



Universiteit
Leiden
The Netherlands

Comparison of the Stopping Opioids after Surgery (SOS) score to preoperative morphine milligram equivalents (MME) for prediction of opioid prescribing after lumbar spine surgery

Karhade, A.V.; Schwab, J.H.; Harris, M.B.; Schoenfeld, A.J.

Citation

Karhade, A. V., Schwab, J. H., Harris, M. B., & Schoenfeld, A. J. (2020). Comparison of the Stopping Opioids after Surgery (SOS) score to preoperative morphine milligram equivalents (MME) for prediction of opioid prescribing after lumbar spine surgery. *The Spine Journal*, 20(11), 1798-1804. doi:10.1016/j.spinee.2020.06.005

Version: Publisher's Version

License: [Licensed under Article 25fa Copyright Act/Law \(Amendment Taverne\)](#)

Downloaded from: <https://hdl.handle.net/1887/4302602>

Note: To cite this publication please use the final published version (if applicable).

Clinical Study

Comparison of the Stopping Opioids after Surgery (SOS) score to preoperative morphine milligram equivalents (MME) for prediction of opioid prescribing after lumbar spine surgery

Aditya V. Karhade, BE^b, Joseph H. Schwab, MD, MS^b,
Mitchel B. Harris, MD^b, Andrew J. Schoenfeld, MD, MSc^{a,*}

^a Department of Orthopaedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

^b Department of Orthopaedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

Received 4 February 2020; revised 9 May 2020; accepted 3 June 2020

Abstract

BACKGROUND CONTEXT: Reliable estimation of the likelihood for prolonged postoperative opioid use may aid targeted interventions for high-risk patients. Previous studies have recommended differing methodologies for prediction of sustained postoperative opioid use.

PURPOSE: To compare the performance of the Stopping Opioids after Surgery (SOS) score and preoperative morphine milligram equivalents (MME) for postoperative opioid prescription exposure in a contemporary cohort of lumbar surgery patients.

PATIENT SAMPLE: Adult patients undergoing posterior decompression with or without fusion for degenerative lumbar conditions between January 31, 2016 and May 31, 2019.

STUDY DESIGN/SETTING: Retrospective review at two academic medical centers and three community hospitals.

OUTCOME MEASURES: The primary outcome was sustained postoperative prescription opioid exposure at 3 months and 6 months. Reoperations and readmissions were considered secondarily.

METHODS: The Stopping Opioids after Surgery score and MME were assigned to patients based on data from their preoperative surgical evaluation. Performance for both measures was assessed for all outcomes by discrimination, including c-statistic and receiver-operating curve analysis. Calibration of the low, medium and high-risk strata with the observed rates of postoperative adverse events were examined.

RESULTS: Overall, 4,165 patients were included in this study. Preoperative prevalence of prescription opioid use was 31%. Rates of postoperative opioid prescriptions at 3 months and 6 months, were 3.3% (n=136) and 1.5% (n=61). The c-statistics of preoperative oral MME and SOS score for 3-month sustained opioid prescriptions were 0.64 and 0.78, respectively. The c-statistics of preoperative oral MME and SOS score for 6-month sustained opioid prescriptions were 0.64 and 0.82, respectively. C-statistics of preoperative oral MME and SOS score were much lower for reoperation and readmission, although SOS score outperformed MME for both outcomes.

CONCLUSIONS: The SOS score clinically outperformed oral MME as a predictive measure for outcomes following lumbar spine surgery. The SOS score may be valuable for identifying

FDA device/drug status: Not applicable.

Author disclosures: **AVK:** Nothing to disclose. **JHS:** Consulting: Stryer (B). **MBH:** Nothing to disclose. **AJS:** Royalties: Wolters Kluwer (B). Grants: NIH NIAMS (G, paid directly to institution), DoD (H, paid directly to institution), OREF (F, paid directly to institution).

*Corresponding author. Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, 75 Francis Street, Boston, MA 02115, USA. Tel.: 857-307-3793; fax: 617-975-0882.

E-mail address: ajschoen@neomed.edu (A.J. Schoenfeld).

individuals at high-risk for sustained prescription opioid use and associated adverse events following spine surgery. © 2020 Elsevier Inc. All rights reserved.

