J Shoulder Elbow Surg (2020) 29, S115–S125

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Increased opioid use following rotator cuff repair associated with prior opioid use and surgeon prescription patterns

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Background: Prescription opioids are standard of care for postoperative pain management after musculoskeletal surgery, but there is no guideline or consensus on best practices. Variability in the intensity of opioids prescribed for postoperative recovery has been documented, but it is unclear whether this variability is clinically motivated or associated with provider practice patterns, or how this variation is associated with patient outcomes. This study described variation in the intensity of opioids prescribed for patients undergoing rotator cuff repair (RCR) and examined associations with provider prescribing patterns and patients' long-term opioid use outcomes.
Methods: Medicare data from 2010 to 2012 were used to identify 16,043 RCRs for patients with new shoulder complaints in 2011. Two measures of perioperative opioid use were created: (1) any opioid fill occurring 3 days before to 7 days after RCR and (2) total morphine milligram equivalents (MMEs) of all opioid fills during that period. Patient outcomes for persistent opioid use after RCR included (1) any opioid fill from 90 to 180 days after RCR and (2) the lack of any 30-day gap in opioid availability during that period. Generalized linear regression models were used to estimate associations between provider characteristics and opioid use for RCR, and between opioid use and outcomes. All models adjusted for patient clinical and demographic characteristics. Separate analyses were done for patients with and without opioid use in the 180 days before RCR.
Results: In this sample, 54% of patients undergoing RCR were opioid naive at the time of RCR. Relative to prior users, a greater proportion of opioid naive users had any opioid fill (85.7% vs. 75.4%), but prior users received more MMEs than naive users (565 vs. 451 MMEs). Providers' opioid prescribing for other patients was associated with the intensity of perioperative opioids received for RCR. Total MMEs received for RCR were associated with higher odds of persistent opioid use 90-180 days after RCR.
Conclusions: The intensity of opioids received by patients for postoperative pain appears to be partially determined by the prescribing habits of their providers. Greater intensity of opioids received is, in turn, associated with greater odds of patterns of chronic opioid use

This systematic review did not require institutional review board approval.

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https://doi.org/10.1016/j.jse.2020.04.037

after surgery. More comprehensive, patient-centered guidance on opioid prescribing is needed to help surgeons provide optimal postoperative pain management plans, balancing needs for short-term symptom relief and risks for long-term outcomes.
Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Opioid use; rotator cuff repair; Medicare; dosage; pain management; prescription patterns

The United States opioid epidemic, characterized by increasing rates of chronic use of opioid medications and related overdoses,[8,14,17] is often linked to standards issued by the Joint Commission on the Accreditation of Health Care Organization, designating pain as a "fifth vital sign."[9] Each year from 2006 to 2012, approximately 1 in 3 Medicare beneficiaries were prescribed an opioid and 1 in 10 had chronic opioid use.[2] Musculoskeletal problems have been identified as a significant source of opioid prescriptions for this older cohort. The United States Bone and Joint Initiative[1] found that nearly 70% of adults over age 65 reported a musculoskeletal problem and over 11 million musculoskeletal procedures were performed in 2013. Little is presently known about how the intensity of opioid prescriptions received for postsurgical pain management may impact potential for opioid-related misuse or other related problems, and, consequently, there is little guidance for providers.

Rotator cuff repair (RCR) is the most common shoulder surgery impacting patients over age 65 and is associated with potentially severe short-term postoperative pain.[19,21] As prescription of opioid analgesics became standard of care for these patients, providers had to formulate dosing strategies without support from robust evidence or clinical guidelines. As such, broad variation in opioids prescribed for similar patients is possible without any clinical rationale. Evaluating opioid prescriptions for 81 patients who received RCR from a single institution, a recent study found that the total pills provided at discharge varied from 18 to 100, or from 90 to 500 morphine milligram equivalents (MMEs).[15] Variable opioid intensity may reflect clinical judgment about required efficacious dose or other patient-specific considerations but has been suggested to often represent excessive prescribing. One study found that 61% of patients receiving RCR reported unused opioids,[15] consistent with other studies' finding that most opioids prescribed after musculoskeletal surgery go unused.[12] Excess prescribing may place some patients at unneeded risk of chronic opioid use or other problems. Increasing opioid prescribing intensity through greater days supplied or opioid MMEs has been shown to be associated with the increased risk of opioid addiction and duration of opioid use.[3,13,20]

To support the ultimate development of broadly applicable patient-centered guideline recommendations for opioid prescribing, we must first characterize and understand existing variability in opioid prescriptions and the corresponding differences in patient outcomes. The primary objective of this study was to characterize provider opioid prescription patterns for patients undergoing surgical RCR and examine associations between the intensity of opioids received by patients and long-term persistent opioid use outcomes.

We first described variability in the intensity of opioids filled during a perioperative period for RCR at the patient and provider levels. We then examined predictors of intensity of opioids received by patients for RCR, including characterizing the average intensity of opioids prescribed by the patients' RCR providers to other patients. Finally, we examined associations between the intensity of opioids received for RCR and outcomes related to persistent opioid use after RCR. We investigated these relationships separately for new opioid users and patients who were current or recent opioid users.

Materials and methods

Data

These were retrospective cohort study administrative data. Data for this study included 2010-2012 Medicare Part A and Part B fee-for-service claims, Part D event (PDE) data containing information on drug fills, and beneficiary summary files of demographic and enrollment data. Available data included all files from 2010 to 2012 for beneficiaries, with any of 110 specified International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes indicating a shoulder-related problem during 2011.

Cohort

Two cohorts were created for this study. The first and larger cohort, referred to as the measurement cohort, was used to create provider-level measures of opioid prescribing characteristics. The second cohort is a subset of the measurement cohort that was used for analysis for associations between provider characteristics, intensity of opioids received, and ongoing opioid use outcomes.

