



United States opioid prescribing trends after shoulder surgery and their correlation with opioid misuse

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Background: Orthopedic surgery has been highlighted as a contributor to the opioid epidemic. There is a paucity of literature focused specifically on opioid prescribing trends following shoulder surgery. Our aims were to describe national and regional trends in opioid prescribing following total shoulder arthroplasty, proximal humerus fracture fixation, and rotator cuff repair (RCR), and to correlate opioid prescribing trends after shoulder surgery with regional heroin use and new opioid misuse diagnoses.

Methods: This is a retrospective study of 218,577 patients from a commercial insurance dataset who had undergone orthopedic shoulder procedures from 2014 to 2020. Opioid prescription data within 90-day postoperative were converted to morphine milligram equivalents (MMEs). Multivariate modelling was used to evaluate independent associations between MME's prescribed and subsequent new post-operative diagnosis of opioid dependence. Additionally, longitudinal mixed effects modeling was employed to understand aggregated prescriber habits by state over time and the subsequent effects on estimates of state heroin use and drug overdose deaths.

Results: From 2014 to 2020, the mean number of MMEs prescribed nationally decreased by over 50% for total shoulder arthroplasty, proximal humerus fracture fixation, and RCR. Over the study period, most states demonstrated an overall downtrend of 90-day opioid prescribing for these procedures. Individuals with a new opioid misuse diagnosis following shoulder surgery were found to be younger (standardized mean difference [SMD] = 0.27, $P < .001$), have increased comorbidities (SMD = 0.38, $P < .001$), and increased MME's prescribed (SMD = 0.94, $P < .001$). Increased comorbidity score (odds ratio [OR] = 3.28, $P < .001$) and increased 90-day MME's prescribed (OR = 1.05, $P < .001$) were all found to increase the OR of a postoperative opioid misuse diagnosis in patient's undergoing shoulder surgery, while increased age (OR = 0.97, $P < .001$) and patient's undergoing RCR (OR = 0.79, $P = .001$) were found to have a decreased OR of developing a new opioid misuse diagnosis. The predictors of regional heroin use included the within-state 90-day MMEs prescribed ($P = .002$). The predictors of drug overdose death included year ($P < .001$), but did not include type of surgery or 90-day MMEs.

Conclusion: Orthopedic surgeons successfully reduced the number of opioids prescribed nationally after shoulder surgeries by over 50% during our study period with similar trends seen at the state level. Our data indicate a relationship between increased opioid prescribing after shoulder surgery and heroin use. This study highlights that while progress has been made, there is evidence that opioid prescribing following shoulder surgery is associated with the more widespread opioid epidemic, and that more research is needed to further lower postoperative opioid misuse in the future.

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During the first year of the pandemic in 2020–2021, drug overdose deaths in the United States (US) rose to over 100,000, up

almost 30% from the year prior. About 75% of those deaths were opioid-related, up from 55% the year prior.¹⁰ The US is uniquely vulnerable to opioid-related death given that despite only making up 5% of the world's population, the US consumes almost 80% of the global opioid supply and 99% of the world's hydrocodone supply.¹⁴ However, the strain of the opioid epidemic in the US costs not just lives but also money. Prescription opioid overdose, abuse, and dependence are estimated to cost the US

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approximately \$80 billion a year, a quarter of which is paid for by the public sector.⁸

There have been recent efforts within the medical field to curb opioid overprescribing. Amongst all physician subspecialties, orthopedic surgeons rank in the top 3 for highest opioid prescribers.¹⁹ While opioid prescribing trends have been described in certain areas of orthopedic surgery, there is a paucity of literature focused on opioid prescribing trends following shoulder surgery. Much of the opioid-related research in shoulder surgery is focused on risk factors for postoperative opioid dependence in an effort to more effectively identify at-risk patients preoperatively.^{13,17} Leroux et al showed that 80% of individuals undergoing elective shoulder surgery are opioid naïve, but almost 15% are still filling opioid prescriptions 180 days after surgery.¹³ However, to our knowledge the effect of opioid use after shoulder surgery on opioid-related morbidity and mortality has not been described nor has the relationship between postshoulder surgery prescribing patterns and rates of new opioid misuse diagnoses.