Keywords: Lumbar spine surgery; Morphine milliequivalents; Opioid dependence; Prescription opioid use; Risk score; Stopping Opioids after Surgery (SOS) score

Introduction

In the midst of the American public health crisis associated with opioid abuse and addiction, deaths related to prescription opioid use have increased dramatically in the last two decades [1–4]. More deaths are now annually attributed to prescription opioids than heroin and cocaine combined [5]. Opioid analgesia prescribed for regular postoperative pain control may evolve into long-term iatrogenic dependence, with associated hyperalgesia, impaired cognition and function, as well as reduced patient satisfaction and outcomes [3,6,7]. Spine surgery for degenerative conditions has previously been reported to be one of the highest risk procedures for iatrogenic opioid dependence [8]. As a result, clinicians and researchers have shown recent interest in developing risk scores to effectively identify high-risk patients prior to surgery [7,9,10]. Targeted interventions in these high-risk populations could represent a more resource-efficient method for preventing long-term dependence [11].

Several studies have previously defined prognostic models for prolonged postoperative opioid use [9,12]. Some of these rely on preoperative oral morphine milligram equivalents (MME) [13]. Determinations regarding MME can be challenging, and prone to calculation and classification error, as these parameters may be fluid over time and patients can have difficulty relating the type and extent of prescription opioid use over an extended time-frame. Chaudhary et al. recently described the Stopping Opioids after Surgery (SOS) score and used a time-based scalar assessment of preoperative opioid prescriptions [9]. The SOS consists of a ranked assessment of factors associated with sustained prescription opioid use, including age, socioeconomic status, depression and anxiety, procedural characteristics, and prior opioid exposure. Use of the SOS also avoids the need for a conversion table with multiplication and division operations, which can be time consuming and prone to error. Intuitively, the checklist style of the SOS is simpler for patients and providers in clinical practice, and less sensitive to information bias or errors in dosage calculation [14]. However, there are no studies that directly compare the relative utility of these different risk-based assessments for outcomes following spine surgery.

In this context, we sought to compare the performance of the SOS score and preoperative MME on postoperative outcomes, including sustained prescription opioid exposure, readmissions and reoperations, in a contemporary cohort of lumbar spine surgery patients. We hypothesized that the SOS score would more accurately predict sustained prescription opioid exposure, readmission and reoperations in this cohort of patients.

Materials and methods

Data source

This study was approved by our institutional review board prior to commencement. We queried our institutional registry for (1) adult patients 18 years or older who underwent (2) primary procedure of posterior lumbar decompression with or without fusion for (3) lumbar degenerative disorders between January 31, 2016 and May 31, 2019 at one of the five medical centers in our health system [two academic medical centers and three community hospitals in Massachusetts, United States of America (US)]. Patients who underwent other types of lumbar surgery, or received lumbar procedures for trauma, tumor, infection, or scoliosis were excluded.

Outcome

The primary outcome consisted of sustained postoperative opioid prescription exposure: evaluated at 3 months and 6 months. These time points were selected based on the surveillance periods used in studies that developed and validated the SOS score for use in spine surgical patients, as well as other investigations conducted in the field of spine surgery [9,10,15]. In line with prior research, patients classified with 3-month sustained opioid prescription exposure were those that had (1) at least one opioid prescription from postoperative day 0 to 30 (2) at least one opioid prescription from day 31 to 90 and (3) at least one opioid prescription from day 91 to 180 [15,16]. Patients with 6-month sustained opioid prescriptions met the criteria for 3-month and had at least one additional opioid prescription from day 181 to 270. Secondary outcomes consisted of reoperation and readmission, as surveyed by natural language processing of medical records in our health system's registry, supplemented by manual review where necessary [17].

Variables

The following variables were collected for all patients: age (years), biologic sex (female, male), procedure indication (lumbar disc herniation, stenosis, spondylolisthesis), insurance status, prior opioid prescriptions in the year before the index procedure, comorbidities (diabetes, depression, and anxiety), length of stay following surgery (days), and discharge disposition (home and nonhome).

