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Clinical Study

Comparing different chronic preoperative opioid use definitions on outcomes after spine surgery

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Abstract

BACKGROUND CONTEXT: No consensus exists for defining chronic preoperative opioid use. Most spine studies rely solely on opioid duration to stratify patients into preoperative risk categories.
PURPOSE: The purpose of this study is to compare established opioid definitions that contain both duration and dosage to opioid models that rely solely on duration, including the CDC Guideline for Prescribing Opioids for Chronic Pain, in patients undergoing spine surgery.
STUDY DESIGN: This was a retrospective cohort study that used opioid data from the Tennessee Controlled Substance Monitoring Database and prospective clinical data from a single-center academic spine registry.
PATIENT SAMPLE: The study cohort consisted of 2,373 patients who underwent elective spine surgery for degenerative conditions between January 2011 and February 2017 and who completed a follow-up assessment at 12 months after surgery.
OUTCOME MEASURES: Postoperative opioid use and patient-reported satisfaction (NASS Satisfaction Scale), disability (Oswestry/Neck Disability Index), and pain (Numeric Rating Scale) at 12 month follow-up.
METHODS: Six different chronic preoperative opioid use variables were created based on the number of times a prescription was filled and/or daily morphine milligram equivalent for the one year before surgery. These variables defined chronic opioid use as 1) most days for > 3 months (CDC), 2) continuous use for ≥ 6 months (Schoenfeld), 3) >4,500 mg for at least 9 months (Svendsen wide), 4) >9,000 mg for 12 months (Svendsen intermediary), 5) >18,000 mg for 12 months (Svendsen strict), 6) low-dose chronic (1-36 mg for >91 days), medium-dose chronic (36-120 mg for >91 days), and high-dose chronic (>120 mg for >91 days) (Edlund). Multivariable regression models yielding C-index and R^2 values were used to compare chronic preoperative opioid use definitions by postoperative outcomes, adjusting for type of surgery.
RESULTS: Chronic preoperative opioid use was reported in 470 to 725 (19.8% to 30.6%) patients, depending on definition. The Edlund definition, accounting for duration and dosage, had the highest predictive ability for postoperative opioid use (77.5%), followed by Schoenfeld (75.7%), CDC (72.6%), and Svendsen (59.9% to 72.5%) definitions. A combined Edlund and Schoenfeld duration and dosage definition in post-hoc analysis, that included 3 and 6 month duration cut-offs, performed the best overall with a C-index of 78.4%. Both Edlund and Schoenfeld definitions explained similar amounts of variance in satisfaction, disability, and pain (4.2% to 8.5%). Svendsen and CDC definitions demonstrated poorer performance for patient-reported outcomes (1.4% to 7.2%).

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CONCLUSIONS: The Edlund definition is recommended for identifying patients at highest risk for postoperative opioid use. When opioid dosage is unavailable, the Schoenfeld definition is a reasonable choice with similar predictive ability. For patient-reported outcomes, either the Edlund or Schoenfeld definition is recommended. Future work should consider combing dosage and duration, with 3 and 6 month cutoffs, into chronic opioid use definitions.

Key Words: Opioid use; Chronic pain; Spine surgery; Spinal disorders

Over-prescription of opioids for pain relief has contributed to a widespread opioid epidemic within the United States [1-6]. Opioid expenditures for spine-related pain has increased by 660% from 1997-2006 [7], with opioid prescriptions doubling in patients with chronic back pain [8]. Current literature estimates up to 60% of patients with spine pain are exposed to opioids prior to surgery [9,10]. Preoperative opioid use is an important risk factor for postsurgical pain and disability and prolonged opioid dependence in patients following spine surgery [2,3,9-15].

No consensus exists in the literature for defining chronic preoperative opioid use. Dunn et al. [16] defined chronic opioid use based on a single opioid prescription prior to spine surgery. The 2016 CDC Guideline for Prescribing Opioids for Chronic Pain [17,18], defining chronic opioid therapy as most days for greater than 3 months, has also been used to classify opioid use in spine surgery populations [9,19-22]. While the CDC Guideline was developed for primary care physicians, providers have found the cut-off of 90 days to be relevant to opioid use in other clinical settings [23,24]. In addition, some studies have required continuous use of preoperative opioids for at least 6 months [9,15,25,26] or one year [14]. A more robust chronic preoperative opioid definition, with 4-levels that includes a 6 month cut-off, was proposed by Schoenfeld et al. for spine surgery [9]. However, a limitation of these preoperative classification methods is the reliance solely on opioid duration.