Our aims were to first describe national and state trends in opioid prescribing following total shoulder arthroplasty (TSA), proximal humerus fracture fixation, and rotator cuff repair (RCR); and second, to correlate opioid prescribing trends after shoulder surgery with heroin use and new opioid misuse diagnoses.

Materials and methods

Data sources and study sample

State provider prescribing habits

This study was a retrospective observation study. The primary data source was a 2014–2020 limited Health Intelligence Company LLC (HIC) commercial administrative claims dataset, containing Health Insurance Portability and Accountability Act compliant deidentified data for more than 45 million people. Claims filled between January 1, 2014 and December 31, 2020 were queried for relevant information. Included patients were defined as covered members who had undergone a proximal humerus fracture open reduction and internal fixation, an arthroscopic RCR, an anatomic TSA, or a reverse TSA (current procedural terminology code: 23615, 29827, 23472, respectively) and had a covered pharmacy benefit. Member prescription data during the 90-day postoperative window was converted to morphine milligram equivalents (MMEs) utilizing available National Drug Codes and the 2020 Centers for Disease Control and Prevention conversion tables.⁴ Methadone-related prescriptions were removed from analysis. For state-level outcomes MME's prescribed in the 90-day postoperative window were averaged across each state and year. Appropriate mean centering procedures were employed to isolate variations within- and between-state prescribing habits. Furthermore, state-level analyses include state prescriber habit data from 2014 to 2019 to examine contemporaneous associations.

National and state trends

State and national average MME's were calculated over time and across applicable shoulder procedures utilizing the HIC dataset. Furthermore, state and national indicators of heroin use and drug overdose deaths were calculated over time based upon documented diagnoses as described below.

Patient-level outcome

A search for International Classification of Diseases (ICD)-9 and ICD-10 diagnosis codes associated with opioid misuse (Supplementary Table S1) was conducted in the HIC patient sample. Patients with a diagnosis of opioid misuse prior to the selected

shoulder procedures were excluded from the analysis. MME's prescribed within the 90-day postoperative window of index shoulder surgery were compared across patients with a subsequent diagnosis of opioid misuse and patients with no diagnosis of opioid misuse. Age, sex, and the Elixhauser Comorbidity Index (ECI) were included as variables in the patient level analysis. The ECI was calculated utilizing all patient diagnoses within a one-year period prior to index shoulder procedure.⁷

State-level outcomes

State estimates of heroin use prevalence from 2014 to 2019 were obtained from the publicly available National Survey on Drug Use and Health.²⁰ Interviewees were asked if they had used heroin within the past year. State level estimates of heroin use were developed utilizing a survey-weighted hierarchical Bayes estimation methodology.⁵ Prevalence data was converted to the rate per 100,000 residents for each state and year.

Data of provisional opioid-related overdose deaths for each state from 2014 to 2019 was obtained from the National Center for Health Statistics' National Vital Statistics System.² Provisional drug-related overdose deaths were compiled utilizing the International Statistical Classification of Diseases and Related Health Problems scheme.²² Drug overdose deaths were identified based on opium (T40.0); heroin (T40.1); natural opioid analgesics (T40.2); synthetic opioid analgesics (T40.3, T40.4); cocaine (T40.5); unspecified narcotic (T40.6); and/or psychostimulants (T43.6). Counts were converted to rate per 100,000 residents for each state and year using U.S. Census Bureau state population estimates from 2015 to 2019.³

Analytic procedures

Patient-level outcome

Patient characteristics stratified by subsequent opioid-related diagnosis or absence of diagnosis were subjected to univariate tests including independent samples t-tests for continuous variables and chi-square tests for categorical variables. Considering the size of the sample, standardized mean differences (SMDs) were also calculated for all univariate analyses. The relationship between patient-level MME prescription data and subsequent opioid misuse diagnosis was investigated utilizing a multivariate binary logistic regression model. Procedure type, age, sex, and ECI were included as variables.

