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Reduction in Narcotic Use After Lumbar Decompression and Fusion in Patients With Symptomatic Lumbar Stenosis or Spondylolisthesis

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Abstract

Study Design: Retrospective cohort study.

Objectives: The purpose of this study is to assess change in opioid use before and after lumbar decompression and fusion surgery for patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods: A large insurance database was queried for patients with symptomatic lumbar stenosis or spondylolisthesis undergoing index lumbar decompression and fusion procedures between 2007 and 2016. This database consists of 20.9 million covered lives and includes private/commercially insured and Medicare Advantage beneficiaries. Opioid use 6 months preoperatively through 2 years postoperatively was assessed.

Results: The study included 13 257 patients that underwent 1-, 2-, or 3-level posterior lumbar instrumented fusion. Overall, 57.8% of patients used opioids preoperatively. Throughout the 6-month preoperative period, 2 368 008 opioid pills were billed for (51.6 opioid pills/opioid user/month). When compared with preoperative opioid use, patients billed fewer opioid medications in the 2-year period postoperatively: 33.6 pills/patient/month (8 851 616 total pills). In a multivariate logistic regression analysis, obesity (odds ratio [OR] 1.10, 95% CI 1.004-1.212), preoperative narcotic use (OR 3.43, 95% CI 3.179-3.708), length of hospital stay (OR 1.02, 95% CI 1.010-1.021), and receiving treatment in the South (OR 1.18, 95% CI 1.074-1.287) or West (OR 1.26, 95% CI 1.095-1.452) were independently associated with prolonged postoperative (>1 year) opioid use. Additionally, males (OR 0.87, 95% CI 0.808-0.945) were less likely to use long-term opioid therapy.

Conclusions: This study demonstrates that reduction in opioid use was observed postoperatively in comparison with preoperative values in patients with symptomatic lumbar stenosis or spondylolisthesis that underwent lumbar decompression with fusion. Further prospective studies that are more methodologically stringent are needed to corroborate our findings.

Keywords

spondylolisthesis, constriction, pathologic, analgesics, opioid, decompression, surgical, lumbosacral region, postoperative period, preoperative period

Introduction

Lumbar stenosis and spondylolisthesis are 2 of the most common indications for spine surgery.[1,2] While the majority of patients are managed nonoperatively, a subset of patients' require surgery.[1] Surgery can provide a significant improvement in pain and quality of life, as well as a reduction in opioid use.[3,4] While surgery may be the inaugural event for some

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patients to obtain a prescription for narcotics, the majority of patients' present for surgery after a prolonged course of narcotic use (ie, *after maximum medical management*).

When used appropriately, opioid analgesics play an important role as a safe and effective method for acute pain relief. However, the benefits of opioids in treating pain needs to be balanced with their risk, including tolerance, dependence, and abuse. The Centers for Disease Control and Prevention described opioid-associated morbidity and mortality as a national "prescription painkiller overdose epidemic"; and nearly 500 individuals die each week in the United States due to opioid overdose. A retrospective study by Brat et al[5] assessed the misuse of opioids prescribed to postsurgical opioid naïve patients for acute pain management demonstrated that prolonged duration of opioids rather than medication dose was more strongly associated with misuse; where each prescription refill was associated with a 44% increase in the rate of misuse (95% CI 40.8% to 47.2%, $P < .001$). Furthermore, of the 568 465 opioid naïve patients receiving postoperative narcotics, upward of 10% were identified as abusing or misusing their opioid prescriptions.[5] Given the aforementioned risk of prolonged opioid use, we sought to characterize the change in opioid use after lumbar surgery.

To this end, the purpose of this study was to assess the change in opioid use before and after lumbar decompression and fusion surgery for patients with symptomatic lumbar stenosis or spondylolisthesis.

Methods

Data Source

The study sample was derived from a large insurance database. This database consists of 20.9 million covered lives and includes private/commercially insured and Medicare Advantage beneficiaries with an orthopedic diagnosis. Research files were accessed on a remote server hosted by PearlDiver (PearlDiver Technologies, Inc, Colorado Springs, CO). Research records are searchable by Current Procedural Terminology (CPT), National Drug Code (NDC), International Classification of Diseases (ICD) diagnosis and procedure codes, generic drug codes specific, prescription name, and lab results based on Logical Observation Identifiers Names and Codes (LOINC).

Patient Sample

We included adult patients ($\geq$19 years old) with degenerative conditions of the lumbosacral spine who underwent an index 1-, 2-, or 3-level lumbar decompression and fusion procedure between 2007 and 2016. Patients with the following ICD-9 and ICD-10 diagnosis codes (721.3, 721.42 722.10 722.52 722.73 722.93 724.02 724.03 724.20 724.40 724.50) prior to a spinal fusion operation were included in the study sample. Patients with first occurrence ICD-9 or ICD-10 procedure codes (81.07, 81.08, 81.62) were used to identify all primary 1-, 2-, or 3-level fusions. Only patients that were continuously active within the insurance system 6 months prior and 2 years after the index operation were considered in the analysis. Patients were excluded if they underwent greater than 3-level lumbar fusions (81.63, 81.64), had an anterior approach (81.06), or had a history of cervical fusions (81.02, 81.03) or thoracic fusions (81.04, 81.05). Additionally, patients with concurrent diagnosis of fracture (80.54, 80.55, 80.56, 80.57, 80.58, 80.59) or malignancy (170.2, 170.6) were excluded. For each of the aforementioned ICD-9 codes, the relevant corresponding ICD-10 codes were incorporated into the patient selection/exclusion criteria (Appendix A).