The chronic pain literature has reported on persistent or chronic opioid use models that account for both opioid duration and dosage. Svendsen et al. [27] created three chronic opioid use definitions, analyzing intensity, frequency, and distribution of opioids based on data from a prescription database, while Edlund et al. [28] developed a more nuanced 7-category model based on claims data that included opioid days supply and average daily opioid dose for patients with chronic non-cancer pain. These models may be relevant to surgical populations, since an opioid categorization scheme that contains both opioid duration and dosage may improve risk stratification and subsequently postoperative outcomes in patients undergoing spine surgery.

The objective of the current study was to compare chronic opioid use definitions that contain both duration and dosage (Svendsen [27] and Edlund [28]) to models that rely solely on duration (CDC [17] and Schoenfeld [9]) in patients undergoing spine surgery. We hypothesized that a preoperative definition accounting for both opioid duration and dosage would be the best predictor of increased postoperative opioid use and patient-reported outcomes. By identifying the most robust chronic preoperative opioid use model, we hope to improve the clinical utility of predictive models and the decision-making process for opioid management.

Materials and Methods

Study Design and Patient Population

Patients undergoing elective surgery for lumbar or cervical degenerative spine conditions at a single-academic center were enrolled in a prospective, longitudinal registry. This registry collects demographic and clinical characteristics as well as preoperative disability, pain, and quality of life from medical record review and interviews. Patients complete postoperative follow-up questionnaires in-person, through phone interviews, or by survey. Inclusion criteria are English-speaking patients, older than 18 years, who are willing to participate in the registry. Patients having surgery for tumor, infection, or trauma are excluded from the registry. The registry is approved by the institutional review board and all patients provide informed consent. For the current study, we included registry participants with surgery between January 6, 2011 and February 27, 2017 who had complete 12-month patient-reported follow-up data. Data were entered into a web-based, Research Electronic Data Capture (REDCap) management system [29].

Preoperative Opioid Use

The Tennessee Controlled Substance Monitoring Database (CSMD) [30] was queried to obtain prescription data from one year before surgery to one year after surgery. For each opioid prescription, we collected the date the prescription was filled, duration of prescription and daily morphine milligram equivalent. These opioid data were used to create six chronic preoperative opioid use variables based on the definitions provided by CDC, Schoenfeld et al., Svendsen et al., and Edlund et al. (Table 1) [9,17,27,28].

The first chronic opioid use variable was based on the CDC Guideline for Prescribing Opioids for Chronic Pain, which defines chronic opioid therapy as most days for greater than 3 months [17,18]. The second variable was from work by Schoenfeld et al. [9] and the preoperative

Table 1
Chronic Preoperative Opioid Use Variables Based on Established Definitions (N = 2,373)

Duration Definitions		Duration and Dosage Definitions			
CDC Guideline, No. (%)	Schoenfeld et al., No. (%)	Svendsen et al. Wide, No. (%)	Svendsen et al. Intermediary, No. (%)	Svendsen et al. Strict, No. (%)	Edlund et al., No. (%)
Non-chronic, 1,682 (70.9%)	No opioid use, 513 (21.6%)	Non-chronic, 1,849 (77.9%)	Non-chronic, 2,028 (85.5%)	Non-chronic, 2,179 (91.8%)	No opioid use, 513 (21.6%)
Chronic (most days for > 3 months), 691 (29.1%)	Acute (first prescription < 30 days prior to surgery), 113 (4.8%)	Wide (> 4500 mg; at least 9 months), 524 (22.1%)	Intermediary (> 9000 mg for 12 months), 345 (14.5%)	Strict (> 18000 mg for 12 months, at least 10 prescriptions), 194 (8.2%)	Low-dose, acute (1-90 days, 1-36 mg), 731 (30.8%)
	Exposed (receipt of opioids in 12 months before surgery, non-continuous use), 1,277 (53.8%)				Medium-dose, acute (1-90 days, 36-120 mg), 393 (16.6%)
	Intermediate Sustained (continuous use for < 6 months), 178 (7.5%)				High-dose, acute (1-90 days, >120 mg), 11 (0.5%)
	Chronic Sustained (continuous use for ≥ 6 months), 292 (12.3%)				Low-dose, chronic (> 91 days, 1-36 mg), 310 (13.1%)
					Medium-dose, chronic (> 91 days, 36-120 mg), 299 (12.6%)
					High-dose, chronic, (> 91 days, >120 mg), 116 (4.9%)

mg = milligrams of morphine equivalents. Empty cells are present because the six variables for comparison have different number of levels.

opioid use levels were no opioid use, acute (< 30 days), exposed (non-continuous use for 12 months), intermediate sustained (continuous use for < 6 months), and chronic sustained (continuous use for ≥ 6 months). The third, fourth, and fifth variables were based on a prescription database definition from Svendsen et al. [27] that defined persistent opioid use with three nested definitions: wide chronic user (> 4500 mg for at least 9 months), intermediate chronic user (> 9000 mg for 12 months), and strict chronic user (> 18000 mg for 12 months, ≥ 10 prescriptions). Finally, we used a 7-category definition from Edlund et al. [28] that described prescribed opioid use in patients with chronic non-cancer pain, based on duration (0 days, 1-90 days, or > 90 days) and dosage (0 mg, 1-36 mg, 36-120 mg, > 120 mg).