State-level outcomes

The relationship between state-level prescribing habits after shoulder surgery and state-level heroin use as well as drug overdose deaths over time was investigated with random intercepts and slopes mixed effects models. Within- and between-state variations were included as predictors after controlling for time. In addition, interaction terms between procedure type and both within- and between-state variations were included to determine if differences in prescribing habits across procedure type demonstrated a significant relationship with either outcome.

Results

National and state trends

From 2014 to 2020, the mean number of MMEs prescribed nationally over a 90 day period decreased by 57% (Δ 765.95 MME's) for TSA, 57% (Δ 692.34 MME's) for proximal humerus fracture fixation, and 54% for (Δ 495.53 MME's) RCRs. (Table 1, Fig. 1). Similar decreases were also seen at the individual state level. Overall, TSA had the most MME's prescribed over a 90 day

Table 1
National variable characteristics across time.

	2014	2015	2016	2017	2018	2019	2020
TSA/rTSA MME's (mean (SD))	1348.93 (1672.22)	1259.23 (1484.46)	1232.96 (1584.92)	1053.02 (1417.58)	848.71 (1316.35)	677.42 (1135.64)	582.98 (1036.87)
Prox hum fx MME's (mean (SD))	1207.42 (1500.74)	1201.34 (1439.33)	1080.81 (1345.35)	973.80 (1320.51)	676.89 (1019.12)	588.20 (935.87)	515.08 (820.82)
Rotator cuff MME's (mean (SD))	922.89 (11785.33)	931.71 (1196.15)	864.30 (1128.04)	767.93 (1069.01)	599.53 (945.51)	492.51 (852.92)	427.36 (767.09)
Heroin use* (mean (SD))	357.16 (177.16)	406.07 (265.25)	408.54 (163.75)	411.49 (159.20)	379.30 (152.57)	353.76 (116.30)	-
Drug overdose deaths* (mean (SD))	17.44 (6.70)	20.77 (9.41)	22.48 (10.89)	21.49 (9.99)	22.48 (10.19)	28.51 (13.77)	-

SD, standard deviation; TSA, total shoulder arthroplasty; rTSA, reverse total shoulder arthroplasty; MME, morphine milligram equivalents.

*Per 100,000 residents.

period—12% more than proximal humerus fracture fixation and 27% more than RCR.

The average regional estimates of heroin use increased through the first four years of the study window peaking at 411.5 users per 100,000 residents. Data from 2018 and 2019 saw a drop in the rate of heroin users. The rate of drug overdose deaths increased over the course of the study window by 64%, from 17.4 deaths per 100,000 residents to 28.5 deaths in 2019.

Patient-level outcomes

A total of 218,577 patients were included in this analysis. 1717 patients, 0.79%, were found to have a new opioid misuse diagnosis following shoulder surgery by the end of our sampled timeframe, 2020. Broken down by surgery type, 0.011% of arthroplasty patients, 0.012% of proximal humerus open reduction internal fixation patients, and 0.007% of rotator cuff patient developed a new opioid misuse diagnosis. Univariate analysis (Table II) suggests patients with a new opioid misuse diagnosis following a shoulder procedure tend to be younger ($P < .001$, $SMD = 0.27$), more likely to have additional comorbidities represented by an increased ECI ($P < .001$, $SMD = .34$), and prescribed a higher number of opioids within the 90-day postoperative period ($P < .001$, $SMD = .94$). Multivariate analysis (Table III) further demonstrates that older patients are less likely to be diagnosed with a subsequent opioid misuse diagnosis (odds ratio [OR] = 0.97, $P < .001$) and that patients with a greater number of comorbidities are more likely to be associated with this diagnosis (ECI 1–4: OR = 1.78, $P < .001$, ECI ≥ 5 : OR = 3.28, $P < .001$). Furthermore, patients undergoing a RCR procedure were found to be less likely to acquire an opioid misuse diagnosis following surgery in comparison to TSA (OR = 0.79, $P = .001$). Increases in the amount of opioids prescribed within 90-days of the postoperative window resulted in a greater OR of subsequent opioid misuse diagnosis (OR = 1.05, $P < .001$) (Table III).

