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Impact of preoperative insomnia on poor postoperative pain control after elective spine surgery and the modified Calgary postoperative pain after spine surgery (MCAPPS) score

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ABSTRACT

Background: Approximately 30% to 64% of patients experience inadequate pain control following spine surgery. The Calgary postoperative pain after spine surgery (CAPPS) score was developed to identify this subset of patients. The impact of preoperative insomnia on postoperative pain control is unknown. This study aimed to investigate the relationship between preoperative insomnia and poor pain control after spine surgery, as well as improve the predictive accuracy of the CAPPS score.

Methods: A prospective cohort study was conducted in patients undergoing elective spine surgery. Poor pain control was defined as a mean numeric rating scale pain score >4 at rest within the first 24-hours after surgery. Patients were evaluated using the CAPPS score, which included 7 prognostic factors. A multivariable logistic regression model was used to examine the association between preoperative insomnia severity index (ISI) and poor pain control, adjusting for the CAPPS score. The Modified CAPPS score was derived from this model.

Results: Of 219 patients, 49.7% experienced poorly controlled pain. Prevalence of clinical insomnia (ISI≥15) was 26.9%. Preoperative ISI was independently associated with poor pain control (odds ratio [OR] 1.09, [95%CI=1.03–1.16], p=.004), after adjusting for the CAPPS score (OR 1.61, [95%CI=1.38–1.89], p<.001). The model exhibited good discrimination (c-statistics 0.80, [95%CI=0.74–0.86]) and calibration (Hosmer-Lemeshow chi-square=8.95, p=.35). The Modified CAPPS score also demonstrated good discrimination (c-statistic 0.78, [95%CI=0.72–0.84]) and calibration (Hosmer-Lemeshow chi-square=2.92, p=.57). Low-, high-, and extreme-risk groups stratified by the Modified CAPPS score had 17.3%, 49.1%, and 80.7% predicted probability of experiencing inadequate pain control compared to 32.0%, 64.0%, and 85.1% in the CAPPS score.

Conclusions: Preoperative insomnia is prevalent and is a modifiable risk factor for poor pain control following spine surgery. Early identification and management of preoperative insomnia may lead to improved postoperative pain outcomes. Future external validation is needed to confirm the accuracy of the Modified CAPPS score.

Introduction

The prevalence of insomnia in the adult population ranges from 5% to 27% [1,2]. Insomnia is associated with increased health-care costs, work absenteeism, decreased work productivity, and interference with daily living as compared to healthy individuals [3]. Sleep dysfunction has been associated with decreased pain thresholds in normal subjects, and hyperalgesia in patients who suffer from chronic pain [3–7]. Further, studies have found insomnia to be significantly correlated with increased pain intensity in both subjective instruments (eg, sleep diaries) and objective patient reported outcome measures [5,8]. We recently showed through a systematic review and meta-analysis that preoperative sleep difficulty was the largest risk factor for poor postoperative pain control after surgery in other surgical dis-

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ciplines [9]. However, its impact on pain control after spine surgery is unknown.

Poorly controlled pain after surgery is associated with a myriad of negative outcomes such as increased postoperative opioid utilization, risk for opioid dependence, and the development of persistent post-surgical pain [9–12]. Poor postoperative pain control is common and is observed in 30% to 64% of patients after elective inpatient spine surgery [12,13]. We previously developed and validated the Calgary postoperative pain after spine surgery (CAPPS) risk prediction score (https://calgaryspine.ca/research/capps) to identify patients at risk of poor pain control [12,14].

Based on our previous work, we hypothesized that preoperative insomnia, measured by the validated Insomnia severity index (ISI) is an important risk factor for poor pain control after spine surgery. Accordingly, our goals in this study were to (1) explore the relationship between preoperative insomnia and poor pain control after elective spine surgery while controlling for known risk factors, (2) determine the incremental improvement in the discriminative performance of the CAPPS score by including ISI, and (3) to update the CAPPS score to include ISI.

Methods

Reporting guideline and ethics

This study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement [15]. Ethics approval was provided by the University of Calgary's Conjoint Health Research Ethics Board, and all subjects provided informed consent.

Study design and setting

In this prospective cohort study, consecutive patients were enrolled at the Foothills Medical Center in Calgary, Alberta, between June 2019 and October 2020. Patient recruitment was paused between March 2020 and August 2020 due to the COVID-19 pandemic. A subset of this study sample was previously used to independently validate the CAPPS score [14].

Entry criteria

Adult patients (≥18 years) who underwent elective inpatient or outpatient spine surgery were included. Patients were excluded if they required postoperative admission to the intensive care unit, if surgery was cancelled after enrollment, if surgery was for traumatic fractures, or if they received intraoperative intrathecal or postoperative epidural analgesia (previously shown to significantly improve postoperative pain scores) [16,17]. Patients were also excluded if there was missing ISI data or variables contained in the CAPPS score.