Outcomes

The outcomes for this study were postoperative opioid use and satisfaction, disability, and axial and extremity pain at 12 months after surgery. CSMD [30] opioid data from hospital discharge to one year after surgery were used to determine the percentage of patients with an opioid prescription each day during the postoperative year. Postoperative opioid use was also defined as a dichotomous outcome (yes/no) at 12 months after surgery based on whether the patient had an active prescription. Satisfaction was assessed with the 4-point NASS Satisfaction scale [31]. Low back and neck disability were assessed with the Oswestry Disability Index (ODI) and the Neck Disability Index (NDI) [32-36]. Extremity (leg/arm) and axial (back/neck) pain were assessed with an 11-point Numeric Rating Scale (NRS) [37-40], with responses ranging from 0 points, being no pain, to 10 points, being the worst pain imaginable.

Statistical Analysis

Descriptive statistics were used to report the distribution of patient and clinical characteristics (i.e., age, gender, race, body mass index (BMI), smoking status, surgical approach, revision, and American Society of Anesthesiologists (ASA) classification) for the entire cohort and for postoperative opioid use by the six chronic preoperative opioid use definitions. GEE logistic regression analyses were used to predict opioid use on a daily basis for 365 days after surgery for each preoperative opioid use definition. Multivariable regression models, adjusting for lumbar or cervical surgery, compared the six chronic preoperative opioid use definitions for the outcomes of postoperative opioid use, satisfaction, disability and pain at 12 month follow-up. The concordance statistic (C-index) or R-squared value was calculated to examine the predictive ability of each chronic preoperative opioid use definition. Post-hoc analysis was conducted with a seventh chronic preoperative opioid use definition based on a combination of the Edlund and Schoenfeld categories. This combined variable had the following levels: no opioid use, acute (1-90 days), low-dose

intermediate (1-36 mg, 91 days to 6 months), medium-dose intermediate (36-120 mg, 91 days to 6 months), low-dose chronic (1-36 mg, ≥ 6 months), medium-dose chronic (36-120 mg, ≥ 6 months), and high-dose chronic (>120 mg, ≥ 6 months). We were unable to include a high-dose, intermediate level due to small sample size (n=4). Significance was defined a priori as $p < .05$. All statistical analyses were performed using SPSS V. 25.0.

Results

Patient Demographics

A total of 4,469 patients had elective surgery for degenerative conditions between January 6, 2011 and February 27, 2017, consented to allow data to be used for research, and were entered into our registry. Out of 4,469 registry participants, 3,506 (78%) had 12 month patient-reported data available and 2,373 (53%) had preoperative and postoperative opioid data in the CSMD as well as complete 12-month follow-up data from the registry. Due to the large sample size, effect size differences were used to evaluate differences between the full registry cohort (4,469) and analysis data (2,373) on baseline demographic and clinical characteristics. No differences were found when using d = .20 or Cramer's V = .10 as a cutoff. Any significant differences with effect sizes less than d = .20 or Cramer's V = .10 are considered not meaningful [41].

Sixty-nine percent of patients had lumbar surgery, while 31% were scheduled for cervical surgery. The mean age [SD] of the analysis cohort was 58 [12.9] years, 50.6% were female, and 87% were White. The mean [SD] body mass index was 30.7 [6.9] and 19% reported being a current smoker prior to surgery. For surgery procedures, 238 (10%) had a lumbar microdiscectomy, 445 (18.8%) lumbar laminectomy, 921 (38.8%) lumbar fusion with or without laminectomy, 473 (19.9%) anterior cervical discectomy and fusion, 225 (9.5%) posterior cervical laminectomy with or without fusion, and 71 (3%) anterior and posterior cervical or lumbar 2 stage. Twenty-six percent of patients underwent a revision procedure. For the ASA classification, 31% were grade 1 and 2 and 69% were grade 3 and 4.

Preoperative Opioid Use

Out of 2,373 patients, 513 (21.6%) had no opioid prescriptions prior to surgery. The adapted CDC Guideline demonstrated that 691 (29.1%) were defined as chronic opioid users (Table 1). Twenty two percent were identified as having chronic opioid use based on Svendsen's wide definition and 19.8% were sustained opioid users (intermediate and chronic combined) from Schoenfeld's classification. Edlund's definition identified 30.6% of patients as chronic opioid users prior to surgery.

