J Shoulder Elbow Surg (2019) 28, 2225–2231

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

BASIC SCIENCE

Development of a clinical risk calculator for prolonged opioid use after shoulder surgery

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Background: Understanding risk factors associated with prolonged opioid use to help mitigate abuse and develop presurgical screening programs to identify at-risk patients is paramount. The purpose of this study was to develop and validate a clinical risk assessment tool to preoperatively predict prolonged opioid use after shoulder surgery.

Methods: A total of 561 patients who underwent shoulder surgery within a tertiary health care system were identified, and opioid prescription data were retrospectively collected from the Connecticut Prescription Monitoring and Reporting System. The inclusion criteria were patients aged 18 years or older, and the exclusion criteria were patients not registered in the Connecticut Prescription Monitoring and Reporting System. Quantities of opioids prescribed were documented. Demographic characteristics, surgery type, medications, and medical comorbidities were identified by chart abstraction. Logistic regression was used to calculate odds ratios of patients using opioids longer than 6 weeks, and multivariate analysis was performed on 10 identified patient factors. A concordance index was used to calculate the discriminatory ability of a nomogram to predict prolonged opioid use.

Results: Multivariate analysis demonstrated that opioid use prior to surgery, insurance type, procedure type, body mass index, smoking status, and psychiatric disorders were responsible for prolonged opioid use. The prediction accuracy of this model was good, with a calculated concordance index of 0.766 (95% confidence interval, 0.736-0.820).

Conclusions: We present a preoperative predictive calculator to help identify at-risk patients and quantify their risk of prolonged opioid use after shoulder surgery. This is a valuable clinical decision-making tool to identify patients benefitting from referral to pain management specialists and to possibly reduce the risk of opioid abuse and addiction.

Level of evidence: Basic Science Study; Development of Classification/Prediction Tool

Keywords: Prolonged opioid use; nomogram; clinical risk calculator; shoulder surgery; shoulder arthroplasty; rotator cuff; shoulder instability; proximal humerus fracture

Opioid addiction has become a crisis in the United States, with the Centers for Disease Control and Prevention reporting 33,091 US deaths in 2015 due to opioid overdose.[11] This statistic now outnumbers the deaths from both gunshot wounds and motor vehicle accidents. The US Department of Health & Human Services has reported that

This investigation was approved by the Yale University Human Investigation Committee (HIC protocol No. 1606018004).

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https://doi.org/10.1016/j.jse.2019.03.033

the mortality rate from opioid-related overdose is approximately 116 persons per day and that 75% of heroin users report misusing prescription opioids prior to starting heroin use.[4] Meanwhile, the economic burden resulting from nontherapeutic opioid use is estimated at over $50 billion owing to lost productivity and criminal justice costs.[5,9] These figures highlight the worsening epidemic associated with opioid prescriptions and the need for evaluating persons at risk of prolonged opioid use.

Orthopedic surgeons are the third highest prescribers of opioids among physicians in the United States.[9] Opioids can be an integral part of postsurgical pain control and are often used on a continual basis for patients with chronic pain. However, the side effects can be significant, including physical dependence, development of tolerance, respiratory depression, and death.[13] Understanding the risk factors associated with prolonged opioid use to help mitigate abuse and develop presurgical screening programs to identify at-risk patients is key.

Several studies have defined the factors responsible for prolonged opioid use. Patient factors such as lower household income; younger age; comorbidities including heart failure, pulmonary disease, and diabetes; and concurrent use of benzodiazepines, selective serotonin reuptake inhibitors, and angiotensin-converting enzyme inhibitors were associated with a higher risk of using opioids longer than 90 days after surgery.[3] Bartels et al[1] found that high in-hospital opioid use was predictive of prolonged use after discharge. Kim et al[6] found that opioid consumption after upper-extremity outpatient surgery was most strongly related to procedure type and anatomic location but was also significantly associated with anesthesia type, age, and insurance type.