We first constructed the measurement cohort by identifying all RCR events that occurred during 2011-2012. Each RCR was identified using Current Procedural Terminology (CPT) codes for RCR on Medicare Part A and B claims (CPT codes: 23410, 23412, 23420, 29827). Additional criteria were then applied such that RCR events were included in the measurement cohort if the

beneficiary (1) was at least 66 years old on the date of RCR; (2) was continuously enrolled in Medicare Parts A and B, and never enrolled in a health maintenance organization (HMO), from 365 days before the RCR event to 7 days after; (3) was enrolled in a Medicare Part D Prescription Drug Plan from 180 days before the RCR event to 7 days after; (4) had no prior RCR within 365 days before the RCR event; (5) did not have an inpatient length of stay for RCR more than 2 days (1 night); and (6) had no opioid fills with unknown morphine equivalence.

The analysis cohort was then created as a subset of the measurement cohort. Additional inclusion criteria were applied to identify new shoulder patients who had no recent history of shoulder problems, had RCR performed within a limited timeframe from initial shoulder complaint, and had complete data for outcome measurement. Specifically, inclusion in the analysis cohort required that the beneficiary had (1) met all criteria for inclusion in the measurement cohort; (2) shoulder-related diagnosis in 2011; (3) no shoulder-related diagnosis in the 365 days before the first shoulder-related diagnosis in 2011; (4) RCR performed within 180 days of the first shoulder-related diagnosis in 2011; (5) survived and was continuously enrolled in Medicare Parts A, B, and D, and never enrolled in an HMO from 365 days before the first shoulder-related diagnosis in 2011 to 180 days after the RCR was performed; and (6) spent fewer than 10 days in any inpatient facility during the 180-day period after RCR.

Finally, 2 strata of the analytic cohort were created based on any opioid use observed before the RCR. An RCR observation was classified as being for a prior opioid user if the patient had any observed opioid fill from 180 to 3 days before the RCR event; otherwise the RCR was classified as being for a patient who was opioid naive. Ending the prior use period 3 days before the RCR performance date was intended to allow for physicians prescribing in advance of surgery, so patients were not required to visit a pharmacy immediately after surgery.

Measures

The central measure for this study is the intensity of opioids provided for postoperative pain management after RCR. Two primary measures of perioperative opioid use were created for each RCR: (1) any opioid fill during the period and (2) sum total MMEs across all opioid fills during the period. The perioperative period was defined to include all days from 3 days before the RCR performance date to 7 days after. The choice of 7 days after surgery was intended to capture delayed filling of prescriptions if, for example, a patient tries non-narcotic analgesics for first-line pain management. Opioid medications were identified from PDE files by National Drug Code, and the MME of each unit of the prescribed medication was based on a product-specific multiplier. The National Drug Codes for all opioid products and their associated per-unit MME multipliers for 2010-2012 were borrowed from the prescription drug monitoring program resource data originally compiled and described by O'Kane et al.[5,10] All opioid products with nonmissing MME information were included, regardless of dosage form (eg, oral, patch, spray, injection).

Corresponding measures of provider opioid prescribing characteristics were then created for each provider that was associated with any RCR included in the measurement cohort. Provider-level measures included (1) the proportion of a provider's associated RCR events that had any opioid fill and (2) the average total MMEs across a provider's associated RCR events that had any opioid fill. Providers were identified by the National Provider Identifier code. A provider was considered to be associated with an RCR if its National Provider Identifier was indicated as the performing provider on any recorded physician services claim for cuff repair on the performance date for RCR. No limiting criteria, such as specialty, were applied because it was not possible to identify the single provider who provided a prescription. Using these criteria, a single RCR may be associated with multiple providers. For example, if a surgery involves both an attending surgeon and a surgical fellow or resident, each may be included as a performing provider on separate claim lines with CPT for RCR. In such cases, the RCR was associated with both providers and would contribute to measures of opioid prescribing characteristics for each.

Measures of the opioid prescribing patterns of providers associated with each RCR in the study cohort were then created to examine associations with the intensity of perioperative opioid fills received by patients with RCR. These RCR-level measures were created to be exogenous to opioid fills for the patient of that RCR event by aggregating measures of perioperative opioid use across all other patients who had a common provider for RCR. Specifically, measures created based on all RCR events for other patients who shared an associated provider included (1) the average proportion that had any opioid fill and (2) the average total MMEs of events that had any opioid fill.

The primary outcome of interest was long-term or persistent opioid use after RCR. Two measures were created based on the period from 90 to 180 days after the end of the date of RCR: (1) any observed opioid fill during the period and (2) no 30-day gap in opioid therapy, measured based on a comparison of day supply for all fills received and days the patient spent outside any institutional setting. Each measure was binary, with a value of 1 indicating persistent opioid use.

Additional clinical and demographic characteristics included patient age on the date of RCR, sex, Medicare-Medicaid dual eligibility, type of cuff repair (open, arthroscopic, or reconstruction), Charlson Comorbidity Index score,[4] diagnoses of specific comorbidity (eg, chronic obstructive pulmonary disease,[4] sleep apnea, depression,[7] cancer[4]) and mental health conditions over the 365 days before the RCR date, and fills for other prescription drugs (eg, muscle relaxants, sedatives, benzodiazepines) 180 days before the RCR date. Complete details on algorithms for all study measures are available on request.