Postoperative Opioid Use

Patients with chronic preoperative opioid use compared to non-chronic or no opioid users were more likely to have high postoperative opioid use after surgery (Figures 1A-F). For patients with chronic preoperative opioid use based on CDC definition, a median 70.1% (IQR, 28.0-90.1) of patients filled opioid prescriptions over the year following spine surgery (Figure 1A). Svendsen's wide and Edlund's medium-dose, chronic classifications had similar rates of postoperative opioid use, with a median 80.0% (IQR, 46.1-92.3) and 77.3% (IQR, 35.6-93.2), respectively, of patients filling prescriptions. Svendsen's intermediary (86.3%; IQR, 65.9-95.3) and strict (89.0%; IQR, 73.4-95.9), Schoenfeld's chronic sustained (88.0%; IQR, 72.5-95.8) and Edlund's high-dose, chronic (88.8%; IQR, 70.3-95.6) captured the highest percentage of patients using opioids after surgery. GEE models revealed significant differences between non-chronic or no opioid use and all other categories, except when comparing Schoenfeld's acute (< 30 days) to no opioid use (Figure 1E). No differences in postoperative opioid use were found between Edlund's low-dose, medium-dose, and high-dose, acute groups. However, significant differences in postoperative opioid use were noted between Schoenfeld's exposed, intermediate and chronic sustained groups (Figure 1E) and between Edlund's low-dose, medium-dose, and high-dose, chronic groups (Figure 1F).

Out of the 513 patients who had no opioid prescriptions prior to surgery, 8 (1.6%) patients had an active opioid prescription and reported using opioids at 12 months after surgery (Table 2). In addition, 40.1% and 65.1% of patients who were identified as chronic users prior to surgery based on CDC and Schoenfeld et al. definition, respectively, were also using opioids at 12 months after surgery. For high-dose chronic preoperative opioid users (Edlund et al. definition), 62.9% of these patients had an active opioid prescription at 12 months after surgery. Overall, chronic postoperative opioid use was noted in 40.1% to 65.5% of chronic preoperative opioid users, depending on definition.

The logistic regression models for 12-month postoperative opioid use, controlling for lumbar or cervical surgery, found the highest odds ratio (OR) for Edlund's high-dose, chronic group (OR, 52.52; 95% CI, 29.10-94.78; p<.001) and Schoenfeld's chronic sustained group (OR, 55.29; 95% CI, 35.64-85.76; p<.001) compared to no opioid use (Table 3). The lowest OR for the chronic preoperative opioid use categories was found for CDC guideline (OR, 9.71; 95% CI, 7.93-11.89; p<.001) and Svendsen's wide (OR, 15.18; 95% CI, 11.95-19.3; p<.001) compared to non-chronic users. The Edlund and Schoenfeld definitions overall had the best predictive ability for the postoperative opioid use outcome (77.5% and 75.7%, respectively; Table 4). The lowest C-index value was for Svendsen's strict definition. Post-hoc analysis, combining Edlund and Schoenfeld definitions, found significant differences across all 7-levels