Data collection

Data were collected prospectively by research assistants and clinical care nurses. All baseline patient characteristics and prognostic variables were collected prospectively in the preoperative holding area prior to the patient's planned surgery. Baseline patient characteristics collected included age, sex, chief complaint (back pain, neck pain, radiculopathy, myelopathy, neurogenic claudication, or other), principal pathology (disc herniation, degenerative disc disease, spinal stenosis, spondylolisthesis, deformity, tumor, or other), smoking history, body mass index, nature of the surgical procedure (fusion, minimally invasive, revision surgery, and surgical approach), length of hospital stay, oral morphine equivalent dose in the first 24-hours after surgery, and preoperative Oswestry disability index (ODI) and Neck disability index (NDI). A procedure was considered minimally invasive if soft-tissue dilation rather than muscle stripping dissection was performed. All case report forms were corroborated against patient hospital records to ensure accuracy.

Primary outcome

Poor postoperative pain control after surgery has been defined variably in the literature, ranging between ≥3 to >7 out of 10 using the numeric rating scale (NRS) [9]. The NRS, records pain intensity on a 11-point scale (where 0 indicates no pain and 10 indicates worst pain possible). In this study, we defined poor postoperative pain control as a mean NRS for pain >4 at rest during the first 24-hours after surgery, consistent with the definition used to develop the CAPPS score [12]. The postoperative NRS was recorded prospectively by clinical care nurses, without knowledge of the research objectives or patient risk factors as part of usual patient care after surgery. Patients were asked while recumbent to verbally rate their pain by selecting an integer on a scale of 0 to 10 as defined above. Pain assessments were collected in the postoperative anesthetic care unit and inpatient wards. Frequency of pain assessments were personalized to the patient (eg, more frequent when pain was poorly controlled), prior to administration of analgesic medication, and at least every 6 hours according to our institutional policy. Pain assessments were deferred during sleep and when off the clinical unit for reliable patients. For patients undergoing outpatient surgery, pain assessments were recorded while the patients were in hospital.

Preoperative insomnia

Preoperative insomnia was measured by the ISI, a validated 7-item self-reported questionnaire assessing the nature, severity, and impact of insomnia [18]. The dimensions evaluated included: difficulty with sleep onset, sleep maintenance, problems with morning awakening, sleep dissatisfaction, interference of sleep difficulties with daytime function, noticeability of sleep problems by others, and distress caused by sleep difficulty [19]. A 5-point Likert scale (0–4) was used to rate each item, yielding possible scores between 0 and 28 [19]. The ISI includes 4 groups: no clinically significant insomnia (scores 0–7), subthreshold insomnia (scores 8–14), moderate insomnia (15–21), and severe insomnia (scores 22–28). A score of ≥15 has been previously defined as the threshold for clinical insomnia [19]. ISI was collected in the preoperative holding area. No patients were treated for their insomnia prior to surgery. ISI was chosen to quantify the degree of preoperative sleep dysfunction because it has been previously shown to be modifiable through functional restoration programs [20].

Calgary postoperative pain after spine surgery score

The CAPPS score is a validated 14-point prediction score that allows clinicians to identify patients at increased risk for developing poorly controlled pain after elective spine surgery [12,14]. The higher the score, the higher the risk of developing poorly controlled pain after spine surgery. The 7 known predictors of poor postoperative pain were incorporated into this score: age<70 years, female sex, preoperative daily use of opioid medication, preoperative axial neck or low back pain >7 on NRS, patient-health questionnaire-9 depression (PHQ-9) score≥ 10, ≥3 motion segment surgery, and fusion surgery [12,14]. All patients were scored (using the web calculator at https://calgaryspine.ca/research/capps), and based on the presence or absence of these prognostic factors, a numeric score between 0 and 13 was determined for each patient. This score was used to adjust for the exposure-outcome relationship between ISI and poor pain control.

Statistical analyses

Descriptive statistics were used to summarize patient demographics and study characteristics. The two-sample *t* test and chi-square test were used to compare continuous and categorical variables to the primary

