Association of Opioid Use Disorder on Postoperative Outcomes Following Lumbar Laminectomy: A Nationwide Retrospective Analysis of the Medicare Population

Adem Idrizi, Noorulain Paracha, Aaron W. Lam, Adam M. Gordon, Ahmed Saleh and Afshin E. Razi

Int J Spine Surg published online 30 June 2022
http://ijssurgery.com/content/early/2022/06/28/8322

The International Journal of Spine Surgery
2397 Waterbury Circle, Suite 1,
Aurora, IL 60504, Phone: +1-630-375-1432

International Journal of Spine Surgery, Vol. 00, No. 0, 2022, pp. 1–7
https://doi.org/10.14444/8322

Association of Opioid Use Disorder on Postoperative Outcomes Following Lumbar Laminectomy: A Nationwide Retrospective Analysis of the Medicare Population

ADEM IDRIZI, BS[1,2]; NOORULAIN PARACHA, BS[1,2]; AARON W. LAM, MD[1]; ADAM M. GORDON, MD[1]; AHMED SALEH, MD[1]; AND AFSHIN E. RAZI, MD[1]

[1]*Department of Orthopaedic Surgery, Maimonides Medical Center, Brooklyn, NY, USA;* [2]*SUNY Downstate Health Sciences University, College of Medicine, Brooklyn, NY, USA*

ABSTRACT

Background: Research focused on the association of opioid use disorder (OUD) on postoperative outcomes in patients undergoing primary lumbar laminectomy is lacking. This study aims to observe the impact of OUD on (1) hospital length of stay (LOS), (2) readmission rates, (3) medical complications, and (4) health care expenditures.

Methods: A retrospective query was performed using a nationwide claims database from January 2005 to March 2014 for all patients who underwent lumbar laminectomy, yielding a total of 131,635 patients. The study cohort included 3515 patients with OUD, while 128,120 patients served as the comparison cohort. Multivariate binomial logistic regression analyses were used to determine the association of OUD on readmission rates and medical complications, whereas Welch's *t* tests were used to compare LOS and health care expenditures. A *P* value less than 0.001 was considered statistically significant.

Results: Patients with OUD undergoing lumbar laminectomy had significantly longer hospital LOS (3.68 vs 1.13 days, $P < 0.0001$). Readmission rates were significantly higher (14.57% vs 7.39%, OR: 1.73, $P < 0.0001$) in patients who had an OUD. The study cohort was found to have higher incidence and odds (32.36% vs 9.76%, OR: 3.53, $P < 0.0001$) of 90-day medical complications and total global 90-day episode of care reimbursement rates ($13,635.81 vs $8131.20, $P < 0.0001$) compared with their counterparts.

Conclusions: This study demonstrates OUD to be associated with longer hospital LOS, increased rates of 90-day readmissions, medical complications, and health care expenditures following lumbar laminectomy.

Level of Evidence: 3.

Clinical Relevance: Results indicate that OUD is associated with worse outcomes following lumbar laminectomy.

Lumbar Spine

Keywords: opioid use disorder, lumbar spine laminectomy, spine decompression, outcomes, complications

INTRODUCTION

According to *The Diagnostic and Statistical Manual for Mental Health Disorders, Fifth Edition*, opioid use disorder (OUD) is characterized by a pattern of excessive, chronic opioid use leading to problems or distress, which can involve misuse of prescription medication, use of diverted medication, or illegally obtained heroin.[1,2] In 2019, approximately 1.6 million people developed an OUD, which resulted in more than 70,000 deaths due to opioid overdose.[3] The disorder has contributed significantly to the opioid epidemic, which has become a national crisis with detrimental impacts on both public health and social and economic welfare.[4,5] Studies have reported the prevalence of patients who consume opioids prior to spine surgery to be as high as 72%.[6–8] Additionally, chronic opioid use and misuse have been linked to several complications following spine surgery.[9]

Specifically, limited studies investigating patients undergoing lumbar laminectomy have shown that those with preoperative opioid use have continued postoperative use and longer hospital length of stay (LOS).[10,11] However, these studies fail to exclusively analyze patients with a clinical diagnosis of OUD who have undergone lumbar laminectomy.[10,11] In addition to the paucity of this poorly studied association of OUD on postoperative complications, these reports have also been limited to their analysis of only continued postoperative opioid use and LOS. Thus, further studies exploring patients who specifically have OUD preoperatively and are undergoing lumbar laminectomy that include other outcome measures are highly warranted.