Although previous work has identified risk factors for prolonged opioid use after shoulder surgery, this information has yet to be applied to the development of a multivariate predictive model. Such a model would allow for the preoperative identification of at-risk patients and pre-emptive referral to pain management specialists, providing counseling on appropriate opioid risk and use or prescribing an alternative non–opioid-based pain regimen altogether. The potential for this increased collaboration among surgeons, pain management specialists, and patients would help reduce the risk of prolonged opioid use, enhance shared decision making, and ultimately, improve patient safety by avoiding the detrimental effects of dependence and subsequent abuse.

The purpose of this study was to develop and validate a clinical risk assessment tool to preoperatively predict prolonged opioid use after shoulder surgery. Using information easily obtained before surgery, we developed a patient-facing nomogram for predicting the likelihood that a patient will need opioids for greater than 6 weeks after surgery. If accurate, such a clinical risk assessment tool could prove valuable in preoperatively planning a patient's perioperative opioid needs, managing patient expectations, and implementing an interdisciplinary opioid-sparing pain management regimen with pain management and anesthesia specialists.

Materials and methods

In this retrospective case-control study, patients aged 18 years or older who underwent shoulder surgery within a single tertiary health care system from January 2015 to February 2017 were identified by review of the institution's Current Procedural Terminology code database. The procedures consisted of shoulder replacement, stabilization surgery including labral repair, rotator cuff repair and reconstruction, and fracture repair (Supplementary Table S1). Multimodal analgesia was used at the discretion of the surgeon and included a standardized protocol consisting of general anesthesia supplemented with a peripheral nerve block, oral acetaminophen for 7 days after surgery (1000 mg by mouth every 8 hours), and oral oxycodone. The exclusion criteria were patients who were not registered on the Connecticut Prescription Monitoring and Reporting System (CPMRS) website, which consisted of 8 patients. A total of 561 patients met the criteria and were reviewed.

Opioid prescription data for these patients were downloaded from the CPMRS website (created on June 21, 2013). The cohort was subsequently separated into 2 groups: those who did not require opioid prescriptions more than 6 weeks after surgery and those who had continued their opioid prescriptions 6 weeks after surgery. The principal outcome of interest was an opioid prescription refill beyond 6 weeks after shoulder surgery. Preoperative opioid prescriptions were downloaded from the CPMRS for up to 3 years prior to the surgical date, in addition to all postoperative prescriptions from the time of surgery until the data collection date. Of the patients, 163 had a minimum 3-year presurgical opioid history in the database, whereas the remaining 398 patients had opioid prescription data ranging from 1.5 to 3 years prior to surgery. Quantities of opioids were documented, and oral morphine equivalents for opioid prescriptions were calculated using a morphine equivalent conversion factor per milligram.[7,8]

A review of the current literature was performed to identify a list of possible patient covariates responsible for prolonged opioid use, defined as greater than 6 weeks after surgery.[1,3,6,10,14] We used this list to collect demographic information such as age, sex, hand dominance, body mass index, and operative side, as well as insurance status, medical comorbidities, active medications, smoking, and drug use, from the institution's electronic medical record system (Epic Systems, Verona, WI, USA) (Supplementary Table S2). The data were abstracted and stored in REDCap (Research Electronic Data Capture, Nashville, TN, USA). Five of the study authors (A.D.N., H.F.K., J.L.S., N.P., and D.K.) then grouped the medical comorbidities as well as patient medications by system (cardiologic, genitourinary, and so on). Review of this distribution was carried out by the senior authors (T.A.B. and D.K.), and consensus agreement was reached. A total of 51 variables were identified for analysis.