Analyses

Variation in the intensity of opioids filled during the perioperative period for RCR was examined cross-sectionally. Associations between provider prescribing characteristics and the opioid exposure for individual RCRs were then examined using generalized linear models. We report results from 8 models, in total: 1 each for 4 dependent variables across the 2 strata by prior opioid use. Dependent variables included (1) the probability of any opioid fill during the perioperative period for RCR; (2) total MMEs of opioid fills during the perioperative period, conditional on any opioid being received; (3) any opioid fill during 90-180 days after RCR; and (4) having no 30-day gap in opioids available at home during 90-180 days after the RCR. Models with binary dependent variables (1, 3, and 4) were estimated using logistic regression with coefficients reported as odds ratios. Coefficients

Table I Number of rotator cuff repair (RCR) event observations by inclusion criteria for measurement cohort and study cohort

Criterion for inclusion	Measurement (N)	Study (N)
Surgical RCR in 2010-2012	133,281	133,281
Age 66 or greater on the RCR date	127,561	127,561
Medicare Parts A, B and no HMO from 365 d before RCR to 7 d after	92,007	92,007
No RCR 365 d before RCR	87,127	87,127
Medicare Part D plan during months of perioperative period	43,405	43,405
Medicare Part D plan 180 d before RCR	42,070	42,070
Inpatient stay overlapping with RCT surgery date less than 2 d (1 night)	40,286	40,286
No opioid prescription with unknown morphine equivalence	40,274	40,274
Associated with at least 1 other RCR episode through shared provider	38,577	38,577
Shoulder diagnosis in 2011 with no shoulder diagnosis in 365 d prior		23,839
RCR performed within 180 d after first shoulder diagnosis in 2011		16,615
Survived 180 d after RCR		16,559
Medicare Parts A, B and no HMO 180 d after RCR		16,365
Medicare Part D plan 180 d after RCR		16,307
No more than 10 d spent in inpatient facility during 180 d after RCR		16,043

HMO, health maintenance organization.

for model 2 were estimated using a simple linear model, by ordinary least squares.

Continuous variables for which a 1-unit change is meaningful were transformed before inclusion as an explanatory variable in regression models in order to produce more interpretable coefficient estimates. The monotonic transformation included centering variables around 0 by subtracting the mean of the raw value and then dividing by a scaling factor, such as the standard deviation, that represents a more meaningful or relevant change in the original concept. Coefficient estimates on the resulting transformed variable then represent the estimated change in the dependent variable expected from increasing the original measure by a quantity equal to the scaling factor.

Results

There were 38,577 RCR events identified for the measurement cohort, of which 16,043 RCR events met criteria to be included in the study cohort (Table I).

Of the 16,043 observations in the study cohort, 54% (8712) had no observed opioid fills in the 180 days before the RCR and so were considered opioid naive. Prior opioid users were similar in age to opioid naive users (72.4 vs. 72.6 years) but had slightly greater comorbidity as measured by the Charlson Comorbidity Index (1.6 vs. 1.3) and rates of individual comorbid conditions of interest such as rheumatoid arthritis (5.1% vs. 3.6%), chronic obstructive pulmonary disease (9.7% vs. 5.5%), sleep apnea (6.5% vs. 4.5%), mental health diagnoses (25.6% vs. 16.2%), and depression (13.1% vs. 7.2%). Prior opioid users, however, did not have greater rates of pre-365 cancer diagnoses (12.7% vs. 12.8%). Prior users had greater rates of pre-180 fills for muscle relaxants (14.6% vs. 5.7%) and sedatives (11.9% vs. 6.6%). Descriptive statistics for the study and measurement cohorts are provided in Table II; summary statistics are provided for the full study sample and for subsamples by status as (1) opioid naive at index and (2) having had any opioid fill during the perioperative period for RCR.

Perioperative opioid therapy

Relative to prior users, a greater proportion of opioid naive users had any opioid fill for RCR (85.7% of naive vs. 75.4% of prior users). However, among those with any opioid fill, prior users received greater total MMEs than naive users (565 vs. 451 MMEs). Naive users with and without an opioid fill were similar in terms of Medicaid dual eligibility (7.9% of nonfillers vs. 7.8% of those with a fill). Conversely, 14.9% of prior users with an opioid fill for RCR were Medicaid dual-eligible compared with 9.4% of those without an opioid fill. Provider opioid prescribing characteristics were similar across prior users and opioid naive users.

In general, and perhaps unsurprisingly, persistent opioid use after the RCR was more common among the prior users. A greater proportion of prior users had any opioid fill in the post 90- to 180-day period (34.6% vs. 11.1%) and had no 30-day gap in opioid availability during that period (48.5% vs. 31.9%). Within each prior-user and opioid-naive sample, long-term opioid use after the RCR was greater among those with an opioid fill.

Variation in the intensity of opioid prescriptions filled by patients during the perioperative period for RCR is depicted in Fig. 1; data are plotted separately for RCRs of patients who were defined as opioid naive (dashed line) and prior users (solid line). Box plots in Fig. 1 (left column) show the full distribution of opioid prescription fills across RCRs.

Table II Descriptive summary of study cohort characteristics by prior opioid use and perioperative opioid use