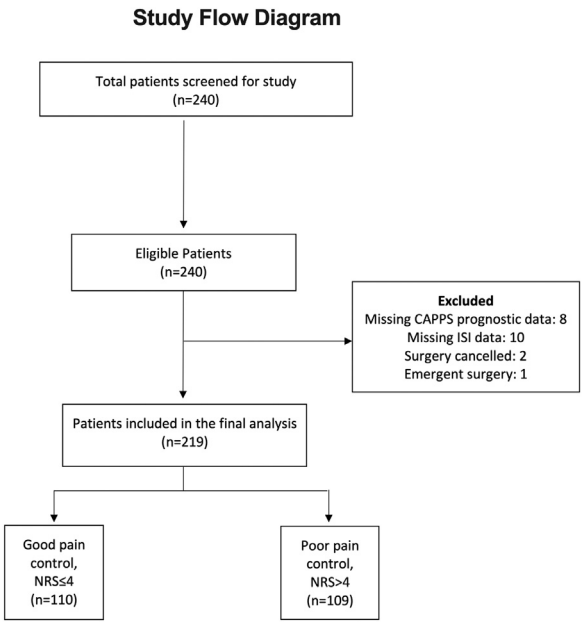

Fig. 1. Study Flow Diagram. CAPPS, Calgary postoperative pain after spine surgery score; ISI, insomnia severity index, NRS, numeric rating scale.

outcome, respectively. Simple linear regression and Pearson correlation coefficient was used to compare independent continuous variables.

A multivariable logistic regression model was used to evaluate the exposure-outcome relationship between ISI, and poor pain control while adjusting for the CAPPS score, and other significant variables not accounted by the CAPPS score on univariable analyses. The final multivariable model was derived from using a backward variable selection method until all variables exhibited a p-value of <.05.

To improve clinical usability and to facilitate the update to the CAPPS score, the clinically important threshold of ISI≥15 was also used to create a multivariable model using the backward variable selection method. Multicollinearity between ISI and the CAPPS score, and the 7 variables within the CAPPS score was examined by and indicated by a variance inflation factor >10 [21]. Apparent model performance was evaluated using the area under the curve (AUC) of a receiver operating characteristics curve and the Hosmer-Lemeshow goodness-of-fit test using 10 groups for discrimination and calibration, respectively.

Sample size

According to Peduzzi et al. [22], in simulations of logistic regression analyses, at least 10 outcome events for each degree of freedom avoids biased regression coefficients, inaccurate variance estimates, and paradoxical associations. Using an estimated incidence of poor postoperative pain control after spine surgery of 57% [12] and 219 patients recruited for this study, there was sufficient sample size to evaluate 12 degrees of freedom (eg, 12 continuous or dichotomous variables).

Assessment of the incremental value of the insomnia severity index

The integrated discriminatory index was calculated to determine the incremental improvement of the discriminatory ability of the prediction model containing ISI compared to the baseline CAPPS model [23,24]. The integrated discriminatory index measures the extent to which the use of a new risk factor correctly revises upward the predicted risk of individuals who experience an event and correctly revises downward the predicted risk of individuals who do not experience the event [25,26]. This method was selected rather than change in AUC as the main measure of improvement due to the observation that once AUC reaches a threshold, it requires unrealistically large effect sizes from a new variable to lead to any appreciable increase [27], By contrast, the integrated discriminatory index is more sensitive to change in a model's ability to discriminate between the 2 possible outcomes (ie, good vs. poor postoperative pain control) [28].

Table 1
Baseline patient characteristics (n=219)

Characteristic	Overall (n=219)
Age in years (mean±SD)	57.6±14.1
Female sex (n, %)	110 (50.2)
Principal pathology (n, %)	
Disc herniation	39 (17.8)
Degenerative disc disease	29 (13.4)
Spinal stenosis	110 (50.2)
Spondylolisthesis	25 (11.4)
Deformity	8 (3.5)
Tumor	0 (0)
Others	8 (3.7)
Chief complaint (n, %)	
Back pain	16 (7.3)
Neck pain	0 (0)
Radiculopathy	123 (56.1)
Myelopathy	40 (18.3)
Neurogenic claudication	38 (17.4)
Others	2 (0.9)
Mean NRS for pain in first 24-h after surgery (mean±SD)	4.0±2.0
Insomnia severity index (mean±SD)	11.5±5.6
Body mass index in kg/m^2 (mean±SD)	30.1±7.0[†]
Smoker (n, %)	54 (26.5)
Daily opioid medication (n, %)	100 (45.7)
Preoperative neck or back pain measured by NRS (mean±SD)	6.0±2.4
Depression on patient health questionnaire-9 (mean±SD)	7.8±4.8
Severe preoperative disability on NDI or ODI[*] (n, %)	77 (35.3)[‡]
Location of surgery (n, %)	
Cervical	64 (29.2)
Thoracolumbar	155 (70.8)
Surgical approach (n, %)	
Any anterior	54 (24.7)
Any posterior	153 (69.9)
Any anterior and posterior	12 (5.5)
Number of motion segment operation (n, %)	
1	130 (59.4)
2	52 (23.7)
≥3	37 (16.9)
Fusion surgery (n, %)	104 (47.5)
Minimally invasive surgery (n, %)	58 (26.7)
Revision surgery (n, %)	25 (11.4)
Length of hospital stay (mean±SD)	2.7±6.1