Simple logistic regression was performed on the 51 identified variables to determine the odds ratios (ORs) of patients using opioids 6 weeks after shoulder surgery. Group comparisons were conducted using χ^2 tests for categorical variables and t tests for continuous variables. Statistical significance was set at $P < .05$ (2-sided). We selected 10 variables for inclusion in

Table I Demographic characteristics and prior opioid use

	Opioid use 6 weeks after surgery		Total (N = 548)
	Yes (n = 153)	No (n = 395)	
Age at time of surgery, yr			
Mean (SD)	55.6 (13.7)	51.9 (18)	52.9 (16.9)
Median (range)	57 (18-85)	54 (18-91)	55 (18-91)
Sex, n (%)			
Female	82 (53.6)	159 (40.3)	241 (44)
Male	71 (46.4)	236 (59.7)	307 (56)
BMI, n (%)			
<25	34 (22.2)	118 (29.9)	152 (27.7)
25-29	47 (30.7)	135 (34.2)	182 (33.2)
30-34	38 (24.9)	93 (23.5)	131 (23.9)
≥35	34 (22.2)	49 (12.4)	83 (15.2)
Prior opioid prescriptions in 3 yr prior to surgery, n (%)			
Yes	127 (83)	181 (45.8)	308 (56.2)
No	26 (17)	214 (54.2)	240 (43.8)
Oral morphine milligram equivalent for opioid prescriptions filled within 6 weeks of surgical date			
Mean (SD)	2483.2 (2857)	665.2 (534.1)	1172.8 (1772)
Median (range)	1425 (1-16,575)	645 (0-4350)	675 (0-16,575)
Oral morphine milligram equivalent for opioid prescriptions filled >6 weeks after surgical date			
Mean (SD)	11,105 (29,413)	0 (0)	3100.5 (16,287)
Median (range)	1162.5 (90-248,614.3)	0 (0)	0 (0-248,614.3)
Current smoker, n (%)			
Yes	28 (41.79)	39 (58.21)	67 (12.23)
No	124 (26.33)	347 (73.67)	471 (85.95)
Missing	1 (0.7)	9 (2.3)	10 (1.8)
Insurance status, n (%)			
Medicaid or Medicare	67 (43.8)	103 (26.1)	170 (31)
Workers' compensation	22 (14.4)	32 (8.1)	54 (9.9)
Private	64 (41.8)	260 (65.8)	324 (59.1)
Procedure type, n (%)			
Labral repair	13 (8.5)	85 (21.5)	98 (17.9)
Shoulder arthroplasty	38 (24.8)	83 (21)	121 (22.1)
Rotator cuff repair	85 (55.6)	190 (48.1)	275 (50.2)
Fracture repair	17 (11.1)	37 (9.4)	54 (9.8)
Hepatobiliary and intestinal disorders, n (%)			
Yes	68 (44.4)	117 (29.6)	185 (33.8)
No	85 (55.6)	278 (70.4)	363 (66.2)
Cardiopulmonary disease, n (%)			
Yes	59 (38.6)	97 (24.6)	156 (28.5)
No	94 (61.4)	298 (75.4)	392 (71.5)
Psychiatric disease, n (%)			
Yes	62 (40.5)	78 (19.7)	140 (25.6)
No	91 (59.5)	317 (80.3)	408 (74.4)
Neurologic disorder, n (%)			
Yes	46 (30.1)	69 (17.5)	115 (21)
No	107 (69.9)	326 (82.5)	433 (79)

SD, standard deviation; *BMI*, body mass index.

multivariate logistic regression analysis based on which variables independently had the significantly highest OR of prolonged opioid use after shoulder surgery. These 10 variables included demographic characteristics, medical comorbidities, active medications, insurance type, and surgical procedure performed. We performed multivariate analysis on 548 patients, with 13 patients excluded for not having data on insurance type.