Measure	Prior opioid user				Opioid naive			
	Overall	No fill	Fill	$P^{\dagger}$	Overall	No fill	Fill	$P^{\dagger}$
N (%)	7331 (45.7)	1807 (24.6)	5524 (75.4)		8712 (54.3)	1250 (14.3)	7462 (85.7)	
Demographic and clinical characteristics								
Age	72.4 (4.7)	72.9 (5.0)	72.3 (4.6)	<.001	72.7 (4.8)	73.3 (5.3)	72.6 (4.8)	<.001
Male, N (%)	3318 (45.3)	850 (47.0)	2468 (44.7)	.085	4301 (49.4)	546 (43.7)	3755 (50.3)	<.001
Non-white race, N (%)	525 (7.2)	131 (7.2)	394 (7.1)	.908	536 (6.2)	86 (6.9)	450 (6.0)	.274
Medicare-Medicaid dual eligible, N (%)	995 (13.6)	170 (9.4)	825 (14.9)	<.001	682 (7.8)	99 (7.9)	583 (7.8)	.941
Acute cuff injury, N (%)	500 (6.8)	98 (5.4)	402 (7.3)	.008	537 (6.2)	98 (7.8)	439 (5.9)	.009
Repair type: arthroscopic, N (%)	4492 (61.3)	1195 (66.1)	3297 (59.7)	<.001	5277 (60.6)	725 (58.0)	4552 (61.0)	.024
Repair type: open, N (%)	2133 (29.1)	467 (25.8)	1666 (30.2)	<.001	2524 (29.0)	365 (29.2)	2159 (28.9)	.994
Repair type: reconstruction, N (%)	706 (9.6)	145 (8.0)	561 (10.2)	.009	911 (10.5)	160 (12.8)	751 (10.1)	.004
Charlson Index score, pre-365, mean (SD)	1.6 (1.8)	1.5 (1.7)	1.6 (1.9)	.005	1.3 (1.6)	1.3 (1.7)	1.3 (1.6)	.183
Rheumatoid arthritis, pre-365, N (%)	373 (5.1)	88 (4.9)	285 (5.2)	.671	317 (3.6)	54 (4.3)	263 (3.5)	.191
Cancer, pre-365, N (%)	934 (12.7)	235 (13.0)	699 (12.7)	.728	1113 (12.8)	157 (12.6)	956 (12.8)	.841
Depression, pre-365, N (%)	958 (13.1)	192 (10.6)	766 (13.9)	<.001	629 (7.2)	101 (8.1)	528 (7.1)	.226
COPD, pre-365, N (%)	708 (9.7)	135 (7.5)	573 (10.4)	<.001	479 (5.5)	68 (5.4)	411 (5.5)	.976
Sleep apnea, pre-365, N (%)	480 (6.5)	99 (5.5)	381 (6.9)	.039	393 (4.5)	54 (4.3)	339 (4.5)	.781
Mental health diagnosis, pre-365, N (%)	1874 (25.6)	387 (21.4)	1487 (26.9)	<.001	1408 (16.2)	228 (18.2)	1180 (15.8)	.034
Fill for a prescribed muscle relaxant, pre-180, N (%)	1071 (14.6)	203 (11.2)	868 (15.7)	<.001	496 (5.7)	56 (4.5)	440 (5.9)	.053
Fill for any prescribed sedative, pre-180, N (%)	870 (11.9)	188 (10.4)	682 (12.3)	.03	579 (6.6)	95 (7.6)	484 (6.5)	.161
Perioperative opioid fills								
Any opioid fill, perioperative, N (%)	5524 (75.4)	0 (0.0)	5524 (100.0)	<.001	7462 (85.7)	0 (0.0)	7462 (100.0)	<.001
Total MME received, perioperative, mean (SD)	426 (600)	0.0 (0.0)	565 (631)	<.001	387 (288)	0.0 (0.0)	451 (260)	<.001
RCR-associated provider(s) (exogenous to RCR)								
Associated providers, mean (SD)	1.67 (0.68)	1.73 (0.71)	1.65 (0.67)	<.001	1.69 (0.68)	1.63 (0.66)	1.70 (0.69)	.001
Associated other patients, mean (SD)	20.9 (26.5)	24.3 (30.2)	19.7 (25.1)	<.001	20.7 (25.5)	20.0 (25.7)	20.9 (25.5)	.27
Associated other patients with fill, mean (SD)	15.7 (20.0)	15.2 (19.8)	15.9 (20.0)	.247	16.8 (20.4)	15.3 (19.8)	17.0 (20.5)	.007
Provider fill ratio, mean (SD)	0.78 (0.23)	0.65 (0.25)	0.82 (0.21)	<.001	0.82 (0.20)	0.77 (0.24)	0.83 (0.19)	<.001
Provider average total MME, mean (SD)	526 (394)	511 (348)	530 (408)	.072	511 (471)	492 (712)	515 (417)	.108
Outcomes: 90-180 d after RCR								
Any opioid fill, post 90-180, N (%)	2533 (34.6)	443 (24.5)	2090 (37.8)	<.001	969 (11.1)	96 (7.7)	873 (11.7)	<.001
No 30-d gap in opioid availability, post 90-180, N (%)	3558 (48.5)	669 (37.0)	2889 (52.3)	<.001	2691 (30.9)	213 (17.0)	2478 (33.2)	<.001

SD, standard deviation; *COPD*, chronic obstructive pulmonary disease; *MME*, morphine milligram equivalent; *RCR*, rotator cuff repair.

† *P* value associated with test statistical test of differences across 2 groups: χ^2 test for frequency differences and *t*-test for mean differences.