Therefore, the purpose of this study was to determine the association of OUD on postoperative outcomes following lumbar laminectomy. Specifically, we investigated the impact of OUD on (1) hospital LOS, (2) readmission rates, (3) medical complications, and (4) health care expenditures.

METHODS

A retrospective analysis from 1 January 2005 to 31 March 2014 of the 100% Medicare standard analytical files, part A and B, was performed from the for-fee-based PearlDiver (PearlDiver Technologies, Fort Wayne, Indiana, United States) database. The database contains information of more than 100 million patients from the Medicare claims and a private insurance database known as Mariner. Due to the large number of patients available, researchers have utilized the database for spine-related and other orthopedic subspecialty-based research.[12–14] The database allows researchers to identify and query cohorts of patients using an open-based syntax language via International Classification of Disease, Ninth Revision (ICD-9), ICD-10, Current Procedural Terminology, National Drug Codes, and Diagnostic-Related Group codes. Information is then downloaded as a comma separated value (.csv) spreadsheet for additional data analyses. As the data were derived from a deidentified national surgical database, the study was therefore exempt from Institutional Review Board approval.

The dataset was initially queried for all patients who underwent lumbar laminectomy using the following Current Procedural Terminology codes: 63005, 63012, 63017, and 63047. Patients who had OUD were identified using ICD-9 diagnostic codes 304.01, 304.02, 305.51, and 305.52. These procedural and diagnostic codes were utilized as they have been used in previously published studies.[11,15,16] The "FIRST_INSTANCE" syntax command was utilized to ensure that patients with these procedures and diagnoses were counted for the first time to prevent any overestimation on the association of OUD on the dependent variables measured within the study. Using Boolean command-syntax language of the PearlDiver database, the inclusion criteria for the study cohort were patients undergoing primary lumbar laminectomy with a concomitant diagnosis of OUD; patients without OUD served as the comparison cohort. As patients may enter and leave the Medicare database, patients with active enrollment 1 year prior and 1 year following the procedure were included in the analyses. Exclusions from the study included those patients undergoing surgery for trauma, infections, or malignant etiologies as done in prior investigations.[17,18]

Primary endpoints of the study were to compare hospital LOS, readmission rates, medical complications, and health care expenditures. Readmission rates and medical complications were those that occurred within the 90-day episode of care interval. Complications analyzed included acute kidney injuries, cerebrovascular accidents, deep vein thromboses, ileus episodes, myocardial infarctions, pneumoniae, pulmonary emboli, respiratory failures, transfusion of blood products, urinary tract infections, and venous thromboemboli. For health care expenditures, day of surgery and total global 90-day episode of care interval costs were analyzed using reimbursement data. Reimbursements were chosen as they are a more accurate predictor of what providers are paid from the insurance companies and have been used as a benchmark in previously published studies from the same database.[18,19]

Statistical Analyses

Statistical analyses were performed using the open programming language known as R (R, Foundation for Computational Statistics, Vienna, Austria). Baseline demographics of the 2 cohorts were analyzed using Pearson's χ^2 analyses or Fischer's exact test for categorical variables. The PearlDiver database provides age as a categorical variable for patients younger than 64, 65 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 years or older. In addition to age, other baseline demographics assessed between the 2 cohorts included sex and prevalence of comorbid conditions, which are found within the Elixhauser Comorbidity Index (ECI). An overall mean ECI score was also calculated for each cohort. For continuous variables, Welch's *t* tests were used to assess the significance for LOS, health care expenditures, and mean ECI scores between the 2 cohorts. A multivariate binomial logistic regression model was constructed to determine the association of OUD on readmission rates and medical complications. The model was adjusted for age, sex, geographic region, alcohol use disorder, chronic obstructive pulmonary disease, diabetes mellitus, general anxiety disorder, hyperlipidemia, hypertension, obesity—defined as a body mass index greater than 30 kg/m^2—and tobacco use. These comorbid conditions were entered into the regression model as studies have shown OUD to be associated with these comorbid conditions. To reduce the probability of a type I error, a Bonferroni correction was performed, and a *P* value less than 0.001 was considered to be statistically significant.