The 10 identified variables were used for multivariate analysis to construct a prediction model for the probability of patients using opioids longer than 6 weeks after shoulder surgery. The

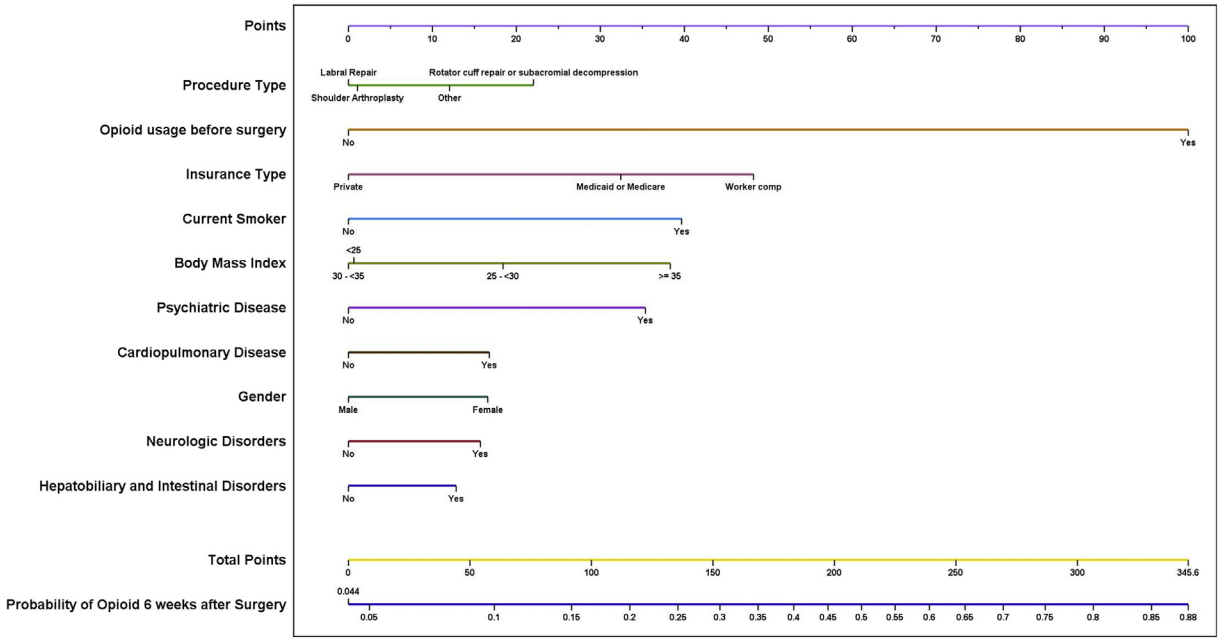

Figure 1 Prediction of prolonged opioid use after shoulder surgery. Opioid use prior to surgery exerts the most influential impact on the prediction of opioid use 6 weeks after shoulder surgery, followed by insurance type, body mass index, procedure type, psychiatric disorder, smoking status, cardiopulmonary disorder, neurologic disorder, sex, and hepatobiliary and intestinal disorder. The instructions for calculating probability are as follows: Locate the procedure type on the y-axis; then, draw a line directly upward to the ''Points'' axis to determine how many points toward the probability of opioid use longer than 6 weeks after surgery. Repeat this process for the remaining predictors. Add the points for all predictors, and locate the total point value on the ''Total Points'' axis; then, draw a line straight downward to find the patient's probability of postsurgical opioid use longer than 6 weeks. *comp*, compensation.

coefficients from the regression model were used to construct the nomogram using the methods described by Yang,[15] and a concordance index was used to calculate the discriminatory ability of the nomogram to predict prolonged opioid use. The nomogram was validated by the bootstrapping method, and a calibration plot was used to examine agreement between observed outcomes and predicted probability. Internal recalibration of the data set using the bootstrapping method was performed by resampling the data set with replacement 1000 times and running the model while fitting each of the 1000 data sets. Smoothed curves were generated using the original data set and the bias-corrected resampled data sets. All statistical analyses, predictive modeling, and creation of the nomogram were performed using SAS software (version 9.4; SAS Institute, Cary, NC, USA).

Results

A total of 548 patients were included in the analysis, including those who underwent rotator cuff repair (n = 275), shoulder replacement (n = 121), labral repair (n = 98), and fracture repair (n = 54). Patient demographic characteristics, predominance of perioperative opioid use, insurance type, and medical comorbidities are listed in Table I. Patients who did not use opioids longer than 6 weeks after shoulder surgery (395 of 548, 72%) used significantly less oral morphine equivalents within 6 weeks leading up to the surgery date than the prolonged–opioid use group (153 of 548, 28%) (665 mg vs. 2483 mg, $P < .001$).