SD, standard deviation; ODI, Oswestry disability index; NDI, neck disability index; NRS, numeric rating scale; CI, confidence interval; N/A, not available.
[*] Neck Disability Index (NRS) ≥50 or Oswestry Disability Index (ODI) >40
[†] Body Mass Index (n=218).
[‡] Severe Preoperative Disability on NDI or ODI (n=218)

Development of the modified Calgary postoperative pain after spine surgery score

In order to update the prediction score to include preoperative insomnia, the adjusted odds ratio (OR) for ISI≥ 15 was rounded to the nearest integer [29]. This integer was added to the existing 14-point CAPPS score to create the Modified Calgary Postoperative Pain after Spine Surgery (MCAPPS) score. Post-test odds of poor pain control were calculated for each tier of the score, and converted to the post-test predicted probability (Bayes' Theorem) [30,31]. Adjacent cells with small sample sizes were grouped until all cells had ≥5 patients and the stratum-specific likelihood ratios (SSLRs) were calculated resulting in a 7-tier MCAPPS score. As an alternate, for convenience and improved clinical penetrance, a 3-tier MCAPPS score was also developed: low-risk (scores 0–6), high-risk (scores 7–9), and extreme-risk (scores 10–15) [30,32].

Level of significance was set at alpha<0.05. Adjusted ORs and 95% confidence intervals (95%CI) were reported. All statistical analyses were performed with STATA version 15.1 (StataCorp).

Results

Two-hundred forty patients were screened, and 219 patients met eligibility criteria. Excluded patients included 8 that had missing CAPPS prognostic data, 10 with missing ISI data, 2 in whom surgery was cancelled, and one who underwent emergent surgery (Fig. 1). The mean age was 57.6 years and 50.2% were female (Table 1). The most common principal pathology and chief complaint were spinal stenosis (50.2%) and radiculopathy (56.1%). Twenty-nine percent underwent cervical spine surgery and 70.8% underwent thoracolumbar surgery.

The incidence of poor pain control after spine surgery was 49.7% (95%CI=43.2–56.4), and the mean NRS for pain in the first 24-hours was 4.0 (standard deviation 2.0). Twenty-seven percent of patients underwent a minimally invasive spine procedure and were smokers. Preoperative daily opioid medication use was observed in 45.7% of the patients. The mean number of postoperative pain evaluations per inpatient in the first 24-hours was 8.2 (standard deviation 2.4). The mean number of pain evaluation in patients undergoing outpatient surgery was 3.8 (standard deviation 2.5). There was no difference in length of hospital stay in patients with poor versus good pain control (2.9 vs. 2.5 days, p=.66). Patients with poor pain control utilized more oral morphine equivalent doses in the first 24-hours after surgery compared to those with good pain control (112.1 mg vs. 43.3 mg, p<.001).

Univariable predictors of poor pain control after spine surgery

Six of the 7 known predictors of poor postoperative pain control after spine surgery were significantly different in this study (Table 2) [12]. Specifically, patients with poor pain control were more likely to be female (57.3% vs. 42.7%, p=.026), more likely to consume daily preoperative opioid medications (58.7% vs 32.7%, p<.001), have higher mean preoperative neck or back pain measured by NRS (6.8 vs. 5.2, p<.001), have higher mean PHQ-9 depression scores (8.5 vs. 7.1, p<.028), have higher number of motion segments operated (p<.005), and had a fusion surgery (60.6% vs. 34.6%, p<.001). Additionally, severe preoperative disability on NDI or ODI (61.0% vs. 39.0%, p=.016) was significantly associated with poor pain control.

Preoperative insomnia

The mean ISI was 11.5 (standard deviation 5.6) and 26.9% of patients had clinically significant insomnia (ISI≥15) (Fig. 2). ISI was not significantly different in those who consumed daily opioid medications versus intermittent or none (11.8 vs. 11.2, p=.45). Higher mean ISI scores were observed in patients with severe preoperative disability as measured by the ODI (>40) or NDI (≥50) (14.5 vs. 9.8, p<.001). Higher ISI scores were not found to be associated with longer length of hospital stay (regression coefficient 0.049, [95%CI=-0.072-0.17], p=.80). Postoperative opioid utilization in the first 24-hours after surgery was similar between patients with clinical insomnia and those without (100.3 mg vs. 71.6 mg, p=.14).