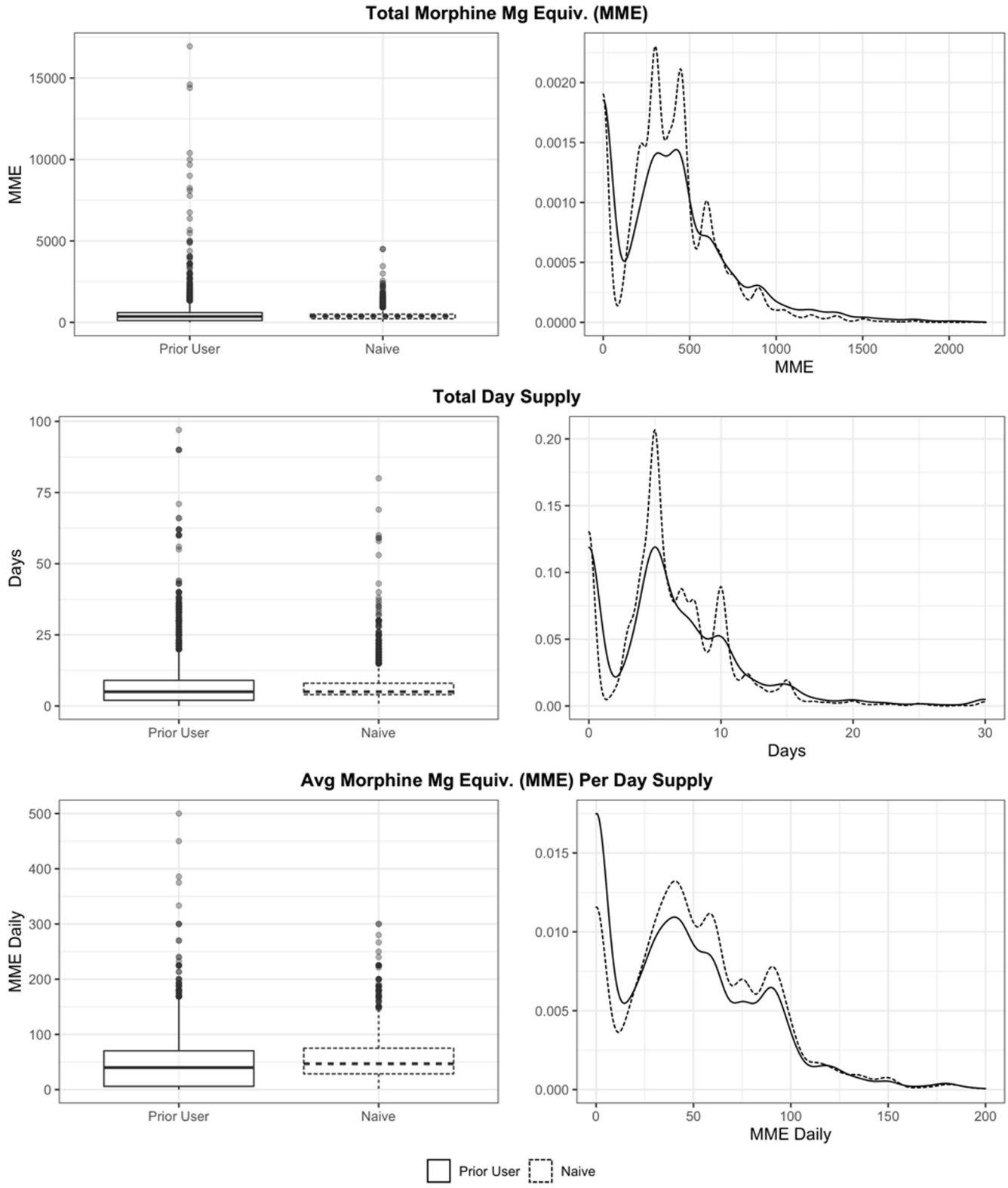

Figure 1 Variation in intensity of perioperative opioid fills for rotator cuff repair (RCR). *MME*, morphine milligram equivalent.

Table III Regression estimates for model fit predicting perioperative opioid fill

Predictors	Prior user	Opioid naive
	Any opioid fill, perioperative period	
	Odds ratio (95% confidence interval)	
Intercept	3.47*** (2.76–4.37)	4.09*** (3.34–5.03)
Provider fill ratio†,‡	1.35*** (1.32–1.38)	1.14*** (1.11–1.17)
Age†	0.87*** (0.81–0.91)	0.87*** (0.82–0.93)
Male	0.96 (0.86–1.08)	1.30*** (1.15–1.48)
Non-white race	0.93 (0.74–1.18)	0.88 (0.68–1.15)
Medicare-Medicaid dualeligible	1.57*** (1.29–1.92)	1.19 (0.94–1.53)
Acute cuff injury	1.30 (1.00–1.70)	0.73* (0.57–0.94)
Repair type: arthroscopic	0.74** (0.59–0.92)	1.44*** (1.18–1.75)
Repair type: open	0.90 (0.71–1.14)	1.46*** (1.17–1.82)
Repair type: reconstruction	Reference	Reference
Charlson Index score, pre-365	1.04 (1.00–1.08)	0.98 (0.93–1.02)
Rheumatoid arthritis, pre-365	0.89 (0.68–1.17)	0.93 (0.69–1.28)
Cancer, pre-365	0.96 (0.79–1.17)	1.10 (0.90–1.37)
Depression, pre-365	0.94 (0.74–1.18)	0.98 (0.74–1.31)
COPD, pre-365	1.19 (0.96–1.48)	1.06 (0.81–1.40)
Sleep apnea, pre-365	1.16 (0.91–1.49)	0.97 (0.72–1.32)
Mental health diagnosis, pre-365	1.21* (1.02–1.45)	0.87 (0.72–1.07)
Fill for a prescribed muscle relaxant, pre-180	1.33** (1.12–1.58)	1.35* (1.02–1.83)
Fill for any prescribed sedative, pre-180	1.12 (0.94–1.35)	0.88 (0.70–1.11)
Observations	7331	8712
R2 Tjur	0.12	0.02

Reference class for surgery type excluded to serve as comparison level for estimated associations.
COPD, chronic obstructive pulmonary disease; *RCR*, rotator cuff repair.
*$P < .05$, **$P < .01$, ***$P < .001$.
† Centered at mean = 0; scaled by 5 (age) and 0.1 (fill ratio).
‡ Exogenous to the patient of the RCR event.

Because the distribution has a very long tail, density plots (right column) include only values within 4 standard deviations of the mean to better show characteristics for the majority of the distributions mass.

