even when controlling for baseline factors (Table IV).

Cost implications of preoperative opioid use and trends in preoperative opioid prescribing

We analyzed costs data and it was found that patients receiving at least 1 preoperative OME had significantly increased care costs. This was, again, a dose-dependent relationship, and those receiving >10 preoperative OMEs had an adjusted cost difference (vs. opioid-naïve patients) of $7082 (95% CI 5379-8785) (Table V).

Over the study period, from 2009-2018, the percentage of opioid-naïve patients increased from 51% in 2009 to 67% in 2018. All opioid groups decreased except for the <1-OME group, which had slight growth over the study period (Fig. 2).

Discussion

The opioid epidemic has emerged as one of the most important public health issues.[1] Despite evidence and recommendations directly contradicting the practice,[6] there are still a high number of patients with chronic pain being managed with chronic opiates. This is contributing to the large number of patients undergoing procedures with pain-related indications, such as total joint arthroplasty, who are on preoperative opioids.[43] Further complicating matters is that many of these preoperative prescriptions are not from orthopedic surgeons.[26] As the patient on preoperative opioids is frequently encountered, the impact that opioids have on postoperative outcomes is critical to understand.

The results of this investigation identify preoperative opioid use as an independent risk factor for complications following primary total shoulder arthroplasty. Even when controlling for demographics and comorbidities, those who received >10 average daily preoperative OMEs had higher odds of sustaining nearly every examined complication

Table IV Analysis of preoperative opioid use, 1-year and 3-year revision surgery

Complication	Opioid use group, n (%)				
	Opioid naïve	<1 OME	1-5 OME	5-10 OME	>10 OME
1-yr revision surgery, n (%)	12,007 (55.64)	1182 (5.48)	3117 (14.44)	1478 (6.85)	3796 (17.59)
Rate of complication, n (%)	128 (1.07)	18 (1.52)	43 (1.38)	18 (1.22)	98 (2.58)
Adjusted OR (95% CI)	Referent	1.38 (0.84-2.34)	1.22 (0.86-1.74)	1.09 (0.66-1.79)	2.16 (1.64-2.88)
Adjusted *P* value	—	.203	.250	.734	<.001
3-yr revision surgery, n (%)	4905 (54.75)	503 (5.61)	1340 (14.96)	635 (7.09)	1576 (17.59)
Rate of complication, n (%)	97 (1.98)	12 (2.39)	28 (2.09)	18 (2.83)	73 (4.63)
Adjusted OR (95% CI)	Referent	1.19 (0.65-2.19)	1.04 (0.67-1.58)	1.42 (0.85-2.36)	2.15 (1.56-2.96)
Adjusted *P* value	—	.563	.874	.184	<.001

OR, odds ratio; *CI*, confidence interval; *OME*, oral morphine equivalent.
Analysis includes patients with 6-month continuous preoperative enrollment with 1- and 3-year continuous postoperative enrollment, respectively.

Table V Multivariate analysis of perioperative cost

	Median cost, USD (IQR)	Adjusted cost difference, USD (95% CI)	*P* value*
Opioid naïve	30,577 (21,461-47,552)	Referent	—
<1 OME	32,972 (22,692-51,338)	2313 (−375 to 5003)	.1575
1-5 OME	34,756 (23,773-54,495)	5066 (3272-6859)	<.001
5-10 OME	35,858 (23,616-56,665)	5685 (3197-8173)	<.001
>10 OME	37,062 (24,216-59,234)	7082 (5379-8785)	<.001

OME, oral morphine equivalent; *USD*, US dollar; *IQR*, interquartile range; *CI*, confidence interval.
* *P* value <.05 indicates statistically significant differences between an opioid use group and opioid-naïve patients.

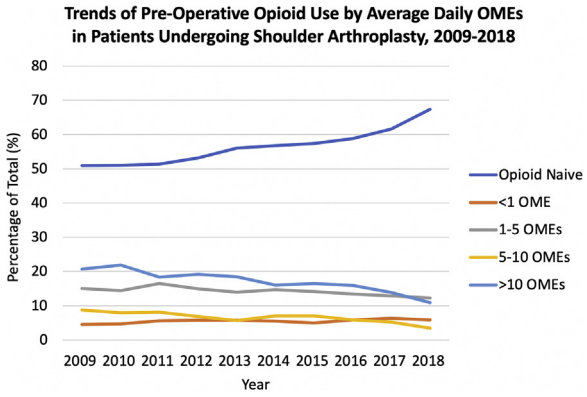

Figure 2 Trends in preoperative opioid use by average daily OMEs in patients undergoing primary total shoulder arthroplasty, 2009-2018. *OME*, oral morphine equivalent.

when compared to those who are opioid naïve. We also found that there is a strong dose effect as increasing preoperative opioid doses led to increased odds of the examined outcomes. However, the >10-OME group had the highest odds of all outcomes, and this group had more than twice the odds of revision surgery at 1 and 3 years postoperatively. It is important, and interesting, to note that even patients receiving 1-5 average daily OMEs had increased odds of PJI, and that all preoperative opioid groups had increased postoperative resource utilization. Not surprisingly, these increased complication and revision profiles translated into increased care costs, with the >10-OME group's care costing >$7000 more than those who are opioid naïve.