Patients with poorly controlled pain had higher mean ISI scores compared to those who had good pain control (13.0 vs. 10.0, p=.001, univariable analysis). There was a direct correlation between ISI and mean NRS for pain in the first 24 hours after surgery (correlation coefficient 0.31, p<.001, Fig. 3). Patients with clinically significant insomnia were more likely to have poor pain control (35.8% vs. 18.2%, p=.003). In subsequent multivariable logistic regression analysis, ISI (as a continuous variable) remained significantly associated with poor postoperative pain control (OR 1.09, [95%CI=1.03–1.16], p=.004) after adjusting for the CAPPS score (OR 1.61, [95%CI=1.38–1.89], p<.001) (Table 3). Severe preoperative disability on ODI or NDI was eliminated from the final model (OR 0.89, [95%CI=0.43–1.84], p=.76). This multivariable model demonstrated good calibration (Hosmer-Lemeshow chi-square=8.95, p=.35) suggesting the predicted probability of poor pain control was not significantly different from the observed probability. The AUC was 0.80 [95%CI=0.74–0.86] indicating that the model adequately discriminated between patients with good and poor pain control (Supplementary Fig. 1A). In comparison, the AUC for the baseline model containing only the CAPPS score was 0.77 (95%CI=0.71–0.84).

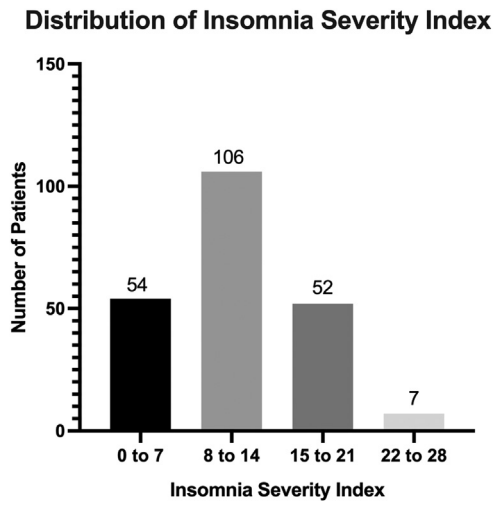

Fig. 2. Distribution of insomnia severity index scores (n=219).

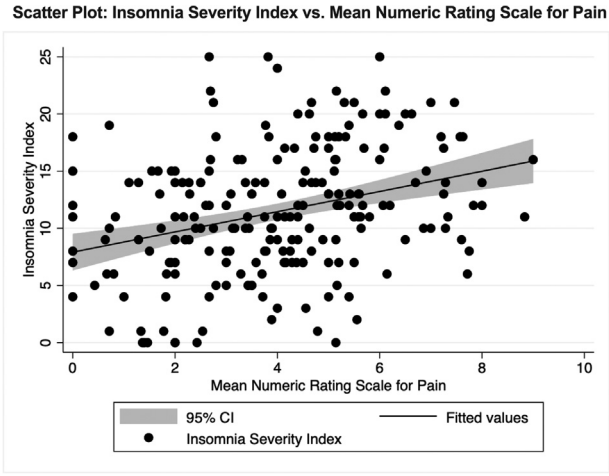

Fig. 3. Scatter plot between mean numeric rating scale for pain at rest and insomnia severity index. Correlation coefficient 0.31, p<.001.

To improve clinical usability and to facilitate updates to the CAPPS score, the multivariable model was repeated with ISI dichotomized to ≥ and <15. The dichotomized variable (ISI≥ 15) remained significantly associated with poor pain control (OR 2.45, [95%CI=1.20–4.97], p=.014) after controlling for the CAPPS score (OR 1.63, [95%CI=1.40–1.91], p<.001) (Table 3). Severe preoperative disability on ODI and NDI remained nonsignificant (OR 0.92, [95%CI=0.44–1.93], p=.83). This revised model was calibrated (Hosmer-Lemeshow chi-square=8.6, p=.38) and discriminative for the outcome (AUC 0.79, [95%CI=0.73–0.85]) (Supplementary Fig. 1B).

Both ISI and ISI≥15 retained their independent association with poor pain control when adjusted for the 7 individual predictors within the CAPPS score in sensitivity analyses (Supplementary Table 1). We did not find evidence of multicollinearity between ISI or ISI≥15 and the 7 variables in the CAPPS score or the CAPPS score itself.