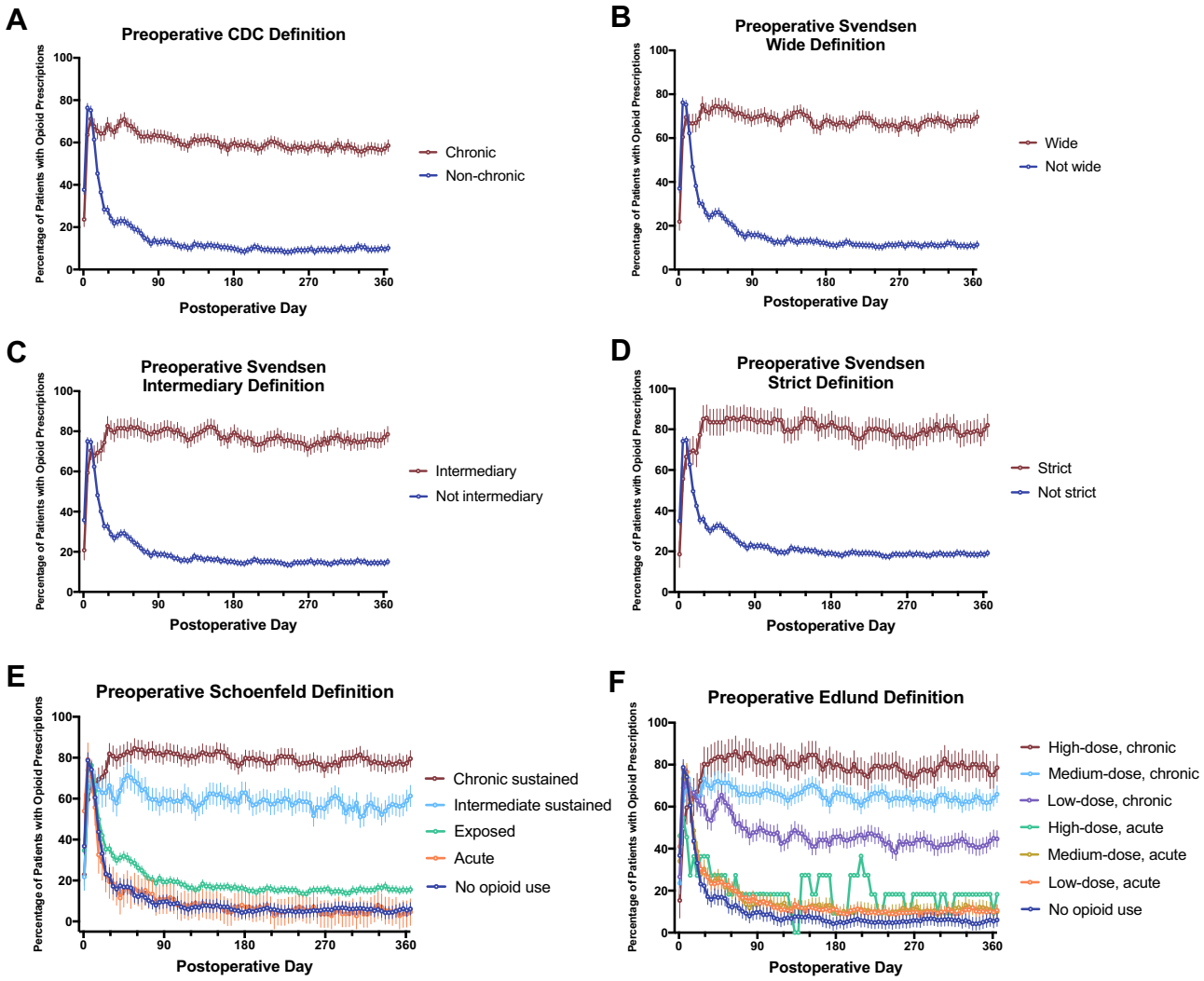

Figure 1. Percentage of Patients with Opioid Prescriptions in the Postoperative Year
Percentage of population with an opioid prescription by definition level reported with 95% confidence intervals for everyday of the postoperative year.

(Figure 2). The C-Index for predicting postoperative opioid use for the combined definition was higher (78.4%) than the other six, *a priori* models, with an OR of 63.09 for the high-dose, chronic group (95% CI, 33.59-118.49; p<.001) compared to no opioid use (Figure 2).

Patient-Reported Outcomes

The strongest association between preoperative chronic opioid use and 12-month satisfaction (OR, 3.20; 95% CI, 2.02-5.08) and disability (β, 15.34; 95% CI, 11.93-18.41) was for Edlund's high-dose chronic group compared to no opioid use (p<.001; Table 3). For 12-month axial and extremity pain, patients in Schoenfeld's chronic sustained use group had the highest β, with pain scores 1.93-points higher (95% CI, 1.53-2.33 and 1.49-2.38; p<.001) than patients with no opioid use. The Edlund and Schoenfeld definitions had the best predictive ability for postoperative satisfaction (58.5%) and explained the most variance in patient-reported disability and pain at 12-month follow-up (Table 4). The lowest C-index and R^2 values for all patent-reported outcomes was for Svendsen's strict definition.

Discussion

This retrospective analysis compared the performance of six definitions of chronic preoperative opioid use in 2,373 patients undergoing elective spine surgery for degenerative conditions. Results demonstrated that between 19.8% and 30.6% of patients were chronic opioid users prior to spine surgery, depending on definition. Five hundred and thirteen patients (21.6%) had no opioid prescription prior to surgery. In addition, patients with chronic preoperative opioid use were more likely to have high postoperative opioid use. Median rates were as high as 70.1% to 88.8% during the first postoperative year and 40.1% to 65.5% continued to have an active opioid prescription at 12 months after

Table 2
Postoperative Opioid Use at 12 Months By Chronic Preoperative Opioid Use (N = 2,373)