Table 1. Baseline demographics of patients with opioid use disorder and comparison cohort undergoing lumbar spine laminectomy.

	Opioid Use Disorder		Comparison Cohort		
Demographics	***n***	**%**	***n***	**%**	***P* Value**
Age, y					<0.0001
<64	1977	56.24	14,522	11.33	
65–69	686	19.52	34,910	27.25	
70–74	409	11.64	32,494	25.36	
75–79	252	7.17	25,603	19.98	
80–84	138	3.93	14,680	11.46	
>85	53	1.51	5911	4.61	
Sex					<0.0001
Female	2011	57.21	62,253	48.59	
Male	1504	42.79	65,867	51.41	
Comorbidities					
Alcohol use disorder	772	21.96	5368	4.19	<0.0001
Arrhythmias	1607	45.72	48,035	37.49	<0.0001
BMI 19–24 kg/m^2	128	3.64	2023	1.58	<0.0001
BMI 25–29 kg/m^2	214	6.09	4277	3.34	<0.0001
BMI 30–39 kg/m^2	614	17.47	12,646	9.87	<0.0001
BMI 40–70 kg/m^2	296	8.42	4322	3.37	<0.0001
Congestive heart failure	1081	30.75	27,085	21.14	<0.0001
Coagulopathy	668	19.00	16,026	12.51	<0.0001
Depressive disorders	2699	76.79	40,359	31.50	<0.0001
Diabetes mellitus	1729	49.19	52,110	40.67	<0.0001
Hypertension	3172	90.24	114,339	89.24	0.001
Hypothyroidism	1374	39.09	40,344	31.49	<0.0001
Iron deficiency anemia	2184	62.13	54,887	42.84	<0.0001
Liver failure	802	22.82	10,566	8.25	<0.0001
Neurological deficits	869	24.72	17,268	13.48	<0.0001
Peptic ulcer disease	649	18.46	12,160	9.49	<0.0001
Peripheral vascular disease	1455	41.39	46,191	36.05	<0.0001
Renal failure	340	9.67	7562	5.90	<0.0001
Rheumatoid arthritis	1466	41.71	26,868	20.97	<0.0001
Valvular disorders	1157	32.92	33,986	26.53	<0.0001
Pathologic weight loss	449	12.77	6939	5.42	<0.0001
Elixhauser Comorbidity Index, mean	9		4		<0.0001

Abbreviation: BMI, body mass index.

RESULTS

Patient Population

A total of 131,635 patients who underwent lumbar laminectomy were identified for analysis following the inclusion/exclusion criteria. Of these cases, 3515 (2.67%) had OUD while 128,120 (97.33%) served as the comparison cohort. Linear regression demonstrated the number of patients with OUD undergoing lumbar laminectomy increased over 3-fold from 317 patients in 2005 to 1091 patients by the end of the first quarter of 2014 ($P < 0.0001$). There were multiple significant differences between the 2 cohorts with respect to age ($P < 0.0001$), sex ($P < 0.0001$), and prevalence of comorbid conditions. The study group contained significantly greater percentage of patients younger than 64 years (56.24%), had a female predominance (57.21%), and more commonly had a significantly higher prevalence of each of the medical comorbidities assessed ($P < 0.0001$) with an exception to hypertension, which was found to be similar to that of the general population (Table 1).

Hospital LOS and Readmission Rates

Patients undergoing lumbar laminectomy with OUD were found to have significantly longer hospital LOS (3.68 vs 1.13 days, $P < 0.0001$). Additionally, study group patients were found to have a higher incidence and odds of readmission rates within the episode of care interval (14.57% vs 7.39%, OR: 1.73, 95% CI: 1.56–1.92, $P < 0.0001$) compared with the matched cohort population.