Distributions of opioid intensity measures across RCR events appeared multimodal, with modes for total MMEs near 300 and 500 and modes for MME/d appearing proximal to significant Center for Disease Control (CDC) risk cutoffs (50 MMEs/d, 90 MMEs/d).[6] Although the ranges of opioid intensity across naive and prior users are similar, the distributions for prior users appear slightly flatter, with less pronounced local modes.

Provider-associated opioid therapy characteristics

There were 14,644 unique providers associated with the 38,577 RCR events included in the measurement cohort. Provider opioid prescribing characteristics were based on the average perioperative opioid use of 21 distinct RCR events, on average. The average provider fill ratio was 0.80 (ie, 80% of providers' patients received any opioid during the perioperative period), and the average total MME across providers' patients who received any opioid was 541. Supplementary Table S1 provides additional summary characteristics for providers.

Distributions for measures of provider opioid prescribing were overall very similar to those for corresponding measures of individual RCR opioid intensity, with the exception that provider measure distributions appeared smoother and had a single mode. Variation in measured characteristics of provider opioid prescribing is illustrated in Supplementary Fig. S1.

Regression model results

Any opioid fill for RCR

Table III shows estimated odds ratios and 95% confidence interval values from the logistic regression model fit predicting any observed fill for an opioid during the perioperative period for RCR, by status as prior user or opioid naive. On average, adjusting for other measured variables, a 0.1 increase in the provider fill ratio was associated with 1.35 greater odds of having any opioid fill among prior users and 1.14 greater odds of having any opioid fill among opioid naive patients. An increase in patient age of approximately 5 years was associated with 0.87 lower odds of having any opioid fill. Among opioid naive patients,

Table IV Regression estimates for model fits predicting intensity of opioid fills during perioperative period for RCR, for cohort with fill

Predictors	Prior user	Opioid naive
	Total MMEs, perioperative fills	
	Estimates (95% confidence interval)	
Intercept	527.5*** (465.6 to 589.5)	459.6*** (438.4 to 480.7)
Provider fill ratio†,‡	2.7 (−5.3 to 10.7)	6.1*** (3.0 to 9.1)
Provider average total MMEs supplied†,‡	86.9*** (66.5 to 107.2)	79.2*** (72.4 to 86.1)
Age†	−44.8*** (−62.7 to −26.9)	−23.3*** (−29.4 to −17.3)
Male	−9.5 (−43.8 to 24.9)	9.9 (−1.8 to 21.6)
Non-white race	−76.7* (−143.2 to −10.2)	−44.1*** (−69.4 to −18.8)
Medicare-Medicaid dual eligible	59.3* (10.0 to 108.6)	−0.5 (−23.3 to 22.3)
Acute cuff injury	−45.1 (−114.6 to 24.4)	−7.5 (−33.5 to 18.5)
Repair type: arthroscopic	−13.5 (−72.3 to 45.3)	−16.0 (−36.4 to 4.3)
Repair type: open	27.4 (−36.3 to 91.0)	−18.8 (−40.8 to 3.16)
Repair type: reconstruction	Reference	Reference
Charlson Index score, pre-365	−1.7 (−12.2 to 8.8)	−0.1 (−4.5 to 4.2)
Rheumatoid arthritis, pre-365	70.4 (−5.57 to 146.3)	23.8 (−7.5 to 55.0)
Cancer, pre-365	9.8 (−45.8 to 65.4)	3.4 (−16.3 to 23.0)
Depression, pre-365	78.3* (15.5 to 141.0)	−2.8 (−31.0 to 25.4)
COPD, pre-365	70.1* (13.2 to 126.9)	2.2 (−23.5 to 27.8)
Sleep apnea, pre-365	24.6 (−41.18 to 90.4)	−5.05 (−32.57 to 22.46)
Mental health diagnosis, pre-365	−0.1 (−49.3 to 49.2)	16.2 (−3.7 to 36.1)
Fill for a prescribed muscle relaxant, pre-180	73.2** (27.5 to 118.9)	16.9 (−7.3 to 41.1)
Fill for any prescribed sedative, pre-180	62.0* (11.6 to 112.5)	19.2 (−3.98 to 42.3)
Observations	5524	7462
R2/adjusted R^2	0.03/0.03	0.08/0.08

Reference class for surgery type excluded to serve as comparison level for estimated associations.
RCR, rotator cuff repair; *MME*, morphine milligram equivalent; *COPD*, chronic obstructive pulmonary disease.
*$P < .05$, **$P < .01$, ***$P < .001$.
† Centered at mean = 0; scaled by 5 (age), 0.1 (fill ratio), and 500 (MME).
‡ Exogenous to the patient of the RCR event.

having arthroscopic or open repair was associated with approximately 1.44 greater odds of having any opioid fill, relative to a reconstruction. Conversely, among prior users, arthroscopic repair was associated with 0.74 lower odds of a fill, relative to reconstruction. In both groups, a fill for a prescribed muscle relaxant was associated with approximately 1.3 greater odds of a fill.

Intensity of perioperative opioid fills for RCR

Table IV shows estimated parameter and 95% confidence interval values from linear regression models predicting total MMEs received by patients across fills during the perioperative RCR period, by subsample with prior opioid use (N = 5524) vs. opioid naive (N = 7462). On average, adjusting for other measured variables, an increase of 500 in providers' average total MMEs supplied was associated with 87 more MMEs received during the perioperative period for RCR for prior users and 79 more MMEs received among opioid naive patients. The provider fill ratio was trivially, though statistically significantly, associated with total MMEs received for RCR. An increase in age of 5 years was associated with fewer MMEs received for all RCRs (45 fewer for prior users, 23 fewer MMEs received among opioid naive users). Similarly, non-white race was associated with fewer MMEs in models for each prior and naive user (−77 and −44, respectively). Medicaid dual eligibility was associated with 59 greater MMEs received among prior users but had no association in the model for naive users. Prior use of sedative and muscle relaxant drugs was associated with greater MMEs received among prior users but was not meaningful or significant in the model for naive users.