Chronic preoperative opioid use definition	Postoperative opioid use at 12 months		
	N (%)		
	No	Yes	Total
CDC Guideline			
Non-chronic	1643 (97.7)	39 (2.3)	1682
Chronic (most days for > 3 months)	414 (59.9)	277 (40.1)	691
Schoenfeld et al.			
No opioid use	505 (98.4)	8 (1.6)	513
Acute	113 (100.0)	0 (0.0)	113
Exposed	1217 (95.3)	60 (4.7)	1277
Intermediate sustained	120 (67.4)	58 (32.6)	178
Chronic sustained	102 (34.9)	190 (65.1)	292
Svendsen et al.: Wide			
Non-chronic	1788 (96.7)	61 (3.3)	1849
Wide	269 (51.3)	255 (48.7)	524
Svendsen et al.: Intermediary			
Non-chronic	1918 (94.6)	110 (5.4)	2028
Intermediary	139 (40.3)	206 (59.7)	345
Svendsen et al.: Strict			
Non-chronic	1990 (91.3)	189 (8.7)	2179
Strict	67 (34.5)	127 (65.5)	194
Edlund et al.			
No opioid use	505 (98.4)	8 (1.6)	513
Low-dose, acute	715 (97.8)	16 (2.2)	731
Medium-dose, acute	379 (96.4)	14 (3.6)	393
High-dose, acute	10 (90.9)	1 (9.1)	11
Low-dose, chronic	246 (79.4)	64 (20.6)	310
Medium-dose, chronic	159 (53.2)	140 (46.8)	299
High-dose, chronic	43 (37.1)	73 (62.9)	116

Row percentages sum to 100%.

surgery, depending on chronic preoperative opioid use definition.

The Edlund definition, based on claims data from patients with chronic non-cancer pain, performed the best for predicting postoperative opioid use. For satisfaction, disability and pain, Edlund and Schoenfeld definitions had similar performance. Findings highlight the importance of opioid dosage and continuous opioid use greater than 6 months when considering opioid management efforts, which is supported by our post-hoc analysis combining the Edlund and Schoenfeld models.

The prevalence of chronic preoperative opioid use found in this study is consistent with published literature demonstrating that 20% of patients are opioid dependent at the time of spine surgery [25,26,42]. It is important to make a distinction between chronic opioid use and opioid exposure (i.e., yes/no use). Seventy-eight percent of our patients were exposed to opioids preoperatively. The percentage of patients presenting for spine surgery with any preoperative opioid use has risen across time, from 52% in a 2008 study [13] and 55% in a 2013 study [10], to 60% in a 2018 study [9]. Tennessee was ranked in the top three states in the country, between 2010 and 2016, with the highest number of retail opioid prescriptions dispensed per 100 persons [43-49], which may explain the discrepancy in opioid exposure between our study and earlier work. This inconsistency may also be due to rapid increases in opioid use in the last several years, paralleled by rising opioid expenditures for spine related pain [7,8,50,51].

Across all definitions, chronic preoperative opioid use was a significant risk factor for continued postoperative opioid dependency, with a median 70.1% to 88.8% of preoperative chronic opioid users filling opioid prescriptions across the postoperative year. This finding is supported by the literature, with Jain et al. [26] and Deyo et al. [15] reporting that 87.4% and 77.1% of chronic preoperative opioid users continued long-term opioid use postoperatively [26]. These data highlight the importance of managing opioid use both before and after spine surgery.

Patient-reported outcomes, such as pain and disability, are multifactorial outcomes, influenced by a wide array of preoperative clinical characteristics including employment status, psychological distress, education and smoking status [52-60]. Our findings demonstrate that chronic preoperative opioid use is also associated with decreased satisfaction and increased pain and disability at 12-month follow-up. A retrospective analysis in 2017 found that preoperative opioid use was correlated with increased disability and pain a year after transforaminal lumbar interbody fusion [11]. Lee et al. observed increased ODI/NDI scores at 12-months

Table 3
Multivariable Regression Analysis of Outcomes at Twelve Months by Chronic Preoperative Opioid Use Definitions