Opioid Use

Opioid use 6 months prior to index surgery through 2-years after surgery was captured. Generic opioid codes specific to the insurance company were used to capture prescriptions before and after surgery (Appendix B). Specifically, we queried the most frequently prescribed opiate formulations, including oxycodone hydrochloride, hydrocodone/acetaminophen, and oxycodone/acetaminophen, which were prescribed in the majority (>80%) of patients with alternative formulations used in the minority of patients. For preoperative versus postoperative narcotic use comparison, opioid use was normalized to number of pills per patient per month by dividing the total pill count billed by the total number of opioid-using patients and by total time (in months).

Baseline Demographics and Comorbidities

Demographics such as age, gender, geographical region, and ethnicity were captured. As a measure for ensuring patient privacy, patient age data is binned into buckets consisting of 5-year intervals. Patient geographic region is separated into 4 regions (Midwest, Northeast, South, and West), consistent with US census bureau definitions, and is based on the location in which the insurance claim was made. Additionally, ICD-9 and ICD-10 diagnosis codes were used to collect preoperative comorbidities known to influence outcomes in spinal surgery, which included obesity (body mass index $\geq$30 kg/m^2), type 2 diabetes mellitus, smoking status, atrial fibrillation (AFib), myocardial infarction (MI), and chronic obstructive pulmonary disease (COPD), (Appendix C). As an additional variable, hospital length of stay (LOS) associated with the index lumbosacral fusion was obtained for the patient cohort.

Data Analysis

The primary aim of the study was to assess change in opioid used before and after index lumbar decompression and fusion. Direct statistical comparisons were made between opiate use cohorts via chi-square and Mann-Whitney tests when possible and appropriate. P values <.05 were considered statistically significant findings. The secondary aims were to investigate the independent predictors of prolonged opioid use after surgery as well as regional differences in opioid prescription after lumbar fusion surgery. Demographic variables and

Table 1. Characteristics of Lumbosacral Fusion Population.

Characteristic	Patients	%
Total	13 257	n/a
Male	5386	40.6
Female	7871	59.4
Geographical region breakdown		
Midwest	3222	24.3
Northeast	276	2.1
South	8361	63.1
West	1398	10.5
Racial breakdown		
Unknown	1302	9.8
White	10 727	80.9
Black	926	7.0
Other	107	0.8
Asian	33	0.2
Hispanic	132	1.0
North American Native	30	0.2
Preoperative comorbidities		
Obesity (BMI >30 kg/m^2)	3063	23.1
Type 2 diabetes mellitus	4823	36.4
Myocardial infarction	308	2.3
Atrial fibrillation	1071	8.1
Smoking	2295	17.3
COPD	1135	8.6
Opioid use		
Any opioid use 6 months prior to fusion	7656	57.8
Any opioid use 2 years after fusion	10 981	82.8
Patients with prolonged (>1 year) opioid use after fusion	8740	65.9
Patients without prolonged (>1 year) opioid use after fusion	4517	34.1

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; n/a, not applicable.

comorbidities, including age, gender, geographic region, obesity, hospital LOS, and a history of narcotic use 6 months prior to fusion served as covariates in the regression model. Multivariate logistic regression was performed to identify independent predictors of chronic opioid use (defined as opioid use >1 year after surgery). The multivariate regression analysis was carried out in R (The R Project for Statistical Computing) through the PearlDiver database. It should be noted that patient aged 20 to 24 years, female gender, and Midwest region are used for the multivariate baseline comparison group for age, gender, and region, respectively. The terms cost, payment, and reimbursement are used interchangeably to report financial data and represents the actual amount paid by insurers.

Results

Patient Sample

A total of 13 257 patients underwent 1-, 2-, or 3-level posterior lumbar instrumented fusion and satisfied the inclusion criteria (Table 1). Demographically, females (59.4%) and Caucasians (80.9%) comprised the majority of the population. The largest portion of insurance claims were made from the South (63.1%) and Midwest (24.3%) geographic sectors (Table 1). Preoperative comorbidity prevalence was as follows: 17.3% of patients were smokers, 36.4% of patients had type 2 diabetes mellitus, 23.1% were obese, 8.6% of patients had COPD, and 8.1% had AFib (Table 1).

Table 2. Number of Unique Patients Who Used Opioids 6 Months Prior to Fusion Compared With 2 Years After Fusion, N (%).