Ninety-Day Medical Complications and Health Care Expenditures

Patients with OUD who underwent lumbar laminectomy were found to have higher incidence and odds of 90-day medical complications (32.36% vs 9.76%, OR: 3.53, 95% CI: 3.23–3.85, $P < 0.0001$). Specifically, study group patients were found to have higher rates and odds of pneumoniae (6.29% vs 1.23%, OR: 5.23, 95% CI: 3.57–5.99, $P < 0.0001$), requiring transfusion of blood products (0.54% vs 0.15%, OR: 5.12, 95% CI: 2.92–8.48, $P < 0.0001$), respiratory failures (0.54%

Table 2. Comparison of 90-d medical complications between opioid use disorder and comparison cohort following primary lumbar spine laminectomy.

Medical Complications Assessed	Opioid Use Disorder, %	Comparison, %	OR	95% CI	*P* Value[a]
Pneumonia	6.29	1.23	5.23	3.57–5.99	<0.0001
Transfusion of blood products	0.54	0.15	5.12	2.92–8.48	<0.0001
Respiratory failure	0.54	0.12	4.07	2.29–6.87	<0.0001
Urinary tract infection	14.54	4.49	3.57	3.19–3.97	<0.0001
Acute kidney injuries	4.84	1.36	3.31	2.75–3.95	<0.0001
Cerebrovascular accidents	1.74	0.55	3.26	2.42–4.33	<0.0001
Deep vein thromboses	1.48	0.70	2.21	1.61–2.97	<0.0001
Myocardial infarctions	0.77	0.30	2.20	1.40–3.32	<0.0001
Venous thromboemboli	1.62	0.86	2.02	1.50–2.67	0.018
Total medical complications	32.36	9.76	3.53	3.23–3.85	<0.0001

[a]Adjusted for age, sex, geographic region, alcohol use disorder, chronic obstructive pulmonary disease, diabetes mellitus, general anxiety disorder, hyperlipidemia, hypertension, obesity, and tobacco use.

vs 0.12%, OR: 4.07, 95% CI: 2.29–6.87, $P < 0.0001$), urinary tract infections (14.54% vs 4.49%, OR: 3.57, 95% CI: 3.19–3.97, $P < 0.0001$), acute kidney injuries (4.84% vs 1.36%, OR: 3.31, 95% CI: 2.75–3.95, $P < 0.0001$), in addition to other medical complications compared with patients without OUD who underwent lumbar laminectomy (Table 2).

When assessing health care expenditures, patients with OUD were found to have significantly higher day of surgery ($9114.70 vs $5923.80, $P < 0.0001$) and total global 90-day episode of care reimbursement rates ($13635.81 vs $8131.20, $P < 0.0001$) compared with the matched cohort following primary lumbar laminectomy.

DISCUSSION

The opioid epidemic in the United States continues to be a public health crisis, evident by an increase in misuse, overuse, and deaths related to opioid overdose.[20] Increased opioid prescriptions and use in chronic pain patients add to this epidemic with 8% to 12% of these patients developing OUD.[21,22] Patients with back pain are more likely to be prescribed higher opioid doses than those with other pain diagnoses.[23] Specifically, more than half the total number of patients taking opioids long term have low back pain.[21,24] In a 9-year study, Martin et al showed a 660% increase in opioid expenditures nationally for spine-related pain.[25] However, studies evaluating the association of chronic opioid consumption on outcomes following lumbar spine surgery are limited. Therefore, it is imperative to study the association of opioid dependence and abuse on spine surgery outcomes, especially for patients undergoing lumbar laminectomy. This study found that patients with OUD have significantly longer hospital LOS, in addition to greater rates of readmissions, medical complications, and health care expenditures when undergoing laminectomy procedures of the lumbar spine.