Definition Source	Definition Levels	Postoperative Opioid Use (OR, 95% CI)	Satisfaction (OR, 95% CI)	ODI/NDI (β, 95% CI)	Axial Pain (β, 95% CI)	Extremity Pain (β, 95% CI)
CDC Guideline	Chronic (most days for > 3 months)	9.71 (7.93 to 11.89)	2.03 (1.63 to 2.54)	8.62 (7.11 to 10.14)	1.13 (0.88 to 1.38)	1.31 (1.04 to 1.59)
Schoenfeld et al.	Acute (first prescription < 30 days prior to surgery)	1.06 (0.55 to 2.07)	0.57 (0.27 to 1.18)	-8.44 (-11.81 to -5.06)	-0.11 (-0.67 to 0.45)	-0.36 (-0.99 to 0.26)
	Exposed (receipt of opioids in 12 months before surgery, non-continuous use)	3.35 (2.45 to 4.59)	1.14 (0.85 to 1.53)	1.59 (-0.11 to 3.30)	0.48 (0.20 to 0.76)	0.59 (0.27 to 0.90)
	Intermediate Sustained (continuous use for < 6 months)	21.23 (13.78 to 32.72)	2.05 (1.33 to 3.15)	11.69 (8.84 to 14.55)	1.62 (1.15 to 2.10)	1.66 (1.14 to 2.19)
	Chronic Sustained (continuous use for ≥ 6 months)	55.29 (35.64 to 85.76)	2.72 (1.91 to 3.89)	11.92 (9.49 to 14.35)	1.93 (1.53 to 2.33)	1.93 (1.49 to 2.38)
Svendsen et al.	Chronic Wide (> 4500 mg for at least 9 months)	15.18 (11.95 to 19.30)	1.95 (1.54 to 2.47)	10.38 (8.73 to 12.03)	1.20 (0.92 to 1.47)	1.13 (0.82 to 1.44)
Svendsen et al.	Chronic Intermediary (> 9000 mg for 12 months)	17.26 (12.66 to 23.53)	2.53 (1.95 to 3.28)	11.63 (9.69 to 13.56)	1.53 (1.21 to 1.85)	1.44 (1.09 to 1.80)
Svendsen et al.	Chronic Strict (> 18000 mg for 12 months, at least 10 prescriptions)	16.41 (10.74 to 25.07)	2.65 (1.92 to 3.65)	11.76 (9.27 to 14.26)	1.45 (1.04 to 1.86)	1.34 (0.89 to 1.80)
Edlund et al.	Low-dose, acute (1-90 days, 1-36 mg)	2.24 (1.59 to 3.15)	1.02 (0.73 to 1.42)	0.24 (-1.64 to 2.12)	0.23 (-0.08 to 0.54)	0.34 (-0.01 to 0.68)
	Medium-dose, acute (1-90 days, 36-120 mg)	2.45 (1.68 to 3.58)	0.97 (0.66 to 1.43)	-0.96 (-3.14 to 1.21)	0.45 (0.09 to 0.81)	0.29 (-0.11 to 0.70)
	High-dose, acute (1-90 days, >120 mg)	2.00 (0.42 to 9.53)	0.70 (0.09 to 5.60)	-0.25 (-10.04 to 9.54)	1.43 (-0.20 to 3.06)	0.73 (-1.09 to 2.55)
	Low-dose, chronic (> 91 days, 1-36 mg)	12.65 (8.76 to 18.26)	1.77 (1.22 to 2.56)	8.17 (5.82 to 10.52)	1.26 (0.86 to 1.65)	1.51 (1.07 to 1.94)
	Medium-dose, chronic (> 91 days, 36-120 mg)	26.51 (17.97 to 39.13)	2.11 (1.46 to 3.04)	10.09 (7.66 to12.51)	1.66 (1.26 to 2.06)	1.75 (1.31 to 2.19)
	High-dose, chronic (> 91 days, >120 mg)	52.52 (29.10 to 94.78)	3.20 (2.02 to 5.08)	15.34 (11.93 to 18.74)	1.91 (1.35 to 2.47)	1.83 (1.22 to 2.45)

Odds ratio (OR) reported for dichotomous outcome; unstandardized betas reported for continuous outcomes. CDC definition analysis controlled for non-chronic use; Svendsen wide definition analysis controlled for non-wide opioid use; Svendsen intermediary definition analysis controlled for non-intermediary opioid use; Svendsen chronic definition analysis controlled for non-strict opioid use; Schoenfeld definition analysis controlled for no opioid use; Edlund definition analysis controlled for no opioid use.

Table 4
Predictive Ability of Outcomes 12 Months After Surgery by Chronic Preoperative Opioid Use Definition

Chronic Preoperative Opioid Use Definition	C Index		R^2		
	Postoperative Opioid Use	Satisfaction	ODI/NDI	Axial Pain	Extremity Pain
CDC Guideline	72.6%	57.2%	3.9%	2.8%	3.3%
Svendsen Wide	72.5%	55.9%	4.8%	2.6%	3.5%
Svendsen Intermediary	66.9%	56.6%	2.4%	3.1%	2.6%
Svendsen Strict	59.9%	54.3%	2.7%	1.7%	1.4%
Schoenfeld	75.7%	58.5%	6.4%	4.3%	4.2%
Edlund	77.5%	58.5%	5.9%	4.3%	4.5%

All models adjusted for lumbar or cervical surgery and ODI/NDI and pain models adjusted for baseline scores. Percentages for C-index and R^2 represent predictive ability or variance explained, respectively, by the definition variables beyond adjusted outcomes.