Primary outcomes

Table V shows estimated parameter and 95% confidence interval values from logistic regression model fits predicting outcomes related to persistent opioid use 90-180 days after RCR, specifically (1) any opioid fill and (2) no 30-day gap in opioid being available at home. After adjusting for patient characteristics and intensity of perioperative opioid fills, the receipt of any opioid during the perioperative period was associated with greater odds of having no 30-day gap in opioid use, with the magnitude of effect being more pronounced among the opioid naive patients (odds ratio: 1.27 for prior users and 2.07 for opioid naive). However, the receipt of an opioid during the perioperative period was not statistically significantly associated with the probability of having any opioid fill 90-180 days after RCR. Greater total MMEs during

Table V Regression estimates for model fits predicting measures of long-term opioid use after rotator cuff repair

Predictors	Prior opioid users		Opioid naive	
	Any opioid fill, post 90-180	No 30-d gap in opioid, post 90-180	Any opioid fill, post 90-180	No 30-d gap in opioid, post 90-180
	Odds ratio (95% confidence interval)		Odds ratio (95% confidence interval)	
Intercept	0.40*** (0.31–0.50)	0.64*** (0.52–0.79)	0.08*** (0.06–0.11)	0.23*** (0.18–0.29)
Any opioid fill, perioperative	0.95 (0.82–1.11)	1.27*** (1.11–1.46)	1.23 (0.96–1.59)	2.07*** (1.74–2.48)
Total MME, perioperative†	1.68*** (1.54–1.82)	1.34*** (1.24–1.45)	1.35*** (1.20–1.52)	1.22*** (1.11–1.34)
Age†	0.93** (0.88–0.98)	0.90*** (0.86–0.95)	0.89** (0.83–0.96)	0.93** (0.88–0.98)
Male	0.87* (0.78–0.97)	0.93 (0.85–1.03)	0.82** (0.71–0.95)	0.81*** (0.73–0.89)
Non-white race	0.88 (0.71–1.07)	1.05 (0.87–1.28)	0.62** (0.45–0.85)	0.90 (0.73–1.10)
Medicare-Medicaid dual eligible	2.04*** (1.75–2.38)	1.59*** (1.37–1.85)	1.66*** (1.31–2.09)	1.54*** (1.29–1.84)
Acute cuff injury	0.98 (0.79–1.22)	1.01 (0.82–1.23)	1.04 (0.76–1.39)	0.91 (0.74–1.12)
Repair type: arthroscopic	0.85 (0.71–1.02)	0.99 (0.83–1.17)	1.00 (0.79–1.28)	0.89 (0.76–1.05)
Repair type: open	0.89 (0.73–1.08)	1.11 (0.93–1.34)	1.08 (0.84–1.41)	1.03 (0.86–1.23)
Repair type: reconstruction	Reference	Reference	Reference	Reference
Charlson Index score, pre-365	1.11*** (1.07–1.15)	1.03 (1.00–1.06)	1.10*** (1.05–1.15)	1.08*** (1.04–1.12)
Rheumatoid arthritis, pre-365	1.58*** (1.26–1.98)	1.18 (0.95–1.47)	1.33 (0.96–1.81)	1.12 (0.88–1.43)
Cancer, pre-365	0.72*** (0.60–0.85)	0.85* (0.72–0.99)	0.93 (0.74–1.16)	0.90 (0.76–1.05)
Depression, pre-365	1.24* (1.03–1.51)	1.20* (1.00–1.45)	1.03 (0.77–1.37)	0.92 (0.74–1.15)
COPD, pre-365	1.48*** (1.24–1.76)	1.20* (1.02–1.43)	1.18 (0.89–1.54)	1.22 (1.00–1.49)
Sleep apnea, pre-365	1.05 (0.85–1.29)	0.89 (0.74–1.08)	1.18 (0.87–1.58)	1.10 (0.88–1.37)
Mental health diagnosis, pre-365	1.23** (1.06–1.43)	1.14 (0.99–1.32)	1.47*** (1.19–1.80)	1.14 (0.97–1.33)
Fill for a prescribed muscle relaxant, pre-180	1.73*** (1.51–1.99)	1.27*** (1.11–1.46)	1.22 (0.94–1.58)	1.48*** (1.23–1.79)
Fill for any prescribed sedative, pre-180	1.58*** (1.35–1.84)	1.18* (1.02–1.36)	1.37** (1.07–1.74)	1.18 (0.98–1.41)
Observations	7331	7331	8712	8712
R2 Tjur	0.11	0.05	0.02	0.03

MME, morphine milligram equivalent; *COPD*, chronic obstructive pulmonary disease.
*$P < .05$, **$P < .01$, ***$P < .001$.
† Centered at mean = 0; scaled by 5 (age) and 500 (MME).

the perioperative period were consistently associated with more persistent long-term opioid use across all outcomes and sample populations; though the magnitude of the associations was greater among prior opioid users. Among prior opioid users, a 500-unit increase in MMEs received was associated with 1.68 greater odds of any opioid fill during the 90- to 180-day period after RCR and 1.34 greater odds of no 30-day gap during that period. Among naive users, a 500-unit increase in MMEs received was associated with 1.35 greater odds of any opioid fill and 1.22 greater odds of no 30-day gap during that period. Greater age was associated with less long-term opioid use in each of the 4 models. Conversely, Medicaid dual eligibility was associated with greater long-term opioid use in each model. Mental health diagnoses and any fill for a muscle relaxant or sedative in the pre-180 period each were associated with greater long-term opioid use.