Aligned with prior work [9], we considered all class II and III opioid medications including, but not limited to, hydrocodone, oxycodone, fentanyl, hydromorphone, morphine, methadone, oxymorphone, and codeine, as well as

all formulations of these opioids combined with acetaminophen. Preoperative oral MME were calculated for patients with at least one opioid prescription in the 30 days before surgery [18,19]. Patients with multiple opioid prescriptions in this period had the opioid prescription closest to surgery used for the conversion to oral MME. Total daily MME was calculated by multiplying the total daily opioid dose (dose per administration x frequency of administration per day) by the corresponding conversion factor [20]. Rates of missing data for oral MME was 0.7% overall (n=31). Multiple imputation was used to account for variables with less than 30% missing data.

The SOS score weights a variety of sociodemographic and clinical factors beyond preoperative prescription opioid use [9]. The SOS score classifies all spine procedures under the *major surgery* category. The SOS score ranges from 0 to 100 with 0–30 representing low-risk, 31–60 representing medium-risk, and 61–100 representing high-risk for postoperative prescription opioid use.

Performance assessment

SOS score and MME were calculated for all patients at the time of surgery. Comparisons between the prognostic measures were conducted using the receiver-operating curve and c-statistic [21]. C-statistics range from 0 to 1. A model with predictive performance no better than chance has c-statistic of 0.5. A model with perfect discrimination has c-statistic of 1. This was performed first for postoperative prescription opioid exposure, followed by reoperations and readmissions. Subset analyses were conducted for prescription opioid exposure, limiting consideration to homogeneous lumbar conditions: lumbar disc herniation, spinal stenosis and spondylolisthesis. Calibration for both prognostic modalities was assessed by calculating the observed rates of postoperative opioid prescriptions at the low-, medium-, and high-risk strata. R (The R Foundation, Vienna, Austria) and Python (Python Software Foundation, Wilmington, Delaware) were used for all data analysis and statistical testing.

Results

Overall 4,165 patients were included in this study. The median age was 62 (interquartile range=51–72) years (Table 1). Thirty-one percent of the population had received opioid prescriptions at the time of surgery. Among the 310 patients (7.4%) with at least one opioid prescription in the 30 days before surgery, the median MME was 22.5 (interquartile range=15–45) mg.

Rates of prolonged postoperative opioid prescriptions at 3 months and 6 months were 3.3% (n=136) and 1.5% (n=61), respectively. Rates of reoperation at 3 months and 6 months were 3.9% (n=161) and 4.9% (n=203), respectively. Rates of readmission at 3 months and 6 months were 10% (n=416) and 12.1% (n=503), respectively.

Table 1
Baseline characteristics of validation cohort, n=4,165

Variable	n (%) median (IQR)
Total	4,165 (100)
Age	62 (51–72)
Female sex	1,887 (45.3)
Procedure/Diagnosis	
Disc herniation	1,521 (36.5)
Stenosis	1,452 (34.9)
Spondylolisthesis	1,001 (24.0)
Medicaid insurance	425 (8.0)
Prior opioid prescription	1,292 (31.0)
Comorbidities	
Diabetes	407 (9.8)
Depression	378 (9.1)
Anxiety	351 (8.4)
Length of stay (days)	1 (0–3)
Nonhome discharge	348 (8.4)
Postoperative sustained opioid prescriptions	
3-month	136 (3.3)
6-month	61 (1.5)
Reoperation	
3-month	161 (3.9)
6-month	203 (4.9)
Readmission	
3-month	416 (10.0)
6-month	503 (12.1)

IQR, interquartile range; MME, morphine milligram equivalents.

At 90 days, 38 (2.5%) patients undergoing surgery for disc herniation, 50 (3.4%) patients undergoing surgery for spinal stenosis, and 42 (4.2%) of patients undergoing surgery for spondylolisthesis had sustained opioid prescriptions. At 180 days, 17 (1.1%) patients undergoing surgery for disc herniation, 21 (1.4%) patients undergoing surgery for spinal stenosis, and 20 (2.0%) of patients undergoing surgery for spondylolisthesis had sustained opioid prescriptions. At 90 days, 25 (6.1%) patients with diabetes, demonstrated sustained prescription opioid exposure, and this figure changed to 14 (3.4%) at 180 days.

At 90 days, 22 (5.8%) patients with depression had sustained opioid prescriptions versus 114 (3.0%) patients without depression ($p=.005$). Similarly, 21 (6.0%) patients with anxiety had sustained opioid prescriptions compared to 115 (3.0%) patients without anxiety ($p=.005$). At 180 days, 14 (3.7%) patients with depression had sustained opioid prescriptions versus 47 (1.2%) patients without depression ($p<.001$). Similarly, 9 (2.6%) patients with anxiety had sustained opioid prescriptions compared to 52 (1.4%) patients without anxiety ($p=.12$).