State-level outcomes

After controlling for time, between- and within-state variations in 90-day prescribing habits, and procedure type, the estimated rate of heroin users was 383.8 of 100,000 residents (Table IV).

Significant predictors of state-level heroin use include within state ($B = 4.229$, $P = .002$) variation in provider 90-day prescribing habits following selected shoulder procedures (Table IV). Of note, time, between-state variation in provider 90-day prescribing habits, and the interaction between procedure type and both between- and within-state variations in prescribing habits were not significant predictors of state level heroin use. After controlling for time, between- and within-state variations in 90-day prescribing habits, and procedure type, the estimated rate of drug overdose deaths was 17.8 of 100,000 residents (Table IV).

Year was the only significant predictor of drug overdose death ($B = 1.726$, $P < .001$). None of the other included predictors demonstrated a significant relationship with the drug overdose deaths outcome (Table IV).

Discussion

Orthopedic shoulder surgeons successfully reduced the number of opioids prescribed nationally after shoulder surgeries by over 50% during our study period with similar trends seen in most states. Our data show that new opioid misuse diagnoses after shoulder surgery are rare, but potential risk factors including age, increased preoperative comorbidities and number of opioids prescribed after surgery are important to consider when prescribing for patients postoperatively. Previous studies have identified similar risk factors for prolonged opioid use, but to our knowledge, ours is the first to link shoulder surgery prescribing patterns to an actual new diagnosis of opioid use disorder.^{9,13,21} Our study was also unique in that it included trauma patients undergoing proximal humerus fracture repair rather than only elective arthroplasty and arthroscopy cases included in prior studies. This is an important population to include given they are at increased risk of prolonged opioid use as evidenced by previous research and our data.¹¹ Our data suggest an association between orthopedic surgeon prescribing patterns after shoulder surgery and opioid-related morbidity. Importantly, our data indicate a significant relationship between increased opioid prescribing within states after shoulder surgery and heroin use, a major contributor to opioid-related deaths.

Our first aim was to describe national and regional trends in opioid prescribing following TSA, proximal humerus fracture fixation, and RCR. So far, much of the literature focuses on prolonged opioid use preoperative risk factor trends rather than prescribing trends. Vattigunta et al examined opioid prescribing trends after TSA and arthroscopic rotator cuff from a single surgeon and determined age was a statistically significant predictor of less opioid consumption consistent with our findings.²¹ They also showed with regards to a single surgeon that there was no statistical significance in opioids prescribing based on the type of surgery. Of note, they did not include proximal humerus fracture patient in their analysis. Leroux et al analyzed a database of almost 80,000 patients and determined that approximately 80% of individuals undergoing elective shoulder surgery were opioid-naïve at the time of surgery and 15% of those individuals were still using opioids 6 months after surgery.¹³ Of the 15% of nonopioid users who required long term opioid use, risk factors included female sex, higher comorbidity score, alcohol abuse, depression, and anxiety. While their study did not include new opioid misuse diagnoses in the postoperative period, they did include data stretching to 6 months. These findings were echoed by Gil et al who also showed