The results of this investigation coincide with the results of other published studies, as it is well established that preoperative opioid use leads to prolonged hospitalization duration, especially following spine surgery.[9,11,26,27] This study found that patients with OUD had a significantly longer hospital LOS (3.68 vs 1.13 days, $P < 0.0001$) than the comparison population following lumbar laminectomy. Kha et al found that patients with preoperative opioid use have longer hospital LOS (3.7 vs 3.2 days; $P = 0.1009$) compared with the nonopioid group, although this group did not find this to be statistically significant nor did they identify patients with a clinical OUD.[11] Although the present study is the first to show that patients with OUD have longer hospital LOS following lumbar laminectomy, similar studies investigating patients undergoing lumbar fusion found that patients with opioid dependence have longer hospital LOS as well.[26,27] Tank et al found that opioid-dependent patients undergoing lumbar fusion had 2.11 times higher odds of prolonged LOS.[26] Martini et al showed that patients with OUD tended to have extended hospitalization following lumbar fusion for disc degeneration.[27] In addition to prolonged hospital LOS, the present study demonstrated an association of OUD with higher odds of readmissions (OR: 1.73, $P < 0.0001$).

Using commercial insurance data from the Humana database, Jain et al found that out of 24,610 patients studied, 5500 patients undergoing 1- and 2-level posterior lumbar fusion with preoperative chronic opioid therapy (COT) had a significantly higher risk of 90-day readmissions (OR: 1.15; $P = 0.02$) for all complications compared with patients who did not have preoperative COT.[28] In another recent study by the same group, the investigators demonstrated that patients undergoing lumbar discectomy with chronic preoperative opioid use, which included patients with 10 or more prescriptions within 1 year before the scheduled surgery and those with an OUD, had 118% higher readmissions

compared with patients of <3 months opioid use.[29] One potential explanation for the higher rates of readmissions could be due to the higher medical complications observed within the study.

Patients with chronic preoperative opioid use and those with OUD have been shown by numerous studies to be linked with increased medical complications following several types of orthopedic surgeries.[16,26–28,30–32] Regarding lumbar fusions, Jain et al showed that patients with preoperative COT had increased risk of 90-day wound complications.[28] This association between opioid use and wound complications may be explained by the immunosuppressive nature of opioid therapy.[33,34] Interestingly, Jain et al discovered that preoperative COT did not have a significant association with pulmonary, cardiac, or renal pain, dysphagia, deep vein thrombosis, or 90-day risk of systemic infection following lumbar fusion.[28] The results by Jain et al contradict not only the results of this current investigation but also those of Martini et al who discovered that patients with OUD had significantly higher odds of various medical complications, including pneumoniae (OR: 3.059; $P = 0.0115$), venous thromboembolism (OR: 4.165; $P = 0006$), and urinary tract infections (OR: 2.626; $P = 0.0024$) following lumbar fusion.[27] These contrasting findings delineate the importance of distinguishing patients with chronic preoperative opioid use to those with OUD. The frequency and incidence of medical complications, which were seen in patients with OUD, could explain the higher economic expenditure noticed in the study cohort.

Studies focused on spine surgery have shown that preoperative opioid use and dependence lead to increased cost of care.[9,26,27,30,31] Supporting the results of the current study, Berg et al found that opioid dependence among patients undergoing posterior lumbar fusion led to significantly increased hospitalization charges ($37,712.98 vs $30,475.43, $P < 0.001$) compared with nonopioid-dependent patients.[35] The current study showed that OUD had a significant association with pneumonia (OR: 5.23; $P < 0.0001$), which can explain increased costs. Tong et al showed that the mean cost for pneumonia treatment requiring hospitalization was $10962.50.[36]Additionally, the annual financial burden on blood transfusions exceeds $10 billion, though this likely underestimates current costs given time and inflation.[37] There are several approaches orthopedic surgeons can take to reduce postoperative complications for patients with OUD. Using a multimodal analgesic approach to manage pain can reduce opioid consumption postoperatively.[38] Additionally, a 3-month prescription-free period prior to orthopedic surgery can reduce risks for chronic opioid users.[39]