At 3 months, patients with low, medium, and high-risk SOS scores had observed rates of opioid prescriptions of 1% (95% confidence interval [CI]: 0.66–1.4), 7.7% (95% CI: 6.2–9.1), and 18.2% (95% CI: 4.3–32.1), respectively (Table 2). At 6 months, patients with low-, medium-, and high-risk SOS scores had observed rates of opioid prescriptions of 0.3% (95% CI: 0.1–0.5), 3.6% (95% CI: 2.6–4.6), and 15.2% (95% CI: 2.2–28.1), respectively.

Table 2

Observed rate (95% confidence interval) of sustained opioid prescriptions at 3 months and 6 months by strata of SOS score in validation cohort

Risk score category	Overall	LDH	LSS	Spondylolisthesis
3 months				
Low	1.0 (0.66, 1.4)	0.4 (0.08–0.78)	1.1 (0.4–1.7)	1.8 (0.77–2.8)
Intermediate	7.7 (6.2, 9.1)	6.3 (4.2–8.4)	8.7 (6.0–11.3)	9.2 (6.0–12.4)
High	18.2 (4.3, 32.1)	37.5 (–6.6–80.8)	14.3 (–6.6–35.3)	12.5 (–17.1–42.1)
6 months				
Low	0.3 (0.1–0.5)	0 (0–0)	0.3 (0.04–0.6)	0.6 (0.01–1.2)
Intermediate	3.6 (2.6–4.6)	2.8 (1.4–4.3)	4.0 (2.1–5.9)	4.8 (2.4–7.1)
High	15.2 (2.2–28.1)	37.5 (–6.6–80.8)	7.1 (–8.3–22.6)	12.5 (–17.1–42.1)

LDH, lumbar disc herniation; LSS, lumbar spinal stenosis; SOS, stopping opioids after surgery.

Sustained prescription opioid exposure

The c-statistic of preoperative oral MME for sustained opioid prescriptions was 0.64 at both the 3-month and 6-month time-points. The c-statistics of the SOS score for 3-month and 6-month sustained opioid prescription exposure were 0.78 and 0.82, respectively (Figure). At a cutoff of 30, the SOS score had sensitivity of 0.78 and specificity of 0.70 for 3-month sustained postoperative opioid prescriptions (Table 3). At the same cutoff, the SOS score had sensitivity of 0.85 and specificity of 0.69 for 6-month sustained opioid prescription exposure.

These findings for the SOS score were well preserved in subset analyses that limited consideration to homogenous cohorts of patients based on the indication for surgery. In patients undergoing surgery for disc herniation, the c-statistics of the SOS score were 0.82 for 3-month and 0.89 for 6-month sustained opioid prescriptions. In those treated for spinal stenosis, the c-statistics of the SOS score were 0.81 for 3-month and 0.83 for 6-month sustained opioid prescriptions and in individuals treated for spondylolisthesis, the c-statistics were 0.73 and 0.78 for 3- and 6-month sustained opioid prescriptions, respectively.

In patients undergoing surgery for disc herniation, the c-statistics of preoperative oral MME were 0.71 for 3-month and 0.75 for 6-month sustained opioid prescriptions. In those treated for spinal stenosis, the c-statistics of the SOS score were 0.64 for 3-month and 0.62 for 6-month sustained opioid prescriptions and in individuals treated for spondylolisthesis, the c-statistics were 0.61 and 0.59 for 3- and 6-month sustained opioid prescriptions, respectively.

Reoperation

The c-statistics of preoperative oral MME for 3-month and 6-month reoperation were 0.52 and 0.51, respectively. The c-statistics of the SOS score were higher for reoperation at 3 months (0.59) and 6months (0.58).

Readmission

The c-statistics of preoperative oral MME for readmission was 0.50 at 3 months and 6 months. The c-statistics of the SOS score were marginally higher at 0.52 for 3 months and 0.51 for 6 months.