Characteristic	Patients With Any Opioid Use 6 Months Prior to Fusion	Patients With Any Opioid Use Within 2 Years After Fusion	*P*
Total patients	7656	10 981	n/a
Male	3063 (40.0)	4443 (40.5)	.5451
Female	4593 (60.0)	6538 (59.5)	
Geographical region breakdown			
Midwest	1763 (23.0)	2564 (23.3)	.9638
Northeast	149 (1.9)	215 (2.0)	
South	4928 (64.4)	7027 (64.0)	
West	816 (10.7)	1175 (10.7)	
Race breakdown			
Unknown	700 (9.1)	1025 (9.3)	.9064
White	6228 (81.3)	8915 (81.2)	
Black	572 (7.5)	807 (7.3)	
Other	53 (0.7)	83 (0.8)	
Asian	20 (0.3)	23 (0.2)	
Hispanic	72 (0.9)	105 (1.0)	
North American Native	11 (0.1)	23 (0.2)	

Abbreviation: n/a, not applicable

Preoperative Opioid Use

Overall, 7656 (57.8%) of patients had a history of opioid use prior to the index surgery (Table 2). Of these, 60.0% were female and 64.4% were geographically from the South. Over the 6-month period prior to the index operation, a total of 2 368 008 opioid pills (males 947 559 pills; females 1 420 449 pills) were billed for (Table 3). Geographically, 1 496 669 opioid pills were billed by patients from the South, 557 608 opioid pills were billed by patients from the Midwest, and patients from the West billed 255 752 opioid pills (Table 3). When normalized by pill count per patient per month, on average 51.6 opioid pills were billed by patients monthly prior to index surgery (Table 4). The total costs of opioids billed over a 6-month period prior to index surgery was $737 215 (males $315 536; females $421 679) (Table 5). This figure results in a normalized cost of $16.05 per opioid user per month (Table 6).

Postoperative Opioid Use

Overall, 10 981 (82.8%) patients used opiates within the 2-year postoperative period. Additionally, 8740 (65.9%) patients were identified to have continuous opioid use at 1-year postoperatively (Table 1). Postoperative opioid use

Table 3. Total Opioid Units Billed (Pill Count) Comparison in Patients 6 Months Prior to Fusion Versus 2 Years Following Fusion, N (%).

Characteristic	Patients With Any Opioid Use 6 Months Prior to Fusion	Patients With Any Opioid Use Within 2 Years After Fusion
Total patients	2 368 008	8 851 616
Male	947 559 (40.0)	3 630 927 (41.0)
Female	1 420 449 (60.0)	5 220 689 (59.0)
Geographical region breakdown		
Midwest	557 608 (23.5)	2 022 153 (22.8)
Northeast	57 979 (2.4)	182 519 (2.1)
South	1 496 669 (63.2)	5 719 225 (64.6)
West	255 752 (10.8)	927 719 (10.5)
Race breakdown		
Unknown	189 562 (8.0)	712 367 (8.0)
White	1 962 550 (82.9)	7 319 115 (82.7)
Black	161 994 (6.8)	612 600 (6.9)
Other	15 636 (0.7)	68 207 (0.8)
Asian	3370 (0.1)	10 972 (0.1)
Hispanic	30 205 (1.3)	103 312 (1.2)
North American Native	4691 (0.2)	25 043 (0.3)

Table 4. Normalized Opioid Units Billed (Pills/Patient/Month) Comparison in Patients 6 Months Prior to Fusion Versus 2 Years Following Fusion.

Characteristic	Patients With Any Opioid Use 6 Month Prior to Fusion	Patients With Any Opioid Use Within 2 Years After Fusion
Total patients	51.6	33.6
Male	51.6	34.1
Female	51.5	33.3
Geographical region breakdown		
Midwest	52.7	32.9
Northeast	64.9	35.4
South	50.6	33.9
West	52.2	32.9
Race breakdown		
Unknown	45.1	29.0
White	52.5	34.2
Black	47.2	31.6
Other	49.2	34.2
Asian	28.1	19.9
Hispanic	69.9	41.0
North American Native	71.1	45.4

was higher among women (6538 patients, 59.5%) (Table 2). Of the 10 981 patients using opioids after surgery, 7027 (64.0%) patients were from the South and 2564 (23.3%) from the Midwest geographic regions.

Over the 2-year period after index lumbar surgery, a total of 8 851 616 opioid pills were billed for (males 3 630 927 vs females 5 220 689) (Table 3). When normalized by pill count per patient per month, on average 33.6 opioid pills were billed by patients monthly after index surgery (Table 4). When compared with preoperative opioid use, patients billed fewer opioid medications after lumbar fusion (preoperative pills/patient/month 51.6 vs postoperative pills/patient/month 33.6) (Table 4). There was no statistical difference ($P > .05$) in the demographic distribution of patients using opiates prior to surgery versus after the index operation (Table 2).

Table 5. Total Dollars Billed for Opioids (USD) in Patients 6 Months Prior to Fusion Compared With 2 Years Following Fusion, N (%).

Characteristic	Patients With Any Opioid Use 6 Months Prior to Fusion	Patients With Any Opioid Use Within 2 years After Fusion
Total patients	737 215	3 054 860
Male	315 536 (42.8)	1 330 647 (43.6)
Female	421 679 (57.2)	1 724 213 (56.4)
Geographical region breakdown		
Midwest	155 127 (21.0)	592 580 (19.4)
Northeast	25 785 (3.5)	76 156 (2.5)
South	465 958 (63.2)	1 992 566 (65.2)
West	90 345 (12.3)	393 558 (12.9)
Race breakdown		
Unknown	80 719 (10.9)	375 452 (12.3)
White	586 454 (79.5)	2 399 834 (78.6)
Black	53 429 (7.2)	221 459 (7.2)
Other	4998 (0.7)	22 012 (0.7)
Asian	864 (0.1)	2367 (0.1)
Hispanic	9857 (1.3)	27 820 (0.9)
North American Native	894 (0.1)	5916 (0.2)

Abbreviation: USD, United States dollars.