ORs of prolonged opioid use by simple logistic regression and multivariate logistic regression analysis are shown in Supplementary Table S3. Nine factors were significantly associated with prolonged opioid use on simple logistic regression: history of opioid use prior to surgery (OR, 5.68; $P < .001$), psychiatric disease (OR, 2.72; $P < .001$), workers' compensation (OR, 2.68; $P = .002$), Medicaid or Medicare insurance status (OR, 2.64; $P < .001$), current smoker (OR, 2.13; $P = .01$), neurologic disorders (OR, 2.03; $P = .001$), cardiopulmonary disease (OR, 1.94; $P = .001$), hepatobiliary disease and intestinal disorders (OR, 1.93; $P < .001$), and female sex (OR, 1.68; $P = .01$). Four factors were significantly associated on multivariate analysis: history of opioid use (OR, 4.28; $P< .001$), workers' compensation (OR, 2.02; $P = .045$), psychiatric disease (OR, 1.67; $P = .03$), and Medicaid or Medicare (OR, 1.6; $P = .05$).

Figure 1 presents the prolonged–opioid use nomogram along with instructions for calculating the probability of opioid use 6 weeks after shoulder surgery. All 10 variables in the model had statistically significant P values ($P < .05$)

Table II Correlation of total points to estimated risk of prolonged opioid use

Points	Estimated % risk
0.0	4.4
50.0	8.8
100.0	16.6
150.0	29.1
200.0	45.9
250.0	63.7
300.0	78.4
345.6	87.6

for their independent contribution to the prediction. The relative contribution of each predictor can be observed in Figure 1 by noting the length of the variable axis. Prior opioid use before shoulder surgery, insurance type, smoking status, body mass index, and psychiatric disease have the potential for contributing the most points to the model. The "points" from each of the 10 predictors are added (Supplementary Table S4), and the total points are converted to an estimate of the probability of patients using opioids longer than 6 weeks (Table II).

The prediction accuracy of this model was good, with a calculated concordance index of 0.766 (95% confidence interval, 0.736-0.820). Figure 2 shows the calibration of the model by plotting the predicted probability of prolonged opioid used compared with the actual number of patients using opioids for greater than 6 weeks. For patients with an aggregated risk factor up to 40%, the prediction algorithm is accurate. At an aggregated risk factor greater than 40%, the current prediction model tends to overestimate the probability of prolonged opioid use in patients with multiple high-risk factors.

Discussion

We developed and validated a predictive nomogram to calculate the risk of prolonged opioid use after shoulder surgery with good accuracy. Opioid use prior to surgery and insurance type were the strongest factors in predicting continued opioid use 6 weeks after shoulder surgery. Although several studies have identified risk factors for prolonged opioid use, none have used these risk factors to calculate an estimated risk of prolonged opioid use to our knowledge.

We identified 10 risk factors significantly associated with prolonged opioid use after shoulder surgery and used these factors for multivariate analysis to construct a predictive nomogram. The value of the nomogram is in its ability to assign point values to each of the risk factors that are then added to estimate the overall risk of prolonged opioid use in this patient population. We believe this predictive nomogram is a practical clinical decision-making tool for identifying patients who are most at risk because it can be challenging to identify which patients are at risk of nontherapeutic or prolonged opioid use based on clinical judgment alone. Identifying these patients before surgery can assist in perioperative pain management planning and increase patient safety by reducing opioid abuse risk.

We found that patients with opioid use prior to shoulder surgery used significantly more opioids in the first 6 weeks postoperatively than patients without prior opioid use (2483-mg oral morphine equivalents vs. 665-mg oral morphine equivalents). By use of a 1.5:1 conversion ratio for oral morphine to oxycodone,[12] this is equivalent to the prolonged–opioid use group using eight 5-mg tablets of oxycodone per day in the first 6 weeks compared with two 5-mg tablets of oxycodone per day for the group not using opioids longer than 6 weeks.