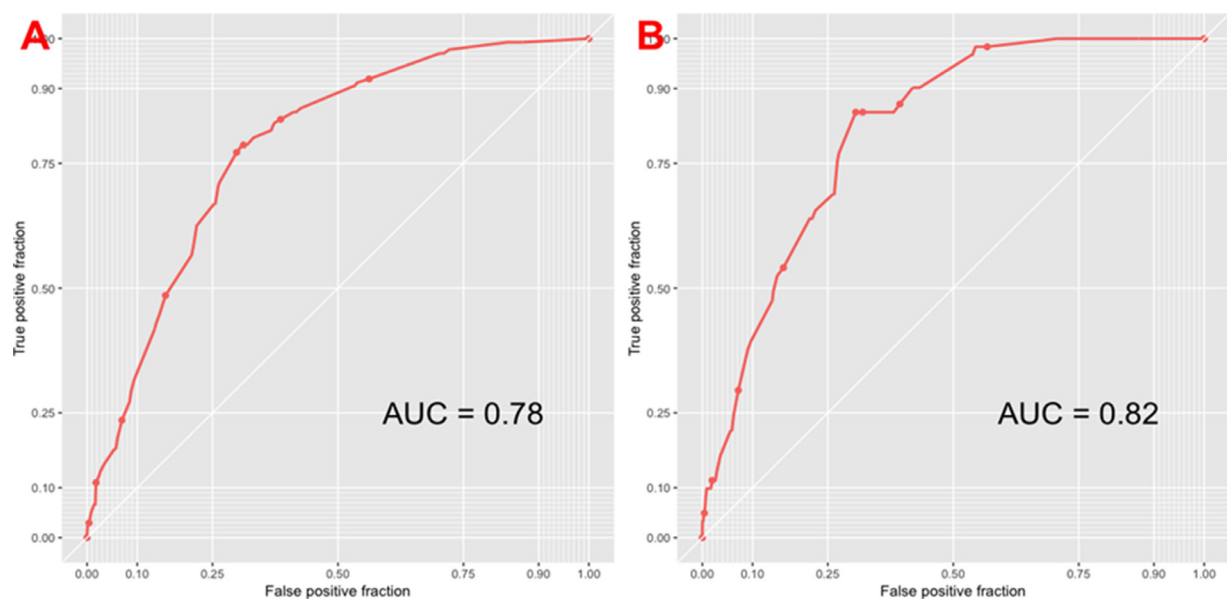


Figure. Receiver operating curves for prediction of (A) 3-month and (B) 6-month sustained prescription opioid exposure using the Stopping Opioids after Surgery (SOS) score.

Table 3

SOS score performance (95% confidence intervals) relative to preoperative oral MME for 3-month and 6-month sustained opioid prescriptions in validation cohort

Metric	3 months	6 months
SOS score		
C-statistic	0.78 (0.74, 0.82)	0.82 (0.74, 0.87)
Cutoff=30		
Sensitivity	0.78 (0.70, 0.85)	0.85 (0.74, 0.93)
Specificity	0.70 (0.68, 0.71)	0.69 (0.67, 0.70)
Cutoff=60		
Sensitivity	0.04 (0.02, 0.09)	0.08 (0.03, 0.18)
Specificity	0.99 (0.99, 1.00)	0.99 (0.99, 1.00)

SOS, stopping opioids after surgery; MME, morphine milligram equivalents.

Discussion

In the aftermath of what represents three decades of opioid overprescribing in the US, surgeons are increasingly challenged to balance the risks of iatrogenic prescription opioid dependence and addiction against inadequate pain control following spinal procedures [22]. Most studies and clinical guidelines maintain the importance of preoperative evaluation of a patient's risk for sustained prescription opioid use, including current opioid use at the time of presentation [13,14]. Controversy remains, however, around how to most effectively and efficiently operationalize this assessment. Within the last 2 years, clinical prediction tools to quantify the risk of sustained prescription opioid use following surgery have become available [2,9,12,15,23–25]. Other researchers have advocated the use of preoperative opioid MME, as these can contextualize an individual's relative magnitude of opioid exposure at the time of surgery [7,14]. Accurate evaluation can be limited, however, both due to a recall bias on the part of patients with respect to extent of opioid use and concerns around precipitating provider-based stigma [9]. Additionally, duration of preoperative opioid exposure, a powerful mediator of postoperative opioid requirements, may be obfuscated to a large extent by assessments that are restricted to MME in the time-period immediately leading up to a surgical intervention [9]. The SOS score has been found to be easy to use at the bedside and can be completed relatively quickly with information obtained from the patient or medical chart (Table 4). It relies of simple addition and does not require conversion tables, or multiplication and division as is necessary for the determination of standardized MME.