Table 2
Univariable analyses based on pain outcome (n=219)

Characteristic	Good pain control (NRS≤4, n=110)	Poor pain control (NRS>4, n=109)	p-value
Age in years (mean±SD)	58.4±15.0	56.8±13.2	.41
Female sex (n, %)	47 (42.7)	63 (57.3)	**.026**
Principal pathology (n, %)			
Disc herniation	23 (20.9)	16 (14.7)	.055
Degenerative disc disease	10 (9.1)	19 (17.4)	
Spinal stenosis	63 (57.3)	47 (43.1)	
Spondylolisthesis	9 (8.2)	16 (14.7)	
Deformity	2 (1.8)	6 (5.5)	
Tumor	0 (0)	0 (0)	
Others	3 (2.7)	5 (4.6)	
Chief complaint (n, %)			
Back pain	4 (3.6)	12 (11)	.11
Neck pain	0 (0)	0 (0)	
Radiculopathy	58 (52.7)	65 (59.6)	
Myelopathy	20 (18.2)	20 (18.4)	
Neurogenic claudication	20 (24.6)	18 (10.1)	
Others	1 (0.91)	1 (0.92)	
Mean NRS for pain in first 24-h after surgery (mean±SD)	2.4±1.2	5.6±1.2	**<.001**
Insomnia severity index (mean±SD)	10.0±5.6	13.0±5.2	**<.001**
Body mass index in kg/m^2 (mean±SD)	29.9±7.1	30.2±6.9	.77
Smoker (n, %)	26 (23.6)	28 (25.7)	.71
Daily opioid medication (n, %)	36 (32.7)	64 (58.7)	**<.001**
Preoperative neck or back pain measured by NRS (mean±SD)	5.2±2.5	6.8±2.0	**<.001**
Depression on patient health questionnaire-9 (mean±SD)	7.1±4.7	8.5±4.9	**.028**
Severe preoperative disability on NDI or ODI* (n, %)	30 (39.0)	47 (61.0)	**.016**
Location of surgery (n, %)			
Cervical	27 (42.2)	37 (57.8)	.13
Thoracolumbar	83 (53.6)	72 (46.5)	
Surgical approach (n, %)			
Any anterior	23 (20.9)	31 (28.4)	.16
Any posterior	83 (75.5)	70 (64.2)	
Any anterior and posterior	4 (3.6)	8 (7.3)	
Number of motion segment operation (n, %)			
1	77 (70)	53 (48.6)	**.005**
2	20 (18.2)	32 (29.4)	
≥3	13 (11.8)	24 (22.0)	
Fusion surgery (n, %)	38 (34.6)	66 (60.6)	**<.001**
Minimally invasive surgery (n, %)	30 (44.1)	28 (30.4)	.075
Revision surgery (n, %)	10 (9.1)	15 (13.8)	.28
Length of hospital stay (mean±SD)	2.5±8.1	2.9±3.2	.66

SD, standard deviation; ODI, Oswestry disability; NDI, neck disability index; NRS, numeric rating scale; CI, confidence interval; N/A, not available.
* Neck Disability Index (NRS) ≥50 or Oswestry Disability Index (ODI) >40.

Table 3
Multivariable logistic regression model for insomnia severity index as a continuous variable and insomnia severity index≥15 adjusted for the CAPPS score (n=219)

Insomnia severity index		
Predictor	Adjusted OR (95%CI)	p-value
Insomnia severity index	1.09 (1.03–1.16)	**.004**
CAPPS score	1.61 (1.38–1.89)	**<.001**
Intercept	0.022 (0.0066–0.073)	**<.001**
Insomnia severity index≥15		
Predictor	Adjusted OR (95%CI)	p-value
Insomnia severity index≥15	2.45 (1.20–4.97)	**.014**
CAPPS Score	1.63 (1.40–1.91)	**<.001**
Intercept	0.044(0.016–0.12)	**<.001**

CAPPS, Calgary postoperative pain after spine surgery score; OR, odds ratio; CI, confidence interval.

Incremental value of the insomnia severity index predicting poor pain control

Since ISI and ISI≥15 were shown to be significantly associated with poor pain control after spine surgery, it was necessary to assess their incremental value to the risk prediction model in terms other than their statistical significance. When ISI was added to the baseline model containing the CAPPS score, the integrated discriminatory index was 0.035 (standard error 0.012, p=.004). Similarly, when ISI≥ 15 was added to the baseline model, the integrated discriminatory index was 0.024 (standard error 0.010, p=.023). This means incorporating ISI or ISI≥15 with the baseline CAPPS model increased the separation of the mean absolute predicted probabilities for poor pain control versus good pain control by 3.5% and 2.4%, respectively.

Modified Calgary postoperative pain after spine surgery score

The ISI≥ 15 predictor was assigned a value of 2 and was added to the 14-point CAPPS score to yield the 16-point Modified CAPPS (MCAPPS) score (Table 4). No erosion of discrimination (AUC 0.79, [95%CI=0.73–0.85]) or calibration (Hosmer-Lemeshow chi-square=7.96, p=.34) was seen with this transformation. This prediction score was further collapsed into a 7-tier MCAPPS score after adjacent cells with small sample sizes were combined. This 7-tier MCAPPS score retained discrimination (AUC 0.78, [95%CI=0.72–0.84]) and calibration (Hosmer-Lemeshow chi-square=2.92, p=.57).