Total costs of opioids consumed over a 2-year period after surgery was $3 054 860 (males $1 330 647 vs females $1 724 213). As a percentage of the total costs, $1 992 566 (65.2%) was paid for claims filed in the South and $592 580 (19.4%) for claims filed in the Midwest.

Predictors of Prolonged Narcotic Use After Surgery

Compared to patients without prolonged narcotic use after surgery, patients with continuous opioid use (>1 year) after surgery were more likely to be obese (prolonged use 24.5% vs no prolonged use 20.3%, $P < .0001$), have a history of type 2 diabetes (prolonged use 37.0% vs no prolonged use 35.1%, $P < .05$), and smoking (prolonged use 20.3% vs no prolonged use 11.4%, $P < .05$). In the cohort of patients with prolonged narcotic use, 68.4% had a history of opioid consumption within the 6 months prior to index surgery compared with 37.1% in patients without prolonged narcotic use (Table 7).

In a multivariate logistic regression analysis, obesity (odds ratio [OR] 1.10, 95% CI 1.004-1.212), preoperative narcotic use (OR 3.43, 95% CI 3.179-3.708), length of hospital stay (OR 1.02, 95% CI 1.010-1.021), receiving treatment South

Table 6. Normalized Dollars Spent on Opioids (USD/Patient/Month) Comparison in Patients 6 Months Prior to Fusion Versus 2 Years Following Fusion.

Characteristic	Patients With Any Opioid Use 6 Months Prior to Fusion	Patients With Any Opioid Use Within 2 Years After Fusion
Total patients	16.05	11.59
Male	17.17	12.48
Female	15.30	10.99
Geographical region breakdown		
Midwest	14.67	9.63
Northeast	28.84	14.76
South	15.76	11.81
West	18.45	13.96
Race breakdown		
Unknown	19.22	15.26
White	15.69	11.22
Black	15.57	11.43
Other	15.72	11.05
Asian	7.20	4.29
Hispanic	22.82	11.04
North American Native	13.55	10.72

Abbreviation: USD, United States dollars.

(OR 1.18, 95% CI 1.074-1.287) or West (OR 1.26, 95% CI 1.095-1.452) were independently associated with prolonged (>1 year) opioid use after index surgery. Additionally, males (OR 0.87, 95% CI 0.808-0.945) were less likely to rely on long-term opioid therapy (Table 8).

Discussion

In this retrospective study of 13 257 adult patients undergoing 1-, 2-, or 3-level posterior lumbar instrumented fusion, we observed that the majority (57.8%) of patients had a history of opioid use prior to index surgery. During the 6-month period prior to lumbar fusion, an average of 51.6 opioid pills were billed by each opioid using patient per month; while over the 2-year period following index surgery patients billed an average of 33.6 opioid pills per month. These results suggest that posterior lumbar fusion for the treatment of symptomatic lumbar stenosis or spondylolisthesis may be associated with a reduction in opioid use.

Recent studies in other surgical disciplines have demonstrated that surgery may be associated with decreased opioid use.[6] Franklin et al,[7] in a retrospective study of 6346 patients undergoing total knee arthroplasty (TKA), demonstrated that 24% of patients had at least one prescription for narcotic medication prior to surgery. Of this subset, only 14% were still being prescribed narcotics 12 months following surgery, while 74% of patients were not.[7] Hansen et al,[8] in a retrospective study of 15 020 patients undergoing TKA in Australia observed a reduction in opioid use 12 months after surgery. Similarly, Bedard et al[6] reviewed 73 959 patients in the Humana Inc administrative claims database and demonstrated that of the 31.2% of patients who were opioid users before surgery, 66.8% were no longer users 12 months following TKA. Analogous to the aforementioned studies, we observed a modest but significant decrease in opioid use after lumbar decompression and fusion for symptomatic lumbar stenosis or spondylolisthesis.

Several factors likely contribute to prolonged opioid use. In a multivariate logistic regression analysis, we observed that preoperative narcotic use, obesity, length of hospital stay, receiving treatment South or West were independently associated with prolonged (>1 year) opioid use after index surgery. Additionally, males (OR 0.87, 95% CI 0.81-0.95) were less likely to rely on long-term opioid therapy. Our findings are consistent with previous studies that have also identified independent risk factors for prolonged opioid usage following surgery. Notably, the use of opioid medications preoperatively has

Table 7. Characteristic Comparison Between Patients Requiring Prolonged Opioid Use (>1 Year) After Fusion and Patients Without Prolonged Opioid Use, n (%).

Characteristic	Patients With Prolonged (>1 Year) Opioid Use After Fusion	Patients Without Prolonged Opioid Use After Fusion	*P*
Total patients	8740	4517	n/a
Male	3458 (39.6)	1928 (42.7)	<.001
Female	5282 (60.4)	2589 (57.3)	
Average LOS (days)	8.05 (SD = 7.9)	7.62 (SD = 6.4)	<.001
Geographical region breakdown			
Midwest	2002 (22.9)	1220 (27.0)	<.0001
Northeast	159 (1.8)	117 (2.6)	
South	5649 (64.6)	2712 (60.0)	
West	930 (10.6)	468 (10.4)	
Race breakdown			
Unknown	728 (8.3)	574 (12.7)	<.0001
White	7149 (81.8)	3578 (79.2)	
Black	673 (7.7)	253 (5.6)	
Other	64 (0.7)	43 (1.0)	
Asian	19 (0.2)	14 (0.3)	
Hispanic	86 (1.0)	46 (1.0)	
North American Native	21 (0.2)	9 (0.2)	
Preoperative comorbidities			
Obesity (BMI >30 kg/m^2)	2145 (24.5)	918 (20.3)	<.0001
Any opioid use 6 months prior to fusion	5982 (68.4)	1674 (37.1)	<.05
Smoker	1778 (20.3)	517 (11.4)	<.05
Type 2 diabetes mellitus	3236 (37.0)	1587 (35.1)	<.05

Abbreviations: BMI, body mass index; LOS, length of stay; n/a, not applicable; SD, standard deviation.