In this study, we used a contemporary cohort (2016–2019) of patients undergoing a variety of lumbar spine surgical procedures for degenerative conditions to compare the accuracy of the SOS score, as compared to MME, for prognosticating postoperative prescription opioid exposure, as well as reoperations and readmissions. Although there are broad ranges of pre- and postoperative opioid exposure cited in the literature, many of these issues result from inherent differences within the populations under study,

Table 4

Factors and point totals used to calculate the Stopping Opioids after Surgery (SOS) risk score

Characteristic	Score
Age	
18–24	0
25–34	4
35–44	7
45–54	7
55–64	7
Sex	
Male	0
Female	4
Discharge status	
Home	0
Nonhome discharge	14
Socio-economic Status	
High	0
Low	7
Procedure category	
Minor	0
Major	5
Length of stay (Days)	
≤3	0
>3	1
Diabetes mellitus	2
Depression	6
Anxiety	7
Prior opioid use	29
Total score	100

including the definition of prescription opioid use employed by researchers. Our observed prevalence of pre- and postoperative opioid prescriptions exist within the range of prior work that has employed definitions of opioid exposure similar to our own [25]. We found that the SOS score outperformed the use of MME in all parameters considered and most prominently with respect to the predilection for sustained prescription opioid exposure postoperatively. Based on a review of c-statistics, MME was modestly predictive of postoperative prescription opioid exposure and virtually uninformative for the purposes of prognosticating readmission or reoperation. In contrast, the c-statistics for the SOS score straddled the threshold for excellent prediction (0.80) at 3- and 6 months and the system also demonstrated adequate sensitivity for predicting sustained prescription opioid exposure at both time-points. While performance was diminished for the SOS score for both readmission and reoperation, the prognostic tool still outperformed preoperative MME.

Our results reinforce previously held beliefs that preoperative MME inadequately encapsulates a patient's overall risk of sustained prescription opioid use [14]. Furthermore, while other studies have demonstrated an association between MME and postoperative events [13], in the present work the measure did not perform well as a prognostic factor for important quality-based outcomes of readmission and reoperation. This may be due to the fact that there is not a direct relationship between preoperative opioid

exposure and these secondary outcomes, which is better accounted for in a predictive scheme, such as the SOS score, that considers other clinical and social characteristics beyond degree of opioid use.

In light of the superior performance of the SOS score in this investigation, as well as previous work validating this version of the SOS score for patients undergoing spinal procedures [24], we believe that the prognostic tool can effectively be utilized at the time of preoperative evaluation as a means of opioid risk assessment and to facilitate patient counseling. Shared-decision making regarding postoperative opioid selection, amount and anticipated duration can be made in light of the SOS score. In addition, individuals at very high risk of sustained prescription opioid use following surgery may benefit from delaying an intervention until effective counseling and opioid weaning occurs.

We recognize several limitations to the current work. This research remains a retrospective study, impacted by the shortcomings inherent to such research designs. The academic and community medical centers included in this study are affiliated with one parent organization in one US state and there is potential for shared institutional culture and practices to impact patient selection and postoperative prescription practices. Postoperative opioid prescription surveillance was performed through pharmacy documentation in electronic health records at these medical centers. More reliable approaches to ascertaining all opioid prescriptions received by patients could include query of state-wide prescription databases. Additionally, illicit opioid use and abuse of other substances could not be assessed in this analysis. Given the study design, we were unable to evaluate the impact of preoperative opioid MME or SOS score on patient-reported outcomes, nor were we able to evaluate other potentially important factors such as postoperative complications. We chose not to evaluate postsurgical complications in this study due to previous work that shows poor performance of administrative coding in capturing patients who experience postoperative morbidity [17,26].