Despite the strengths of using a large national database, there are several limitations to this study. Primarily, its retrospective nature could have led to selection biases based on study design alone. Additionally, the study relies on accurate coding for proper patient identification and procedural and diagnostic coding; however, there are up to 1.3% of coding errors within the use of administrative databases.[40] Furthermore, there may be an underestimation of patients with OUD due to any lack of clinical diagnoses, which could potentially underestimate the analyses of the dependent variables within the study and comparison cohorts. Although patients in the study cohort had a documented diagnosis of OUD, the type of opioid, route of administration, and frequency of use were not available within the Medicare database analyzed and therefore not used to further classify OUD. Additionally, there were baseline differences between the cohorts and while they were controlled statistically, there exists a potential that these differences may bias the results observed. Variations of surgical procedures and protocols for lumbar laminectomy can be an important factor impacting outcomes, but this information was not provided by the database. Also, this study did not analyze lumbar decompression–specific complications including dural tears, worsening back pain, nerve injury, and functional scores. Last, analysis of this study was done using a single insurance database, and the results may not be generalizable and a true representation of the impact of OUD following lumbar laminectomy of those patients with different insurance companies. Despite these limitations, this is the first study to use a large patient population to analyze the association between OUD on multiple outcomes following lumbar laminectomy.

CONCLUSION

Patients with OUD are at a significant risk for increased hospital LOS, readmission rates, medical complications, and health care expenditures following lumbar decompression surgery. Spine surgeons should seek to identify patients with OUD and determine strategies to optimize patient care in the perioperative course of lumbar surgery.

REFERENCES

1. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. American Psychiatric Association; 2013. doi:10.1176/appi.books.9780890425596

2. Alexander M. D, Nitesh K. J, Mohit G. *Opioid Use Disorder | Psychiatry.Org*. StatPearls; 2021. https://www.psychiatry.org/patients-families/addiction/opioid-use-disorder/opioid-use-disorder. Accessed June 28, 2021.

3. Center for Behavioral Health Statistics S. *Results from the 2019 National Survey on Drug Use and Health: Detailed Tables*. 2020. https://www.samhsa.gov/data/.

4. Luo F, Li M, Florence C. State-level economic costs of opioid use disorder and fatal opioid overdose - United States, 2017. *MMWR Morb Mortal Wkly Rep*. 2021;70(15):541–546. doi:10.15585/mmwr.mm7015a1

5. Mattson CL, Tanz LJ, Quinn K, Kariisa M, Patel P, Davis NL. Trends and geographic patterns in drug and synthetic opioid overdose deaths - United States, 2013-2019. *MMWR Morb Mortal Wkly Rep*. 2021;70(6):202–207. doi:10.15585/mmwr.mm7006a4

6. Armaghani SJ, Lee DS, Bible JE, et al. Increased preoperative narcotic use and its association with postoperative complications and length of hospital stay in patients undergoing spine surgery. *Clin Spine Surg*. 2016;29(2):E93-8. doi:10.1097/BSD.0000000000000109

7. Dunn LK, Yerra S, Fang S, et al. Incidence and risk factors for chronic postoperative opioid use after major spine surgery: a cross-sectional study with longitudinal outcome. *Anesth Analg*. 2018;127(1):247–254. doi:10.1213/ANE.0000000000003338

8. Stratton A, Wai E, Kingwell S, et al. Opioid use trends in patients undergoing elective thoracic and lumbar spine surgery. *Can J Surg*. 2020;63(3):E306–E312. doi:10.1503/cjs.018218

9. Yerneni K, Nichols N, Abecassis ZA, Karras CL, Tan LA. Preoperative opioid use and clinical outcomes in spine surgery: a systematic review. *Neurosurgery*. 2020;86(6):E490–E507. doi:10.1093/neuros/nyaa050

10. Schoenfeld AJ, Belmont PJJ, Blucher JA, et al. Sustained preoperative opioid use is a predictor of continued use following spine surgery. *J Bone Joint Surg Am*. 2018;100(11):914–921. doi:10.2106/JBJS.17.00862

11. Kha ST, Scheman J, Davin S, Benzel EC. The impact of preoperative chronic opioid therapy in patients undergoing decompression laminectomy of the lumbar spine. *Spine (Phila Pa 1976)*. 2020;45(7):438–443. doi:10.1097/BRS.0000000000003297