Table 8. Multivariate Regression Results.[a]

Characteristic	OR	CI 2.5%	CI 97.5%
Age-group (years)			
25-29	1.127	0.231	5.513
30-34	1.259	0.321	4.722
35-39	1.170	0.317	4.074
40-44	1.119	0.310	3.794
45-49	1.960	0.549	6.578
50-54	1.876	0.531	6.224
55-59	1.684	0.478	5.561
60-64	1.620	0.461	5.339
65-69	0.989	0.283	3.242
70-74	0.823	0.235	2.700
75-79	0.757	0.216	2.487
80-84	0.707	0.201	2.334
85-89	0.450	0.123	1.541
90+	0.626	0.171	2.162
Gender			
Male	0.874	0.808	0.945
Geographic region			
Northeast	0.856	0.656	1.121
South	1.176	1.074	1.287
West	1.260	1.095	1.452
Additional regression characteristics			
Length of stay	1.015	1.010	1.021
Obesity (BMI >30 kg/m^2)	1.103	1.004	1.212
Opioid use 6 months prior to spinal fusion	3.433	3.179	3.708

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.
[a] Dependent variable—prolonged opioid use (>1 year) after spinal fusion. Independent variables—age, gender, length of stay, geographical region, obesity (BMI >30 kg/m^2), and opioid use 6 months prior to spinal fusion. Note that age 20-24 years, female gender, and Midwest region are used for the multivariate baseline comparison group for age, gender, and region, respectively.

been shown to be a significant risk factor for prolonged usage after multiple types of surgery, including TKA, bariatric surgery, lumbar fusion, cervical fusion, as well as kidney transplantation.[6,9-12] Franklin et al[7] and Singh et al[13] found obesity to be an independent predictor for prolonged opioid usage following surgery by. Sex differences in pain sensitivity and responsivity to pharmacological and nonpharmacological treatments has been identified as an independent predictor of prolonged opioid use after surgery; with women being more likely to use prolonged narcotics when compared with the male counterparts.

Clinical Implications

While opioids remain an integral part of acute postoperative pain management, the literature does not support long-term efficacy. Despite this, the majority of patients presenting for spinal surgery have a history of chronic opioid use. Several experts believe that the risks of opioids far outweigh the potential benefits. Spinal surgery, when indicated may lead to a decrease in opioid use, and potentially prevent the unintended consequences of overdose, misuse, and abuse. Also noteworthy is that our study cohort is comprised mainly of individuals covered by employer-based plans and their dependents; hence our findings highlight the importance of decreasing opioid use among young individuals during their prime years with regard to career and family demands.

Limitations

Despite the many strengths of this study, there are some limitations. The database is only comprised of private/commercially insured patients or Medicare Advantage beneficiaries. As such, Medicaid patients were precluded from this analysis. When constructing the inclusion criteria, both ICD-9 and ICD-10 procedural codes were utilized. The ICD-9 procedural coding system is far broader than ICD-10 and encompasses procedural codes that are irrelevant to the intended study design (eg, sacroiliac joint fixation). Despite efforts to remove these procedure codes, the authors estimate a residual <1% of the sample size is included in the study population. The database lacks diagnostic and therapeutic Nuance that potentially could affect the outcomes of the study. Additionally, this study does not suggest that all spine surgery leads to a reduction in narcotic use. Despite these limitations, this study suggests that operative management for symptomatic lumbar stenosis and spondylolisthesis may be associated with a reduction in the associated costs and pill quantity of opioids used by patients during the postoperative period.

Conclusions

This study demonstrates that reduction in opioid use was observed postoperatively in comparison to preoperative values in patients with symptomatic lumbar stenosis or spondylolisthesis that underwent lumbar decompression with fusion. Further prospective studies that are more methodologically stringent are needed to corroborate our findings.

Appendix A

ICD-9 and ICD-10 Diagnosis Codes for Inclusion and Exclusion Criteria.