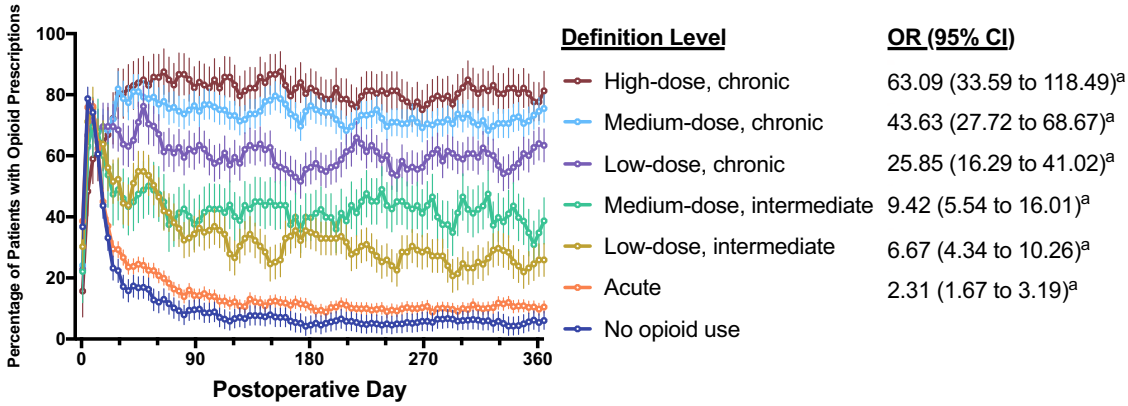

Figure 2. Preoperative Edlund-Schoenfeld Combined Model

Percentage of population with an opioid prescription by definition level reported with 95% confidence intervals for everyday of the postoperative year. Logistic regression model used for dichotomous opioid use outcome. Odds ratio (OR) reported for 12-month yes/no opioid use. Analysis controlled for no opioid use. [a]Denotes p<.001.

after spine surgery among preoperative opioid users ($\beta = 0.05$; 95% CI 0.02-0.09) [12]. Our beta coefficients for chronic opioid use and disability ranged from 8.62 to 15.34, which suggest that a yes/no assessment of opioid use in the week before surgery, as used in prior studies [11,12], may not be sufficient to identify patients at highest risk for poor patient-reported outcomes.

Our hypothesis that a preoperative model accounting for both opioid duration and dosage would be the best performing model was partially supported. Findings suggest that the Edlund model is the best predictor of postoperative opioid use. However, the Edlund and Schoenfeld models explained similar variance in patient-reported outcomes. When preoperative opioid dosage information is not available to clinicians, utilizing duration cutoffs proposed by Schoenfeld (i.e., < 6 months or ≥ 6 months) appears to be a reasonable option for capturing patients at highest risk for poor outcomes. This 6-month cut-off is supported by our post-hoc model results as well as recent spine studies [13,15,21,25,26], and work in the chronic pain literature [61-64].

Opioid dosage was found to differentiate patients by postoperative opioid use when combined with opioid duration cutoffs of 3 months and 6 months. This finding is supported by chronic pain studies that found high opioid dosage to be a risk factor for long-term opioid therapy [65-70]. Opioid dosage can provide crucial information on the optimal course for treatment [71-77]; however, literature on preoperative opioid management programs for patients undergoing spine surgery is limited. A 5-participant case series assessed a biopsychosocial tapering program (6-7 weeks) for preoperative opioid use and found improvement in preoperative and postoperative pain, depression, anxiety, and fatigue [73]. However, preoperative dosage was not considered and weaning for 6-7 weeks may not be enough for patients identified as high-dose, chronic opioid users in light of the 10% opioid dosage reduction per week paradigm [72,75,78,79].

Findings should be interpreted in light of the study's limitations. This was a retrospective analysis of patients from a single-center, which limits generalizability of study findings. We relied on an electronic, statewide database for opioid prescriptions and it is possible that patients did not take opioids as prescribed or filled additional opioid prescriptions out of state. Finally, only eleven patients were captured by the high-dose, acute opioid use group of the Edlund definition, which limits the interpretation of this category.

Conclusions

Results demonstrated that 19.8% to 30.6% of patients were chronic opioid users prior to spine surgery; postoperative opioid use rates in these patients ranged from 70.1% to 88.8% during the first year after surgery and 40.1% to 65.5% continued to have an active opioid prescription at 12 months after surgery. The Edlund chronic opioid use definition had the highest predictive ability for postoperative opioid use, while the Edlund and Schoenfeld models explained similar variance in patient-reported satisfaction, disability and pain. The Schoenfeld model is sufficient for identifying high-risk patients based on chronic opioid duration (≥ 6 months) when opioid dosage is unavailable. We recommend the Edlund definition when considering preoperative opioid management efforts, since chronic preoperative opioid users may require different tapering timelines based on opioid dosage. Additional work is needed to better understand the combined role of opioid dosage and duration for risk stratification and preoperative opioid management.

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