12. Hindoyan K, Tilan J, Buser Z, et al. A retrospective analysis of complications associated with bone morphogenetic protein 2 in anterior lumbar interbody fusion. *Global Spine J*. 2017;7(2):148–153. doi:10.1177/2192568217694010

13. Cancienne JM, Brockmeier SF, Carson EW, Werner BC. Risk factors for infection after shoulder arthroscopy in a large medicare population. *Am J Sports Med*. 2018;46(4):809–814. doi:10.1177/0363546517749212

14. Ofa SA, Ross BJ, Flick TR, Patel AH, Sherman WF. Robotic total knee arthroplasty vs conventional total knee arthroplasty: a nationwide database study. *Arthroplast Today*. 2020;6(4):1001–1008. doi:10.1016/j.artd.2020.09.014

15. Nazareth A, D'Oro A, Liu JC, et al. Risk factors for postoperative venous thromboembolic events in patients undergoing lumbar spine surgery. *Global Spine J*. 2019;9(4):409–416. doi:10.1177/2192568218797094

16. Vakharia RM, Sabeh KG, Cohen-Levy WB, Sodhi N, Mont MA, Roche MW. Opioid disorders are associated with thromboemboli following primary total knee arthroplasty. *J Arthroplasty*. 2019;34(12):2957–2961. doi:10.1016/j.arth.2019.07.042

17. Puvanesarajah V, Cancienne JM, Werner BC, et al. Perioperative complications associated with posterolateral spine fusions: a study of elderly medicare beneficiaries. *Spine (Phila Pa 1976)*. 2018;43(1):16–21. doi:10.1097/BRS.0000000000001771

18. Bell J, Sequeira S, Kamalapathy P, Puvanesarajah V, Hassanzadeh H. Rheumatoid arthritis increases risk of medical complications following posterior lumbar fusion. *World Neurosurg*. 2021;149:e729–e736. doi:10.1016/j.wneu.2021.01.110

19. Brown AE, Lebovic J, Alas H, et al. A cost utility analysis of treating different adult spinal deformity frailty states. *J Clin Neurosci*. 2020;80:223–228. doi:10.1016/j.jocn.2020.07.047

20. Mattson CL, Tanz LJ, Quinn K, Kariisa M, Patel P, Davis NL. Trends and geographic patterns in drug and synthetic opioid overdose deaths - United States, 2013-2019. *MMWR Morb Mortal Wkly Rep*. 2021;70(6):202–207. doi:10.15585/mmwr.mm7006a4

21. Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. *Lancet*. 2018;391(10137):2368–2383. doi:10.1016/S0140-6736(18)30489-6

22. Vowles KE, McEntee ML, Julnes PS, Frohe T, Ney JP, van der Goes DN. Rates of opioid misuse, abuse, and addiction in chronic pain: a systematic review and data synthesis. *Pain*. 2015;156(4):569–576. doi:10.1097/01.j.pain.0000460357.01998.f1

23. Morasco BJ, Duckart JP, Carr TP, Deyo RA, Dobscha SK. Clinical characteristics of veterans prescribed high doses of opioid medications for chronic non-cancer pain. *Pain*. 2010;151(3):625–632. doi:10.1016/j.pain.2010.08.002

24. Deyo RA, Von Korff M, Duhrkoop D. Opioids for low back pain. *BMJ*. 2015;350. doi:10.1136/bmj.g6380

25. Martin BI, Turner JA, Mirza SK, Lee MJ, Comstock BA, Deyo RA. Trends in health care expenditures, utilization, and health status among US adults with spine problems, 1997-2006. *Spine (Phila Pa 1976)*. 2009;34(19):2077–2084. doi:10.1097/BRS.0b013e3181b1fad1

26. Tank A, Hobbs J, Ramos E, Rubin DS. Opioid dependence and prolonged length of stay in lumbar fusion: a retrospective study utilizing the national inpatient sample 2003-2014. *Spine (Phila Pa 1976)*. 2018;43(24):1739–1745. doi:10.1097/BRS.0000000000002714

27. Martini ML, Nistal DA, Deutsch BC, Caridi JM. Characterizing the risk and outcome profiles of lumbar fusion procedures in patients with opioid use disorders: a step toward improving enhanced recovery protocols for a unique patient population. *Neurosurg Focus*. 2019;46(4). doi:10.3171/2019.1.FOCUS18652