We also found that providers are trending away from providing preoperative opioid prescriptions, as the proportion of preoperative opioid-naïve patients increased by nearly 20% over the study period. This finding may reflect general opioid prescription trends, but may also indicate that providers are extrapolating data from the hip and knee arthroplasty realm demonstrating the detrimental effects of preoperative use of opioid analgesics.[3,16,27,31] Our examined study period was also over a time during which addressing the opioid epidemic became a priority of the medical community.[1,32,39]

Although studies on preoperative opioid use as a risk factor following total hip and knee arthroplasty have demonstrated increased risk of complications and increased health care utilization, this is the first, to our knowledge, demonstrating a similar relationship following total shoulder arthroplasty. Prior studies examining preoperative opioid use in TSA have demonstrated that preoperative opioid use leads to inferior clinical outcome scores[24,37] and increased postoperative opioid consumption,[8] but have shown no difference in postoperative complication rates or length of stay.[8] This is in contrast to our findings, which

indicated that preoperative opioid use was a significant risk factor for both prolonged length of stay and complications. The reasons for these discrepant results are likely a result of the different methodology used and the sample size analyzed. To be adequately powered for detection of differences in rare complications, a large sample size is necessitated. The current study includes 29,454 patients, making such comparisons possible, accurate, and reliable.

Several of our findings agree with those identified in the hip and knee arthroplasty literature.[2-4,9,20,27,30,36,42] Similar to these studies, we found that preoperative opioid use was associated with increased risk of infection, complications, and revision surgery. First, we found that patients who received at least 1 preoperative average daily OME had increased rates of infection (both superficial SSI and PJI). Despite the fact that this is a new finding in TSA patients, a similar relationship has been found in hip and knee arthroplasty.[2,4,9,20] Although the reason for this increased infectious risk is likely multifactorial, there is evidence to suggest a link between opioids and delayed wound healing[33] as well as immune cell impairment.[28] On a similar note, this may also explain our observed increased odds of pneumonia (taken together with opioid-associated respiratory depression) and wound complications in patients receiving >10 daily OMEs. Increased rates of wound complication and SSI also explains, to some degree our observed association between preoperative opioid use and revision surgery. Revision surgery may also be driven by the previously identified associations of preoperative opioid use with higher postoperative opioid use and lower patient-reported outcomes following TSA.[8,24,37]

We also found that preoperative opioid use increased the odds of thromboembolic events. The relationship of opioids and thromboembolic events is complex but a similar association in hip and knee arthroplasty has been established.[9] This relationship is, again, likely multifactorial, but some literature suggests that opioids may interact with the prostaglandin pathway and may interfere with the prevention of platelet aggregation.[14] There has additionally been suggestion that opioid-sparing protocols lead to earlier mobilization, which is known to decrease the occurrence of thromboembolism.[23] There appeared to be a dose effect with regard to the implications of preoperative opioid use, as those who received higher OMEs had nearly universally higher risk compared with those in other groups. This dose-dependent increase in risk is in agreement with relationships demonstrated in prior studies.[9]

Given the findings of increased postoperative complications, our findings of increased length of stay, nonhome discharge, readmission, and increased ED visits are not surprising. Given increased rates of early complication, these would be expected and are similar to prior literature on hip and knee arthroplasty.[3,13,27,42] Again, we feel that our large sample size has allowed for the detection of differences in these relatively uncommon events where other authors were unable to note any increased risk in smaller cohorts.[8] These complications and increased health care exposures are likely what drove our finding that those who receive preoperative opioids have significantly higher associated care costs in the perioperative period—an important consideration as value-based reimbursement models emerge.

There are multiple limitations to this investigation, most of which can be attributed to the analysis of large databases. First, we are reliant on accurate coding for proper patient identification as well as reporting of postoperative complications. Second, we used NDC codes to identify preoperative opioid prescriptions. Although there is significant precedence in the literature for this,[9,35,41,42] we are again reliant on accurate coding. We additionally, did not analyze individual medications but instead considered them as a class of medications. However, we did ''normalize'' these data by converting the medications received into OMEs. Third, some factors that have been demonstrated to influence outcomes were not available for analysis and could not be analyzed. These include hospital and surgeon volume[21,29,34] as well as various other perioperative factors.[17,44] Along the same lines, case complexity as dictated by anatomic factors (ie, glenoid bone loss, bone quality, etc.) could not be quantified and controlled for. Therefore, although our analysis controlled for many available factors, it must be acknowledged that many of our examined outcomes of interest have multifactorial influences. Fourth, there were some baseline differences between cohorts (ie, more patients with rheumatoid arthritis in the opioid cohorts), and while we controlled for these statistically the potential exists that these differences could bias our results. Fifth, in our analysis of revision surgery, the indication for revision surgery was not analyzed and we instead report all-cause revision. Last, the Truven Marketscan database contains information only on patients with private, employee-sponsored medical insurance or those with Medicare supplemental insurance. Uninsured patients, those with other private insurance plans not included by the Marketscan database, those with Medicare advantage, and those with Medicaid would not be included in this analysis, potentially limiting the generalizability to these specific patient cohorts.

Despite these limitations, the Truven Marketscan database represents a strength of the current investigation. The database allows for analysis of a large number of patients and unlike many administrative national databases (like the National Inpatient Sample) includes information from both inpatient and outpatient encounters. Additionally, the database allows for longitudinal follow-up as long as the patient remains enrolled in their health care plan. Last, the database tracks administered prescriptions. Therefore, we were able to track preoperative opioid

prescriptions for the 6-month preoperative period and analyzed revisions for 3 postoperative years. This is much more than the 30-90 days allowed by most other databases.[5]

Conclusions

Preoperative opioid consumption is a significant risk factor for complication, revision surgery, increased health care utilization, and increased costs following primary total shoulder arthroplasty. Fortunately, it does appear that the proportion of patients who are preoperatively opioid naïve is increasing whereas those receiving higher-dose preoperative opioids is decreasing. Given the elective nature of total shoulder arthroplasty, it is our recommendation that patients are counseled on the increased risk conferred by preoperative opioids and that cessation of opiates be attempted as part of patient optimization. Future work should focus on definitively determining the modifiability of this important risk factor.

Disclaimer

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