Inclusion/Exclusion Criteria	ICD-9/ ICD-10 Codes
Inclusion Diagnosis Codes	**ICD-9-D**: ICD-9-D-7213, ICD-9-D-72 142, ICD-9-D-72 210, ICD-9-D-72 252, ICD-9-D-72 273, ICD-9-D-72 293, ICD-9-D-72 402, ICD-9-D-72 403, ICD-9-D-7242, ICD-9-D-7243, ICD-9-D-7244, ICD-9-D-7245 **ICD-10-D**: ICD-10-D-M47817, ICD-10-D-M4716, ICD-10-D-M5126, ICD-10-D-M5127, ICD-10-D-M5136, ICD-10-D-M5137, ICD-10-D-M5106, ICD-10-D-M4647, ICD-10-D-M5186, ICD-10-D-M5187, ICD-10-D-M4806, ICD-10-D-M4806, ICD-10-D-M545, ICD-10-D-M5430, ICD-10-D-M5414, ICD-10-D-M5415, ICD-10-D-M5416, ICD-10-D-M5417, ICD-10-D-M5489, ICD-10-D-M549
Inclusion Procedure Codes	**ICD-9-P:** ICD-9-P-8107, ICD-9-P-8108, ICD-9-P-8162 **ICD-10-P:** ICD-9-P-8107, ICD-10-P-0SG0071, ICD-10-P-0SG00J1, ICD-10-P-0SG00K1, ICD-10-P-0SG00Z1, ICD-10-P-0SG0371, ICD-10-P-0SG03J1, ICD-10-P-0SG03K1, ICD-10-P-0SG03Z1, ICD-10-P-0SG0471, ICD-10-P-0SG04K1, ICD-10-P-0SG04Z1, ICD-10-P-0SG3071, ICD-10-P-0SG30J1, ICD-10-P-0SG30K1, ICD-10-P-0SG30Z1, ICD-10-P-0SG3371, ICD-10-P-0SG33J1, ICD-10-P-0SG33K1, ICD-10-P-0SG33Z1, ICD-10-P-0SG3471, ICD-10-P-0SG34K1, ICD-10-P-0SG34Z1, ICD-9-P-8108, ICD-10-P-0SG007J, ICD-10-P-0SG00JJ, ICD-10-P-0SG00KJ, ICD-10-P-0SG00ZJ, ICD-10-P-0SG03JJ, ICD-10-P-0SG03KJ, ICD-10-P-0SG047J, ICD-10-P-0SG307J, ICD-10-P-0SG30JJ, ICD-10-P-0SG30KJ, ICD-10-P-0SG30ZJ, ICD-10-P-0SG337J, ICD-10-P-0SG347J
Exclusion Diagnosis Codes	**ICD-9-D:** ICD-9-D-8055, ICD-9-D-8056, ICD-9-D-8057, ICD-9-D-8058, ICD-9-D-8059, ICD-9-D-1702, ICD-9-D-1706 **ICD-10-D:** ICD-10-D-S32009B, ICD-10-D-S3210XA, ICD-10-D-S322XXA, ICD-10-D-S3210XB, ICD-10-D-S322XXB, ICD-10-D-S129XXA, ICD-10-D-S22009A, ICD-10-D-S32009A, ICD-10-D-S3210XA, ICD-10-D-S322XXA, ICD-10-D-S129XXA, ICD-10-D-S22009B, ICD-10-D-S32009B, ICD-10-D-S3210XB, ICD-10-D-S322XXB, ICD-10-D-C412, ICD-10-D-C414
Exclusion Procedure Codes	**ICD-9-P:** ICD-9-P-8163, ICD-9-P-8164, ICD-9-P-8106, ICD-9-P-8102, ICD-9-P-8103, ICD-9-P-8104, ICD-9-P-8105, ICD-9-P-8054 **ICD-10-P:** ICD-10-P-0SG0070, ICD-10-P-0SG00J0, ICD-10-P-0SG00K0, ICD-10-P-0SG00Z0, ICD-10-P-0SG0370, ICD-10-P-0SG03Z0, ICD-10-P-0SG3070, ICD-10-P-0SG30J0, ICD-10-P-0SG30K0, ICD-10-P-0SG30Z0, ICD-10-P-0SG33J0, ICD-10-P-0RG1070, ICD-10-P-0RG10J0, ICD-10-P-0RG10K0, ICD-10-P-0RG10Z0, ICD-10-P-0RG13K0, ICD-10-P-0RG13Z0, ICD-10-P-0RG4070, ICD-10-P-0RG40J0, ICD-10-P-0RG40K0, ICD-10-P-0RG40Z0, ICD-10-P-0RG1071, ICD-10-P-0RG10J1, ICD-10-P-0RG10K1, ICD-10-P-0RG10Z1, ICD-10-P-0RG1371, ICD-10-P-0RG4071, ICD-10-P-0RG40J1, ICD-10-P-0RG40K1, ICD-10-P-0RG40Z1, ICD-10-P-0RG6070, ICD-10-P-0RG60Z0, ICD-10-P-0RGA070, ICD-10-P-0RGA0K0, ICD-10-P-0RG6071, ICD-10-P-0RG60J1, ICD-10-P-0RG60K1, ICD-10-P-0RG60Z1, ICD-10-P-0RG63K1, ICD-10-P-0RG64Z1, ICD-10-P-0RGA071, ICD-10-P-0RGA0J1, ICD-10-P-0RGA0K1, ICD-10-P-0RGA0Z1, ICD-10-P-0RGA371, ICD-10-P-0RGA3K1, ICD-10-P-0RGA3Z1, ICD-10-P-0RGA471, ICD-10-P-0RGA4Z1, ICD-10-P-0RQ30ZZ, ICD-10-P-0SQ20ZZ, ICD-10-P-0SQ40ZZ

Appendix B

Humana Generic Drug Codes for Inclusion Narcotics.