Last, we do realize that the prevalence of opioid exposure both in the pre- and postoperative periods is lower than several prior reports, albeit in populations demonstrably different from the one under study here [13]. Some of these distinctions may derive from the recent nature of our data (2016–2019), thus reflecting government-led regulations and limitations on opioid prescribing behavior [27]. National trends reflect this phenomenon at a high-level, with 2018 being the first year in which deaths from opioid prescriptions began to diminish since 1999 [28]. Therefore, we do not consider this fact a true limitation. Rather, we believe it reinforces the utility of the SOS score, even in an environment where the predilection for prescription opioid use is diminishing. Additional retrospective studies might investigate the SOS score's performance in less restrictive prescribing environments, such as using registry data from the years prior to recognition of the opioid crisis (eg, 2000–2013). Further prospective work regarding the efficacy of

the SOS score is necessary, including testing in populations with different sociodemographic, clinical and sustained opioid risk factors from our own. In this regard, we have initiated processes to institute the SOS score as a standardized surveillance measure for patients undergoing orthopedic surgery within our health system.

In conclusion, surgeons are experiencing increased societal and political pressures to reduce the contribution that prescription opioids make to the national burden of opioid abuse. In light of this study's findings, the SOS score may be valuable for identifying individuals at high risk for sustained prescription opioid use and associated adverse events following spine surgery. At a minimum, these results support the introduction of the SOS score to contemporary spine practice. Further work remains to be performed to ensure the system performs well in different health-care settings. Additionally, the clinical efficacy of interventions based on the determinations of the SOS score must be assessed in the future.

References

- [1] Rudd RA, Aleshire N, Zibbell JE, Gladden RM. Increases in drug and opioid overdose deaths—United States, 2000–2014. *MMWR Morb Mortal Wkly Rep* 2016;64(50-51):1378–82.
- [2] Schoenfeld AJ, Nwosu K, Jiang W, Yau AL, Chaudhary MA, Scully RE, et al. Risk factors for prolonged opioid use following spine surgery, and the association with surgical intensity, among opioid-naïve patients. *J Bone Jt Surg Am* 2017;99(15):1247–52.
- [3] Waljee JF, Li L, Brummett CM, Englesbe MJ. Iatrogenic opioid dependence in the United States: are surgeons the gatekeepers? *Ann Surg* 2017;265(4):728–30.
- [4] Karhade AV, Ogink PT, Thio QC, Cha TD, Gormley WB, Hershman SH, et al. Development of machine learning algorithms for prediction of prolonged opioid prescription after surgery for lumbar disc herniation. *Spine J* 2019;19(11):1764–71.
- [5] Manchikanti L, Fellows B, Janata JW, Pampati V, Grider JS, Boswell M. Opioid epidemic in the United States. *Pain Physician* 2012;15(3 Suppl). ES9–38.
- [6] Brummett CM, Waljee JF, Goesling J, Moser S, Lin P, Englesbe MJ, et al. New persistent opioid use after minor and major surgical procedures in US adults. *JAMA Surg* 2017;152(6):e170504.
- [7] Lee D, Armaghani S, Archer KR, Bible J, Shau D, Kay H, et al. Pre-operative opioid use as a predictor of adverse postoperative self-reported outcomes in patients undergoing spine surgery. *J Bone Jt Surg Am* 2014;96(11):e89.
- [8] Jiang X, Orton M, Feng R, Hossain E, Malhotra NR, Zager EL, et al. Chronic opioid usage in surgical patients in a large academic center. *Ann Surg* 2017;265(4):722–7.
- [9] Chaudhary MA, Bhulani N, de Jager EC, Lipsitz S, Kwon NK, Surgeon DJ, et al. Development and validation of a bedside risk assessment for sustained prescription opioid use after surgery. *JAMA Netw Open* 2019;2(7). e196673–e.
- [10] Karhade AV, Thio QC, Ogink PT, Bono CM, Ferrone ML, Oh KS, et al. Predicting 90-day and 1-year mortality in spinal metastatic disease: Development and internal validation. *Neurosurgery* 2019;85(4):E671–E81.
- [11] Van Denburg AN, Vilardaga JP, Shelby RA, Keefe FJ. Opioid therapy and persistent pain: can cognitive behavioral therapy help? *Pain* 2018;159(3):411–5.
- [12] Karhade AV, Ogink PT, Thio QC, Broekman ML, Cha TD, Hershman SH, et al. Machine learning for prediction of sustained opioid