28. Jain N, Phillips FM, Weaver T, Khan SN. Preoperative chronic opioid therapy: a risk factor for complications, readmission, continued opioid use and increased costs after one- and two-level posterior lumbar fusion. *Spine (Phila Pa 1976)*. 2018;43(19):1331–1338. doi:10.1097/BRS.0000000000002609

29. Jain N, Sharma M, Wang D, Ugiliweneza B, Drazin D, Boakye M. Burden of preoperative opioid use and its impact on healthcare utilization after primary single level lumbar discectomy. *Spine J*. 2021;21(10):1700–1710. doi:10.1016/j.spinee.2021.04.013

30. Vakharia RM, Donnally IiiCJ, Rush IiiAJ, et al. Comparison of implant survivability in primary 1- to 2-level lumbar fusion amongst opioid abusers and non-opioid abusers. *J Spine Surg*. 2018;4(3):568–574. doi:10.21037/jss.2018.07.07

31. Jain N, Brock JL, Phillips FM, Weaver T, Khan SN. Chronic preoperative opioid use is a risk factor for increased complications, resource use, and costs after cervical fusion. *Spine J*. 2018;18(11):1989–1998. doi:10.1016/j.spinee.2018.03.015

32. Wilson JM, Farley KX, Gottschalk MB, Daly CA, Wagner ER. Preoperative opioid use is an independent risk factor for

complication, revision, and increased health care utilization following primary total shoulder arthroplasty. *J Shoulder Elbow Surg*. 2021;30(5):1025–1033. doi:10.1016/j.jse.2020.08.007

33. Sacerdote P. Opioid-induced immunosuppression. *Curr Opin Support Palliat Care*. 2008;2(1):14–18. doi:10.1097/SPC.0b013e3282f5272e

34. Sacerdote P, Franchi S, Panerai AE. Non-analgesic effects of opioids: mechanisms and potential clinical relevance of opioid-induced immunodepression. *Curr Pharm Des*. 2012;18(37):6034–6042. doi:10.2174/138161212803582496

35. Berg J, Wahood W, Zreik J, et al. Economic burden of hospitalizations associated with opioid dependence among patients undergoing spinal fusion. *World Neurosurg*. 2021;151:e738–e746. doi:10.1016/j.wneu.2021.04.116

36. Tong S, Amand C, Kieffer A, Kyaw MH. Trends in healthcare utilization and costs associated with pneumonia in the United States during 2008-2014 11 medical and health sciences 1117 public health and health services. *BMC Health Serv Res*. 2018;18(1). doi:10.1186/s12913-018-3529-4

37. Shander A, Hofmann A, Ozawa S, Theusinger OM, Gombotz H, Spahn DR. Activity-based costs of blood transfusions in surgical patients at four hospitals. *Transfusion*. 2010;50(4):753–765. doi:10.1111/j.1537-2995.2009.02518.x

38. Koepke EJ, Manning EL, Miller TE, Ganesh A, Williams DGA, Manning MW. The rising tide of opioid use and abuse: the role of the anesthesiologist. *Perioper Med (Lond)*. 2018;7(1):16. doi:10.1186/s13741-018-0097-4

39. Jain N, Brock JL, Malik AT, Phillips FM, Khan SN. Prediction of complications, readmission, and revision surgery based on duration of preoperative opioid use: analysis of major joint replacement and lumbar fusion. *J Bone Jt Surgery, Am Vol*. 2019;101(5):384–391. doi:10.2106/JBJS.18.00502

40. CMS. Medicare fee-for-service 2016 improper payments report executive summary the medicare fee-for-service improper payments report. www.cms.gov/cert.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

IRB Approval: IRB approval was deemed exempt as this was a database study which did not apply to patient medical records.

Corresponding Author: Adem Idrizi, Department of Orthopaedic Surgery, Maimonides Medical Center, 927 49th St, Brooklyn, NY 11219, USA; adem.idrizi@downstate.edu

Published 28 June 2022