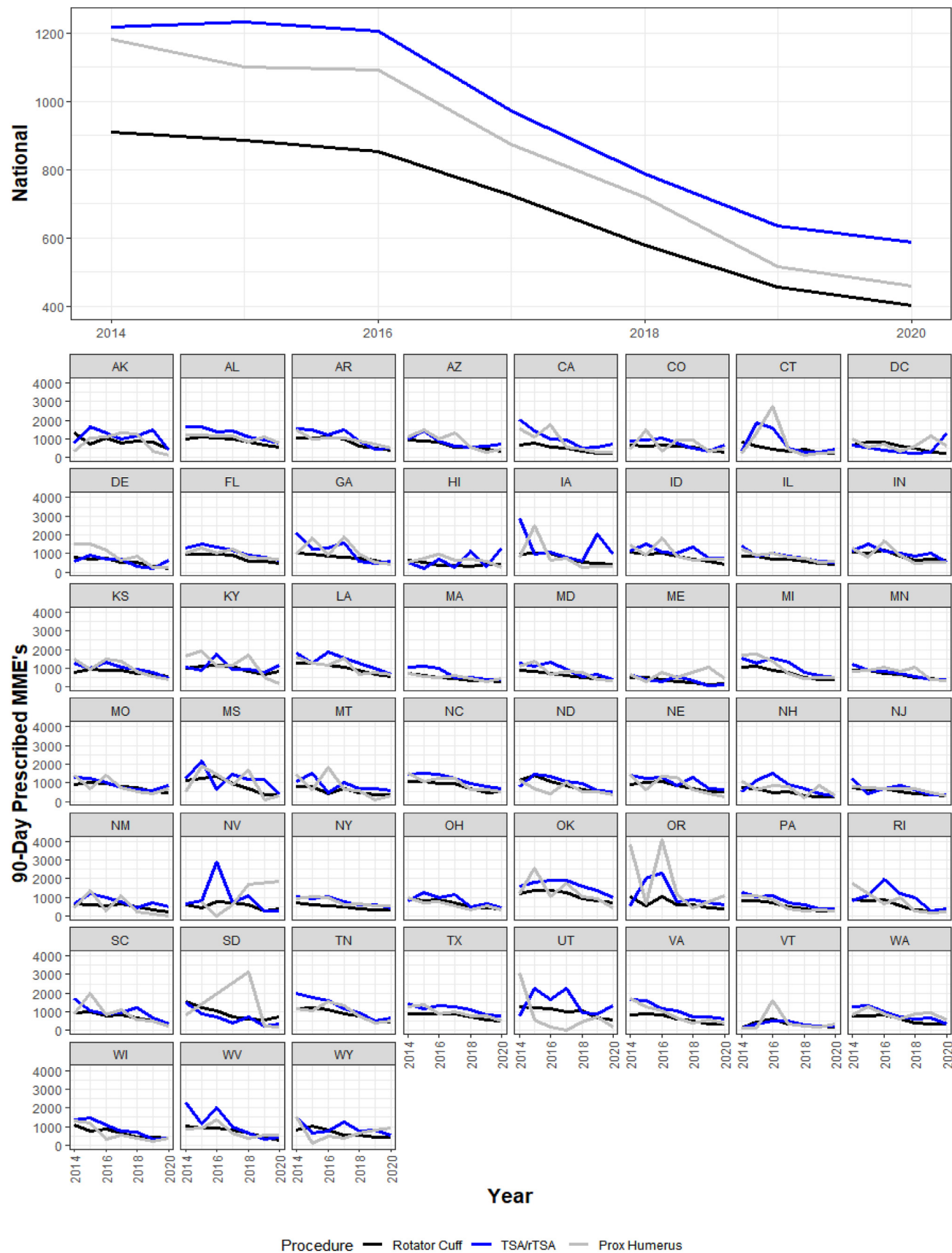


Figure 1 National- and state-level morphine milligram equivalent units prescribed over time. TSA, total shoulder arthroplasty; rTSA, reverse total shoulder arthroplasty; MME, morphine milligram equivalents.

Table II

Patient-level characteristics stratified by subsequent opioid misuse diagnosis.