Discussion

Our results show that there is wide variation in the intensity of opioids prescribed for postoperative pain management after RCR, both for patients with and without opioid use before surgery. Patients who received more intense opioids were also more likely to have had persistent opioid use through the 90- to 180-day period after surgery. These results and interpretations are consistent with other studies showing wide variation in opioid prescribing for musculoskeletal surgery and finding patients who receive more intense opioids for an isolated incident or have opioid use before surgery and are more likely to exhibit patterns of chronic opioid use.[12,15]

Opioid prescribing guidelines for common surgical procedures developed, and published in 2018, by a panel of experts including surgeons, patients, pharmacists, and pain management professionals recommended that patients undergoing uncomplicated RCR should receive 0-20 opioid pills or 0-100 MMEs.[11] The results from our study, like others,[12,15,16,18] show that actual opioid prescribing far exceeds these recommendations.

The probability that patients filled an opioid during the perioperative period for RCR and the total MMEs of opioids filled were nontrivially associated with prescribing patterns of their providers for RCR. This suggests that

physician practice patterns or beliefs, independent of patients' clinical characteristics, influence whether a patient receives any opioid and the intensity of opioids they receive. These considerations are important for surgeons managing acute, severe pain after RCR, especially in a more vulnerable elderly population.

Our results add to past studies that have restricted analyses of provider prescribing patterns and chronic opioid use outcomes to a sample of opioid naive patients,[3] in part due to complexity in attributing the source and reason behind opioid fills for prior users. The present study is subject to these same limitations but considers reporting results for both prior user and naive groups as a necessary starting point to gain insights for improved measurement and methodology. Results for the prior user group in particular must be considered carefully. Fills in the perioperative period or outcome periods may be for causes unrelated to the RCR and possibly a part of pre-existing chronic opioid use. This complexity and concern for the prior-users models motivated the stratified models used in analyses, as opposed to a single model with interaction terms or a modeled multilevel structure. Alternative multilevel and interaction models were examined and did not produce meaningfully different interpretations. The reported results were chosen for their simpler interpretation and to isolate any issues with data for prior users from the naive model. The complexity in prior users and potential heterogeneity across new and prior users is an area of interest and further work.

This work focused on total MMEs as a single index measure of opioid intensity. A more rigorous analysis of opioid intensity may consider isolating the direct concepts that determine total MMEs and use of non-narcotic therapies. Modeling opioid intensity as a function of the total number of pills provided, MMEs per pill, and recommended total pills daily may have potential for interesting insights into predictors of opioid problems or may better differentiate provider practice patterns. Technical reasons for our choice to focus on MME as an intensity measure for this initial work included (1) concern that more complex measures could exacerbate potential issues from noisy measures of provider opioid prescribing characteristics, (2) concerns about the validity of day supply indications for as-needed medications, and (3) the added complexity communicating interpretations from models with multiple interactions. In exploring more complex models, we did not note meaningfully different interpretations for reported associations. Future work should consider the presence of alternative prescribing strategies in real-world practice and their efficacy for different types of patients. Future work might consider whether or to what extent there is a threshold of total MMEs provided for which the risk of opioid-related problems increases sharply, and how that threshold varies across patients or across forms by which intensity might be provided (ie, greater day supply, greater average morphine equivalents per day). Future work may also include measures of non-narcotic over-the-counter medications that are not generally captured in administrative data.

The proportion of RCR events with any observed fill (provider fill ratio) was theorized to represent how often providers prescribe an opioid as well as how risks and benefits of opioids are communicated to patients. A recent intervention study found that providing education to patients undergoing RCR about opioid use and risks was associated with less opioid consumption and greater likelihood of discontinuing narcotics; results on discontinuation were even more pronounced for patients who were prior users.[18] Further understanding is needed of the extent of variation in providers' approaches to communicating first-line strategies and the risks and benefits of narcotics for postsurgical pain management in practice, and implications for opioid use and outcomes.

A main limitation of this work was an inability to link providers performing the RCR to prescription drug fills in PDE data. Prescriber identifiers on PDE data were encrypted before 2014 and no such linkage was possible. Even with these identifiers, though, other circumstances of reality create complexity in linking surgical providers with prescribing providers in administrative claims. In this work, we attributed all fills in the perioperative period to all providers billing for the RCR procedure on the surgery date. The resulting measures for each provider will include opioid prescriptions that were written by another provider, with whom they are likely familiar. This approach may not include the provider that wrote a prescription, such as in the case of an on-call resident filling a discharge prescription but not billing related to the procedure, but may still capture the patterns of a surgical team with consistent personnel. We expected that this imperfect measure would generally make providers seem more similar to one another than they are in truth and bias results toward finding no association. However, the precise effect on results from these imperfect measures cannot be verified.

Conclusion

Although the opioid epidemic was created by a multitude of factors, none of which are uncomplicated, it is prudent to examine how alternative prescribing patterns may relate to the likelihood of future problems. Charged with treating their patients' pain and also protecting their future health, physicians need better guidance and resources that support more individualized planning for postoperative pain management. A better understanding of patient risk factors for developing opioid dependence and how this risk is modified by alternative prescribing practices can enable better screening and more actionable guidance for patient-centered prescribing, ultimately helping physicians to improve patient outcomes

and reduce complications, as well as reduce physicians' own cognitive burden.

Disclaimer

Data for this study were purchased with funding from the Center for Effectiveness Research in Orthopaedics (CERortho) at the University of South Carolina Arnold School of Public Health.

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

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2020.04.037.

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