- prescription after anterior cervical discectomy and fusion. *Spine J* 2019;19(6):976–83.
- [13] Lee D, Armaghani S, Archer KR, Bible J, Shau D, Kay H, et al. Preoperative opioid use as a predictor of adverse postoperative self-reported outcomes in patients undergoing spine surgery. *J Bone Jt Surg Am* 2014;96(11):e89.
- [14] Oleisky ER, Pennings JS, Hills J, Sivaganesan A, Khan I, Call R, et al. Comparing different chronic preoperative opioid use definitions on outcomes after spine surgery. *Spine J* 2019;19(6):984–94.
- [15] Karhade AV, Cha TD, Fogel HA, Hershman SH, Tobert DG, Schoenfeld AJ, et al. Predicting prolonged opioid prescriptions in opioid-naïve lumbar spine surgery patients. *Spine J* 2019. S1529-9430(19)31157-X.
- [16] Clarke H, Soneji N, Ko DT, Yun L, Wijeyesundera DN. Rates and risk factors for prolonged opioid use after major surgery: population-based cohort study. *BMJ* 2014;348:g1251.
- [17] Karhade AV, Bongers ME, Groot OQ, Kazarian ER, Cha TD, Fogel HA, et al. Natural language processing for automated detection of incidental durotomy. *Spine J* 2020;20:695–700.
- [18] Li Y, Stocchi L, Cherla D, Liu X, Remzi FH. Association of preoperative narcotic use with postoperative complications and prolonged length of hospital stay in patients with Crohn disease. *JAMA Surg* 2016;151(8):726–34.
- [19] Reid DB, Shah KN, Ruddell JH, Shapiro BH, Akelman E, Robertson AP, et al. Effect of narcotic prescription limiting legislation on opioid utilization following lumbar spine surgery. *Spine J* 2019;19(4):717–25.
- [20] Opioid oral morphine milligram equivalent (MME) conversion factors. Center for Medicare & Medicaid Services; 2017. [cited 2020 January 25]; Available from: <https://www.cms.gov/Medicare/Prescription-Drug-Coverage/PrescriptionDrugCovContra/Downloads/Opioid-Morphine-EQ-Conversion-Factors-Aug-2017.pdf>.
- [21] Steyerberg EW, Vergouwe Y. Towards better clinical prediction models: Seven steps for development and an abcd for validation. *Eur Heart J* 2014;35(29):1925–31.
- [22] Seymour RB, Ring D, Higgins T, Hsu JR. Leading the way to solutions to the opioid epidemic: AOA critical issues. *J Bone Jt Surg Am* 2017;99(21):e113.
- [23] Chaudhary MA, Schoenfeld AJ, Harlow AF, Ranjit A, Scully R, Chowdhury R, et al. Incidence and predictors of opioid prescription at discharge after traumatic injury. *JAMA Surg* 2017;152(10):930–6.
- [24] Karhade AV, Chaudhary MA, Bono CM, Kang JD, Schwab JH, Schoenfeld AJ. Validating the stopping opioids after surgery (SOS) score for sustained postoperative prescription opioid use in spine surgical patients. *Spine J* 2019;19:1666–71.
- [25] Schoenfeld AJ, Belmont Jr. PJ, Blucher JA, Jiang W, Chaudhary MA, Koehlmoos T, et al. Sustained preoperative opioid use is a predictor of continued use following spine surgery. *J Bone Jt Surg Am* 2018;100(11):914–21.
- [26] Campbell PG, Malone J, Yadla S, Chitale R, Nasser R, Maltenfort MG, et al. Comparison of ICD-9–based, retrospective, and prospective assessments of perioperative complications: Assessment of accuracy in reporting. *J Neurosurg Spine* 2011;14(1):16–22.
- [27] Reid DB, Shah KN, Shapiro BH, Ruddell JH, Akelman E, Daniels AH. Mandatory prescription limits and opioid utilization following orthopaedic surgery. *J Bone Jt Surg Am* 2019;101(10):e43.
- [28] Gladden RM, O'Donnell J, Mattson CL, Seth P. Changes in opioid-involved overdose deaths by opioid type and presence of benzodiazepines, cocaine, and methamphetamine—25 states, July–December 2017 to January–June 2018. *MMWR Morb Mortal Wkly Rep* 2019;68(34):737.