Several studies have identified risk factors associated with prolonged postoperative opioid use. Using a Canadian population–based administrative database, Clarke et al[3] evaluated opioid use in 39,140 first-time users of opioids undergoing 1 of 9 elective major non-musculoskeletal surgical procedures such as coronary artery bypass graft

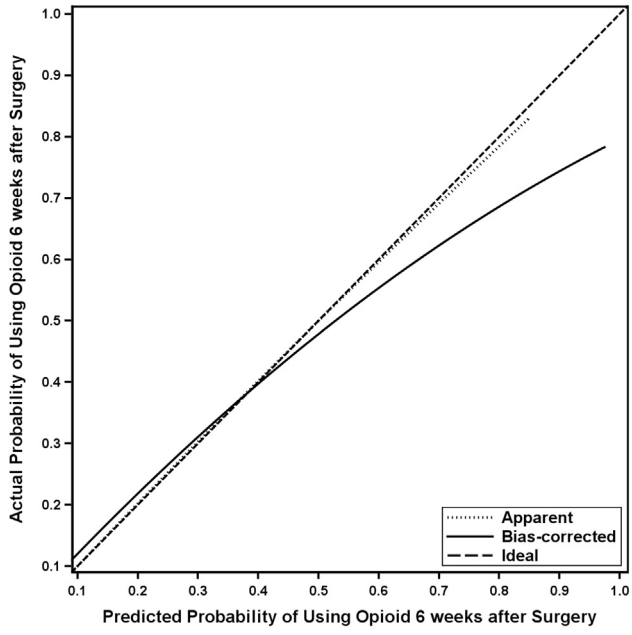

Figure 2 Validation of nomogram: calibration graph. The area under the curve from the receiver operative characteristic curve analysis is 0.766 with a 95% confidence interval of 0.736 to 0.820. A perfectly accurate nomogram would lie on the 45° line. For internal calibration, we resampled the data set with replacement 1000 times (bootstrapping) and ran model fitting on all those data sets. Smoothed curves between predicted and actual probability are generated using the original data set (apparent) and all resampled data sets (bias corrected). The calibration graph shows that the current prediction model overestimates prolonged opioid use in patients with multiple high-risk factors.

surgery or hysterectomy. They found that 49.2% of patients (n = 19,256) were discharged with a prescription for opioids and that 3.1% of opioid-naive patients continued to use opioids 90 days postoperatively. Factors identified as associated with prolonged use were younger age; lower household income; pulmonary disease; diabetes; heart failure; or medication use including benzodiazepines, selective serotonin reuptake inhibitors, and angiotensin-converting enzyme inhibitors. Their identified factors were similar to those identified in our study. The percentage of patients with prolonged opioid use in our study was significantly higher, likely because our primary endpoint was 6 weeks rather than 90 days. The United States consumes 80% of the global opioid supply, and prolonged opioid use may be higher in a United States population than a Canadian one.[2,6,9]

Rodgers et al[10] evaluated opioid use in 250 patients undergoing upper-extremity surgery performed by 5 private practice hand surgeons. Patients were grouped based on soft-tissue or bony procedures and body region. Patients were contacted 1 to 2 weeks after surgery for evaluation of pain, quantity of opioids remaining, alternative pain medications taken, and any reasons for not taking pain medications. Nearly all patients were given 30 tablets of narcotics, with 92% of patients reporting adequate pain control and 82% of patients no longer taking narcotics, with an average of 19 pills left unused. Patients who underwent bony procedures consumed more narcotics than those who underwent soft-tissue procedures (14 pills vs. 9 pills, $P = .010$). We found that patients undergoing soft-tissue shoulder stabilization procedures were less likely to have prolonged opioid use than those undergoing bony procedures such as shoulder arthroplasty but that those undergoing rotator cuff repair procedures were most likely to have prolonged opioid use.