	Opioid misuse diagnosis		<i>P</i>	SMD*
	No	Yes		
<i>n</i>	216,860	1717		
Sex [†] = male (%)	126,888 (58.5)	967 (56.3)	.070	0.044
Age (mean (SD))	55.09 (8.82)	52.72 (8.77)	<.001	0.269
Procedure (%)			<.001	0.178
TSA/rTSA	25,317 (11.7)	279 (16.2)		
Prox hum fx	8941 (4.1)	111 (6.5)		
Rotator cuff	182,602 (84.2)	1327 (77.3)		
Elixhauser Comorbidity Index (%)			<.001	0.375
0	67,572 (31.2)	317 (18.5)		
1–4	138,892 (64.0)	1188 (69.2)		
≥5	10,396 (4.8)	212 (12.3)		
90-day MME's [‡] prescribed (mean (SD))	714.24 (1041.24)	2538.98 (2542.29)	<.001	0.939

SD, standard deviation; TSA, total shoulder arthroplasty; rTSA, reverse total shoulder arthroplasty; MME, morphine milligram equivalents.

Univariate tests across opioid misuse diagnosis include independent samples t-tests for continuous variables and chi-square tests for categorical variables. Significance *P* < .05.

*Standardized mean differences.

†Referent: female.

‡Morphine milligram equivalents.

Table III

Patient-level multivariate binary logistic regression predicting opioid misuse.

Predictors	DV: Subsequent opioid misuse diagnosis		
	Odds ratios	95% CI	<i>P</i>
Intercept	0.0031	0.0025–0.0037	<.001
Sex*: male	1.0237	0.9274–1.1304	.643
Age	0.9655	0.96044–0.9707	<.001
ECI [†] : 1–4	1.7882	1.5730–2.0384	<.001
ECI [†] : ≥5	3.2812	2.7123–3.9619	<.001
Procedure [‡] : prox hum fx	1.0019	0.7889–1.2643	.988
Procedure [‡] : rotator cuff	0.7918	0.6907–0.9108	.001
90-day MME's [‡] prescribed	1.0469	1.0450–1.0487	<.001
Observations	218,576		
R ² Tjur	0.029		

95% CI, 95% confidence interval; ECI, Elixhauser Comorbidity Index; TSA, total shoulder arthroplasty; MMI, morphine milligram equivalents; DV, dependent variable.

Significance *P* < .05.

*Referent: female.

†Elixhauser comorbidity index referent: 0.

‡Referent: TSA.

‡Morphine milligram equivalents (×100).

Table IV

Multivariate mixed effects model investigating predictors of regional heroin use.

Predictors	DV: Rate of heroin use			DV: Drug overdose deaths		
	Estimates	95% CI	<i>P</i>	Estimates	95% CI	<i>P</i>
Intercept	383.809	323.95 to 443.67	<.001	17.82	15.659 to 19.980	<.001
Year	1.041	–8.46 to 10.54	.830	1.726	1.278 to 2.173	<.001
CPT [prox hum fx]	–1.776	–16.87 to 13.32	.817	0.062	–0.427 to 0.552	.802
CPT [rotator cuff]	–6.219	–27.10 to 14.66	.559	0.035	–0.653 to 0.723	.92
MME _{withinstate} * [†]	4.229	1.52 to 6.94	.002	0.039	–0.049 to 0.127	.388
MME _{betweenstate} [†]	–2.752	–8.32 to 2.82	.332	0.007	–0.178 to 0.192	.941
N _{state_code}	51			51		
Observations	910			910		
Marginal R ² /conditional R ²	0.005/0.774			0.071/0.937		

95% CI, 95% confidence interval; ECI, Elixhauser Comorbidity Index; TSA, total shoulder arthroplasty; MMI, morphine milligram equivalents; DV, dependent variable.

Significance *P* < .05.

*Within-state/district centered 90-day prescribing habits.

†Between-state/district centered 90-day prescribing habits.

mental illness as a significant risk factor for prolonged opioid use in elective rotator cuff surgery.⁹ These studies, however, only used prolonged opioid use as their negative outcome; our study took this one step further and showed the effect prolonged use has on opioid misuse diagnoses and heroine use.