Bayesian statistics were then applied to develop the SSLRs and resultant predicted probabilities for each of the 7-tiers (Table 5). The SSLR progressed from 0.16 for scores 0-4, to 8.41 for scores 10 to 15. Using the pretest probability 49.7% (the incidence of poor pain control in this

Table 4
Modified Calgary postoperative pain after spine surgery (MCAPPS) score

Predictor	Score
Insomnia severity index≥15	2
Age <70 y	2
Female sex	2
Daily preoperative opioid use	3
Preoperative NRS neck/back pain>7	1
Moderate to severe depression (PHQ-9≥10)	1
≥3 motion segment operation	2
Fusion surgery	2
Total score	*0–15*

PHQ-9, patient health questionnaire-9.

study), the post-test predicted probability progressed from 7.38% for scores 0–4 to 80.7% with scores ≥10. Further, when the MCAPPS score was streamlined into a 3-tier score for improved convenience and to promote clinical application, there was a similar stepwise increase in the predicted probability of poor pain control: 17.3% for low-risk (scores 0–6), 49.1% for high-risk (scores 7–9), and 80.7% for extreme-risk groups (scores 10–15) (Table 5). In comparison, the predicted probability of poor pain control in the original CAPPS score was: 32.0% for low-risk (scores 0–4), 63.0% for high-risk (scores 5–8), and 85.1% for extreme-risk groups (scores 9–13) (Table 6) [12].

Discussion

As clinical practice moves towards personalized medicine, there is a need to continually improve existing predictive tools to help physician make appropriate therapeutic decisions. Further, the identification of novel modifiable risk factors creates an opportunity to develop preventative therapies based on individual patient risk. In this prospective cohort study, we found preoperative insomnia measured by the ISI was significantly associated with poor postoperative pain control after elective spine surgery, independent of known risk factors. The inclusion of ISI into the baseline model led to significant improvements in the discriminative performance and an improved clinical tool (MCAPPS score).

In this study, the prevalence of clinically important insomnia was 26.9%, higher than what has been reported in the general adult population, and lower than those suffering from chronic disabling occupational musculoskeletal disorders [1,2,20]. Early evidence suggested a reciprocal relationship between sleep dysfunction and pain [33]. More recent longitudinal and population-based studies supported the notion that sleep disorder is a stronger, more reliable predictor of pain than pain is of sleep impairments [34]. Further, poor sleep has been correlated with increased pain intensity and new onset of chronic pain in pain-free individuals [5,8,34]. In this study, every point increase in ISI was associated with a 9% increase in the odds of developing poorly controlled pain after spine surgery. Similarly, patients with clinically important insomnia (ISI≥15) had 2.45 times the odds of developing poorly controlled pain compared to those without clinically important insomnia or subthreshold insomnia. These findings are consistent with the results of a meta-analysis by our group where we found that patients with preoperative sleep difficulties had 2.32 times the odds of developing poorly controlled pain after surgery in other disciplines [9].

A component of the Enhanced Recovery after Surgery program for spine surgery is the “pre-hospital” phase where patients are optimized for surgery [35]. This includes adequate patient/family education, the development of a pain management plan, and prehabilitation of select patients [35,36]. The CAPPS score was developed to identify patients at increased risk for experiencing poor pain control after spine surgery so that preventative and personalized treatment strategies could be developed. The CAPPS score contained 3 modifiable risk factors for poor pain control: preoperative daily opioid medication use, preoperative neck or back pain, and depression [12]. This study identified preoperative insomnia as an novel modifiable risk factor that could be targeted to improve postoperative pain outcomes. There is a paucity of data on the effectiveness of preoperative sleep optimization on postoperative clinical outcomes. However, patients with chronic musculoskeletal disorders (eg, chronic back/neck pain) had significant improvement in patient-reported insomnia in response to interdisciplinary functional restoration programs, demonstrating the modifiable nature of this variable [8,20]. In a study by Asih et al. [20], insomnia symptoms were addressed with a variety of treatment approaches including medical (sedatives and antidepressants), educational (individual and classroom education), and cognitive behavior treatment. Further, the authors showed that patients who had lower ISI scores at the end of their program were also more likely to have discontinued their opioid medications. We propose that patients identified as higher risk for poor pain control and who also exhibit modifiable risk factors should be selected for preoperative treatment programs aimed at mitigating these risk factors to improve postoperative pain outcomes.

The addition of ISI into the prediction model resulted in a significant incremental improvement in the level of discrimination between those with and without poor pain control. This created the impetus to develop the MCAPPS score which we hope will lead to more accurate predictions of poor postoperative pain control after spine surgery. The MCAPPS score could be administered during preoperative consultation visits to frame patient expectation of postoperative pain control, to improve shared-decision making on the development of a pain management plan, and help to triage patients for preoperative programs to target specific modifiable risk factors. Improvement in postoperative pain management may lead to a reduction in postoperative opioid utilization, perioperative complications, recovery time, health-care costs, and may improve patient satisfaction [10].