Inclusion Medications	Humana Generic Drug Code
Narcotics	**GENERIC_DRUG:** GENERIC_DRUG-100 055, GENERIC_DRUG-101 802, GENERIC_DRUG-106 030, GENERIC_DRUG-106 414, GENERIC_DRUG-100 504, GENERIC_DRUG-101 215, GENERIC_DRUG-100 548, GENERIC_DRUG-101 126

Appendix C

ICD-9 and ICD-10 Diagnosis Codes for Baseline Comorbidities.

Comorbidity	Diagnosis Codes
Obesity (BMI $\geq$30 kg/m^2)	**ICD-9-D:** ICD-9-D-V8530, ICD-9-D-V8531, ICD-9-D-V8532, ICD-9-D-V8533, ICD-9-D-V8534, ICD-9-D-V8535, ICD-9-D-V8536, ICD-9-D-V8537, ICD-9-D-V8538, ICD-9-D-V8539, ICD-9-D-V8541, ICD-9-D-V8542, ICD-9-D-V8543, ICD-9-D-V8544, ICD-9-D-V8545, ICD-9-D-27 800, ICD-9-D-27 801 **ICD-10-D:** ICD-10-D-Z6830, ICD-10-D-Z6831, ICD-10-D-Z6832, ICD-10-D-Z6833, ICD-10-D-Z6834, ICD-10-D-Z6835, ICD-10-D-Z6836, ICD-10-D-Z6837, ICD-10-D-Z6838, ICD-10-D-Z6839, ICD-10-D-Z6841, ICD-10-D-Z6842, ICD-10-D-Z6843, ICD-10-D-Z6844, ICD-10-D-Z6845, ICD-10-D-E6601, ICD-10-D-E6609, ICD-10-D-E668, ICD-10-D-E669
Type 2 diabetes mellitus	**ICD-9-D**: ICD-9-D-24 900, ICD-9-D-24 901, ICD-9-D-24 910, ICD-9-D-24 911, ICD-9-D-24 920, ICD-9-D-24 921, ICD-9-D-24 930, ICD-9-D-24 931, ICD-9-D-24 940, ICD-9-D-24 941, ICD-9-D-24 950, ICD-9-D-24 951, ICD-9-D-24 960, ICD-9-D-24 961, ICD-9-D-24 970, ICD-9-D-24 971, ICD-9-D-24 980, ICD-9-D-24 981, ICD-9-D-24 990, ICD-9-D-24 991, ICD-9-D-25 000, ICD-9-D-25 001, ICD-9-D-25 002, ICD-9-D-25 003, ICD-9-D-25 010, ICD-9-D-25 011, ICD-9-D-25 012, ICD-9-D-25 013, ICD-9-D-25 020, ICD-9-D-25 021, ICD-9-D-25 022, ICD-9-D-25 023, ICD-9-D-25 030, ICD-9-D-25 031, ICD-9-D-25 032, ICD-9-D-25 033, ICD-9-D-25 040, ICD-9-D-25 041, ICD-9-D-25 042, ICD-9-D-25 043, ICD-9-D-25 050, ICD-9-D-25 051, ICD-9-D-25 052, ICD-9-D-25 053, ICD-9-D-25 060, ICD-9-D-25 061, ICD-9-D-25 062, ICD-9-D-25 063, ICD-9-D-25 070, ICD-9-D-25 071, ICD-9-D-25 072, ICD-9-D-25 073, ICD-9-D-25 080, ICD-9-D-25 081, ICD-9-D-25 082, ICD-9-D-25 083, ICD-9-D-25 090, ICD-9-D-25 091, ICD-9-D-25 092, ICD-9-D-25 093, ICD-9-D-3572 **ICD-10-D:** ICD-10-D-E0800, ICD-10-D-E0801, ICD-10-D-E0810, ICD-10-D-E0811, ICD-10-D-E0821, ICD-10-D-E0822, ICD-10-D-E0829, ICD-10-D-E08311, ICD-10-D-E08319, ICD-10-D-E08321, ICD-10-D-E08329, ICD-10-D-E08331, ICD-10-D-E08339, ICD-10-D-E08341, ICD-10-D-E08349, ICD-10-D-E08351, ICD-10-D-E08359, ICD-10-D-E0836, ICD-10-D-E0839, ICD-10-D-E0840, ICD-10-D-E0841, ICD-10-D-E0842, ICD-10-D-E0843, ICD-10-D-E0844, ICD-10-D-E0849, ICD-10-D-E0851, ICD-10-D-E0852, ICD-10-D-E0859, ICD-10-D-E08610, ICD-10-D-E08618, ICD-10-D-E08620, ICD-10-D-E08621, ICD-10-D-E08622, ICD-10-D-E08628, ICD-10-D-E08630, ICD-10-D-E08638, ICD-10-D-E08641, ICD-10-D-E08649, ICD-10-D-E0865, ICD-10-D-E0869, ICD-10-D-E088, ICD-10-D-E089, ICD-10-D-E1010, ICD-10-D-E1011, ICD-10-D-E1021, ICD-10-D-E1022, ICD-10-D-E1029, ICD-10-D-E10311, ICD-10-D-E10319, ICD-10-D-E10321, ICD-10-D-E10329, ICD-10-D-E10331, ICD-10-D-E10339, ICD-10-D-E10341, ICD-10-D-E10349, ICD-10-D-E10351, ICD-10-D-E10359, ICD-10-D-E1036, ICD-10-D-E1039, ICD-10-D-E1040, ICD-10-D-E1041, ICD-10-D-E1042, ICD-10-D-E1043, ICD-10-D-E1044, ICD-10-D-E1049, ICD-10-D-E1051, ICD-10-D-E1052, ICD-10-D-E1059, ICD-10-D-E10610, ICD-10-D-E10618, ICD-10-D-E10620, ICD-10-D-E10621, ICD-10-D-E10622, ICD-10-D-E10628, ICD-10-D-E10630, ICD-10-D-E10638, ICD-10-D-E10641, ICD-10-D-E10649, ICD-10-D-E1065, ICD-10-D-E1069, ICD-10-D-E108, ICD-10-D-E109, ICD-10-D-E1100, ICD-10-D-E1101, ICD-10-D-E1121, ICD-10-D-E1122, ICD-10-D-E1129, ICD-10-D-E11311, ICD-10-D-E11319, ICD-10-D-E11321, ICD-10-D-E11329, ICD-10-D-E11331, ICD-10-D-E11339, ICD-10-D-E11341, ICD-10-D-E11349, ICD-10-D-E11351, ICD-10-D-E11359, ICD-10-D-E1136, ICD-10-D-E1139, ICD-10-D-E1140, ICD-10-D-E1141, ICD-10-D-E1142, ICD-10-D-E1143, ICD-10-D-E1144, ICD-10-D-E1149, ICD-10-D-E1151, ICD-10-D-E1152, ICD-10-D-E1159, ICD-10-D-E11610, ICD-10-D-E11618, ICD-10-D-E11620, ICD-10-D-E11621, ICD-10-D-E11622, ICD-10-D-E11628, ICD-10-D-E11630, ICD-10-D-E11638, ICD-10-D-E11641, ICD-10-D-E11649, ICD-10-D-E1165, ICD-10-D-E1169, ICD-10-D-E118, ICD-10-D-E119, ICD-10-D-E1300, ICD-10-D-E1301, ICD-10-D-E1310, ICD-10-D-E1311, ICD-10-D-E1321, ICD-10-D-E1322, ICD-10-D-E1329, ICD-10-D-E13311, ICD-10-D-E13319, ICD-10-D-E13321, ICD-10-D-E13329, ICD-10-D-E13331, ICD-10-D-E13339, ICD-10-D-E13341, ICD-10-D-E13349, ICD-10-D-E13351, ICD-10-D-E13359, ICD-10-D-E1336, ICD-10-D-E1339, ICD-10-D-E1340, ICD-10-D-E1341, ICD-10-D-E1342, ICD-10-D-E1343, ICD-10-D-E1344, ICD-10-D-E1349, ICD-10-D-E1351, ICD-10-D-E1352, ICD-10-D-E1359, ICD-10-D-E13610, ICD-10-D-E13618, ICD-10-D-E13620, ICD-10-D-E13621, ICD-10-D-E13622, ICD-10-D-E13628, ICD-10-D-E13630, ICD-10-D-E13638, ICD-10-D-E13641, ICD-10-D-E13649, ICD-10-D-E1365, ICD-10-D E1369, ICD-10-D-E138, ICD-10-D-E139
Myocardial infarction	**ICD-9-D**: ICD-9-D-41 000, ICD-9-D-41 001, ICD-9-D-41 002, ICD-9-D-41 010, ICD-9-D-41 011, ICD-9-D-41 012, ICD-9-D-41 020, ICD-9-D-41 021, ICD-9-D-41 022, ICD-9-D-41 030, ICD-9-D-41 031, ICD-9-D-41 032, ICD-9-D-41 040, ICD-9-D-41 041, ICD-9-D-41 042, ICD-9-D-41 050, ICD-9-D-41 051, ICD-9-D-41 052, ICD-9-D-41 080, ICD-9-D-41 081, ICD-9-D-41 082, ICD-9-D-41 090, ICD-9-D-41 091, ICD-9-D-41 092, ICD-9-D-41 181 **ICD-10-D**: ICD-10-D-I2101, ICD-10-D-I2102, ICD-10-D-I2109, ICD-10-D-I2111, ICD-10-D-I2119, ICD-10-D-I2121, ICD-10-D-I2129, ICD-10-D-I213, ICD-10-D-I214, ICD-10-D-I220, ICD-10-D-I221, ICD-10-D-I222, ICD-10-D-I228, ICD-10-D-I229, ICD-10-D-I230, ICD-10-D-I231, ICD-10-D-I232, ICD-10-D-I233, ICD-10-D-I234, ICD-10-D-I235, ICD-10-D-I236
Atrial fibrillation	**ICD-9-D:** ICD-9-D-42 731 **ICD-10-D:** ICD-10-D-I480, ICD-10-D-I481, ICD-10-D-I482, ICD-10-D-I4891

(continued)

Appendix C (continued)

Comorbidity	Diagnosis Codes
Smoking	**ICD-9-D:** ICD-9-D-3051 **ICD-10-D:** ICD-10-D-Z720
COPD	**ICD-9-D:** ICD-9-D-49 120, ICD-9-D-49 121, ICD-9-D-49 122, ICD-9-D-49 320, ICD-9-D-49 321, ICD-9-D-49 322 **ICD-10-D:** ICD-10-D-J440, ICD-10-D-J441, ICD-10-D-J449

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease.

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