Previous studies have shown that chronic pain and prior opioid exposure can make postoperative pain control more difficult, leading to increased opioid use postoperatively. Data derived from insurance claims databases were used by Waljee et al[14] to review opioid prescriptions given within a 6-week postoperative period in 296,452 patients who underwent hand surgery. They found that 58.5% of patients filled a prescription for opioids, with 4.5% receiving a refill. Patients previously exposed to opioids were more likely than opioid-naive patients to fill a postoperative opioid prescription (66% vs. 59%), receive longer prescriptions (24 days vs. 5 days), receive refills (24% vs. 5%), and have indicators of inappropriate use (19% vs. 6%). Our analysis similarly found prior opioid exposure to be a significant factor associated with higher odds of prolonged opioid use and greater opioid use within the immediate postoperative period.

Among the limitations of this study are the inclusion of only 10 risk factors in the prediction nomogram and the tendency of the model to overestimate prolonged opioid use in patients with a higher composite risk score. It is likely that inclusion of more risk factors in the nomogram could increase prediction accuracy at the expense of making the nomogram unwieldy and potentially impractical for clinical use. Another limitation is that not all patients had 3 years of opioid use data available from before surgery. The CPMRS website was created in 2013 and several of our patients underwent surgery in 2015, potentially limiting the accuracy of preoperative opioid use. A further limitation is that the study was retrospective in nature and could not track the actual number of narcotic medications patients used and when they used them. Rather, we relied on tracking refills and quantities of narcotic medications. It was also not possible to determine that opioid refill prescriptions were specifically for shoulder pathology, although patients using an opioid chronically for another pathology is certainly a risk factor for opioid use longer than 6 weeks after surgery. The fact that this prediction model tends to overestimate the probability of prolonged opioid use in patients with a composite risk score of 40% or greater may be seen as contributing to inaccuracy. However, patients with a score above this cutoff should be considered at high risk regardless, and as such, countermeasures should be in place to mitigate the possibility of dependence within this group anyway, which is the main function of the described tool.

Conclusion

A patient-facing preoperative clinical risk prediction calculator for prolonged opioid use after surgery benefits both patients and surgeons. We developed and validated a nomogram for preoperatively predicting which patients are at risk of prolonged opioid use after shoulder surgery. This nomogram helps identify at-risk patients, and similar risk prediction calculators can be developed for other surgical procedures based on this model. Early identification of patients at risk of prolonged perioperative opioid use allows for an educated conversation and shared decision making between patients and health care providers. This, in turn, empowers both patients and surgeons to tailor a clinical management strategy in consultation with pain management and anesthesia specialists that emphasizes prescribing of opioid-sparing medications and multimodal pain techniques. Such an interdisciplinary approach is preferred over the standardized restriction of opioids for patients undergoing surgery because it minimizes overprescribing of opioids while providing adequate analgesia and targeted interventions for patients with a higher likelihood of postoperative pain requiring treatment. Targeted interventions have the potential to reduce the risk of opioid abuse and addiction and subsequently increase patient safety during this public health epidemic.

Acknowledgments

The authors thank Geliang Gan, PhD, and Fangyong Li, MPH, for providing statistical support for this investigation.

Disclaimer

Funding for this work was made possible by the Yale Shoulder & Elbow Research Foundation.

Theodore A. Blaine owns stock or stock options in Catalyst Orthoscience, is a paid presenter or speaker for Tornier and Zimmer Biomet, serves as a paid consultant for Tornier and Zimmer Biomet, and serves on the editorial or governing board of *AAOS Now* and SAGE Publishing.

David Kovacevic is a committee member of the American Academy of Orthopaedic Surgeons, American Orthopaedic Association, and American Shoulder and Elbow Surgeons and serves on the editorial or governing board of the *Journal of Bone and Joint Surgery*.

The other 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.2019.03.033.

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