Table 5
Stratum specific likelihood ratios and predicted probability for poor postoperative pain control for each tier of the MCAPPS score.

Seven-tier MCAPPS score	Number of patients (%)	Stratum specific LR (95% CI)	Predicted probability of poor pain control (NRS>4) (%)
0–4	59 (26.9)	0.16 (0.081–0.31)	7.38
5	23 (10.5)	1.10 (0.52–2.34)	35.4
6	33 (15.1)	0.74 (0.40–1.39)	26.9
7	32 (14.6)	1.47 (0.78–2.80)	42.3
8	19 (8.7)	2.19 (0.84–5.69)	52.2
9	25 (11.4)	2.59 (1.11–6.09)	56.3
10–15	28 (12.8)	8.41 (2.84–24.9)	80.7
Three-tier MCAPPS score			
Low-risk (0–6)	115 (52.5)	0.42 (0.31–0.57)	17.3
High-risk (7–9)	76 (34.7)	1.94 (1.32–2.86)	49.1
Extreme-risk (10–15)	28 (12.8)	8.41 (2.84–24.9)	80.7

LR, likelihood ratio; NRS, numeric rating scale.
MCAPPS- modified Calgary postoperative pain after spine surgery

Table 6
Comparison between the predicted probabilities for the CAPPS and the MCAPPS score

Three-tier CAPPS score	CAPPS predicted probability (%)	Three-tier MCAPPS score	MCAPPS predicted probability (%)
Low-risk (0–4)	32.0	Low-risk (0–6)	17.3
High-risk (5–8)	64.0	High-risk (7–9)	49.1
Extreme-risk (9–13)	85.1	Extreme-risk (10–15)	80.7
Score: 0–13		Score: 0–15	

CAPPS, Calgary postoperative pain after spine surgery score; MCAPPS, modified Calgary postoperative pain after spine surgery score.

Strengths and limitations

Strengths of this study include the prospective nature of the study design which provides natural protection against selection bias. The CAPPS score was originally developed and validated for patients undergoing inpatient surgery. In this study, the multivariable model and the MCAPPS score retained predictive performance even though 11.0% (n=24) underwent outpatient surgery. This demonstrates the versatility and effectiveness of these risk factors and the MCAPPS score in predicting poor pain control irrespective of length of stay after spine surgery.

However, the findings should be also interpreted within the limitations of the study design. This study was conducted at a tertiary teaching hospital, as such, the results of this study may not be generalizable to all centers. The frequency of pain measurements was not standardized in this study. At our institution, pain assessments were more frequently performed in patients with poorly controlled pain. This could have led to an overestimation of the mean pain scores. Further, patients undergoing outpatient surgery had fewer pain evaluations leading to increased risk of misclassifying their pain control status. The primary outcome in this study was measured by NRS for pain, a more effective way to measure and guide the management of postoperative pain is to combine functional outcome measures (eg, the Functional Pain Scale) and unidimensional pain scales (eg, NRS for pain) [37]. Future pain studies evaluating postoperative pain should include a measure of functional outcome.

This study included a heterogenous group of patients who underwent elective spine surgery. When analyzing decision rules such as the MCAPPS score, heterogeneity is a double-edged sword. Some would appropriately argue it could have a detrimental effect on internal validity. However, in our case, when we validated the original CAPPS score on an independent sample, this heterogeneity did not impact the score's accuracy [14]. On the other hand, a prediction score built on a heterogeneous sample has the benefit of maximizing the external validity and its generalizability into clinical spine practice. We feel this generalizability is a strength of the MCAPPS score.

This study demonstrated statistically the importance of ISI in predicting poorly controlled pain. Future studies should be conducted to evaluate whether the detection of preoperative insomnia leads to changes in clinical decisions, and whether its mitigation leads to improved postoperative pain outcomes. Lastly, the MCAPPS score was not validated and future studies demonstrating adequate predictive performance in an independent population should be performed before widespread adoption of the MCAPPS score.

Conclusion

Preoperative insomnia is common in the elective spine surgery population. Preoperative insomnia measured by ISI is a novel modifiable risk factor for poor postoperative pain control after spine surgery that is independent of age, sex, preoperative daily opioid use, preoperative back or neck pain, depression, ≥3 motion segment surgery, and fusion surgery. ISI≥ 15 was used to update the CAPPS score to create the MCAPPS score, which upon validation may be more accurate in predicting poorly controlled pain after spine surgery. Preoperative detection and optimization of insomnia may lead to improved postoperative pain outcomes.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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