Our second aim was to correlate opioid prescribing trends after shoulder surgery with regional heroin use and new opioid misuse diagnoses. While there has not been nation-wide shoulder surgery opioid prescribing trend studies, there have been studies showing a national decrease in orthopedic opioid

prescribing trends in the general Medicare and pediatric populations.^{2,12} Specifically, they showed the southern region had increased opioid prescribing compared to the northeast. Boddapati et al also showed that orthopedic surgeon prescribing patterns are not uniform throughout the country, particularly with increased numbers seen in the south highlighting the importance of regional strategies rather than nation wide blanket solutions.² Our data echoed this conclusion by showing within state prescribing trends significantly affecting heroine use rates. It has been described that recent trends in heroin use are moving out of cities and into more rural areas.⁶ It is important to recognize that although some regions have a heavier opioid and heroine burden than others, the inequality could be more related to urban vs. rural variability rather than general region. For example, Sabatino et al showed that although NH is not in the south, especially at rural centers there is a surplus of opioid prescriptions and prescriber variability following common orthopedic procedures that put the state at risk of increased opioid misuse.¹⁸ The lack of uniform orthopedic surgery prescribing patterns, including after shoulder surgery, seems to be a promising target to continue to better control opioid misuse in orthopedics.

Solutions lie at the governmental, institutional, and specialty societal levels. Government intervention is the broadest option to address opioid prescribing patterns. Raji et al studied the effect legislation limiting opioid prescribing in Ohio had on prescribing practices after shoulder surgery.¹⁶ The legislation limited opioid prescriptions to 7 days at a time and no more than 30 MMEs a day. They found that in both opioid tolerant and opioid naïve patients after shoulder surgery, there was a significant decrease in MME dosing at 7 days postoperatively. Additionally, the decrease continued for the opioid naïve at both the 30 and 90 day post-operative time points. While only including a single state, the study showed the potential legislation can have on reducing opioid prescriptions after shoulder surgery. More locally, institutional level interventions in decreasing opioid overprescribing have also shown to be effective. Anne Arundel Medical Center in Maryland implemented a system wide quality improvement project to reduce opioid overprescribing. Interventions targeted prescriber education and accountability, reduction of default amounts on prescription orders, and enhanced oversight by individual prescriber assessments. The center saw a 38% drop in opioid prescription rate and a 58% drop in monthly MME prescribed per encounter.¹⁵ Even more granular intervention could come through the American Shoulder and Elbow Surgeons society. In an effort to better understand prescribing principals guiding prescription decisions, Acuña et al surveyed members of the American Shoulder and Elbow Surgeons orthopedic society.¹ Notably they found that of the respondents, 20% used personal prescribing guidelines and 21% were unaware of any prescribing guidelines. They concluded that national society-based guidelines could be an achievable first step to standardize opioid prescribing practices after shoulder and elbow surgery, while providing needed education to patients and surgeons.

Many of the limitations of this study come from the data source. This study utilized data from a commercial administrative claims dataset to provide a large patient sample for analysis and the quality and comprehensiveness of this type of data may be limited by inconsistencies in coding at the clinical care level. Another challenge is the source data only included privately insured patients. Opioid prescribing and consumption habits are likely different across various forms of insurance coverage including Medicare, Medicaid, and the uninsured. This may limit the study's generalizability to the general public. Furthermore, the retrospective and observational nature of our study design precluded controlling for and further

investigation of many of the complex variables that may be related to opioid utilization and opioid abuse. This limitation is inherent to any population-based study of this subject. And lastly, due to the observational design, no causal claims can be made.

Conclusion

Our study utilized a large private insurance database to describe regional opioids prescribing trends and effects after shoulder surgery and demonstrated a broad decrease in opioid prescribing but continued new opioid misuse diagnoses following shoulder surgery. Further our study demonstrated that prescribing practices after shoulder surgery within states have a significant effect on heroin use and contribute to regional variability. Orthopedic surgery and the country at large have made great strides in curbing the opioid epidemic, but our study shows there is still room for improvement, specifically within shoulder surgery.

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Supplementary Data

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