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Postoperative Opioid Use, Complications, and Costs in Surgical Management of Lumbar Spondylolisthesis

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Abstract

Study Design—Retrospective analysis on a national longitudinal database (2007–2014).

Objective—To determine the association between arthrodesis and complication rates, costs, surgical revision, and postoperative opioid prescription.

Summary of Background Data—Arthrodesis in patients receiving laminectomy for lumbar spondylolisthesis remains controversial. However, population-level evidence to support the use of arthrodesis remains limited.

Methods—We identified 73,176 patient records and used coarsened exact matching to create comparable populations of patients who received laminectomy or laminectomy with arthrodesis. We use linear and logistic regression models to analyze the relationship between arthrodesis and postoperative complications, length of stay, costs, readmissions, surgical revisions, and postoperative opioid prescribing.

Results—Patients who underwent arthrodesis spent one more day in the hospital on average ($p < 0.01$), and had higher costs of care at their index visit (\$24,126, $p < 0.01$), which were partially offset by lower costs of care over the two years following their procedure (\$14,667 less in arthrodesis patients, $p = 0.01$). Patients with arthrodesis were less likely to have a surgical revision (OR=0.66, $p < 0.01$). Patients with arthrodesis used more opioids in the first two months following their procedure, but had comparable opioid use to patients undergoing laminectomy without arthrodesis in all other post-operative months over the next two years, and were not more or less likely to convert to chronic opioid use. Postoperative opioid prescription varied dramatically across states ($p < 0.01$); geographic variation in opioid use is substantially greater than differences in opioid use based on procedure performed.

Conclusion—Arthrodesis is associated with reduced likelihood of surgical revision and increased use of opioids in the first two months following surgery, but not associated with greater or lesser opioid use beyond the initial two postoperative months. Geographic variation in opioid

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use is substantial even after accounting for patient characteristics and for whether patients underwent arthrodesis.

Keywords

spondylolisthesis; opioids; complications; arthrodesis

Introduction

Recently, two high profile randomized controlled trials (RCTs) investigated the role of arthrodesis in determining the postoperative course for patients undergoing laminectomy for lumbar spondylolisthesis.^{1, 2} The studies reached conflicting conclusions, with one study finding that arthrodesis improved patient disability and was associated with lower rates of surgical revision, while the other found no improved clinical outcomes, no reduction in surgical revision rates, and higher costs of care. Both studies found that arthrodesis was associated with longer postoperative hospital stays and more operative blood loss. These RCTs did not investigate any association between arthrodesis and postoperative opioid use.

While RCTs excel in providing high quality evidence by minimizing bias, these studies may be limited by cost, timeliness, small sample sizes, and applicability to real world patient populations.³ Observational studies using longitudinal databases can be helpful in assessing real world outcomes that are difficult to capture in an RCT, or that the RCT was not designed to assess.⁴ Lad *et al.* leveraged this advantage of observational databases studies by evaluating long-term complication and reoperation rates and health care utilization between laminectomy and laminectomy with lumbar arthrodesis for spondylolisthesis.⁵

While Lad *et al.* provided important evidence for long term outcomes and costs for patients with lumbar spondylolisthesis who receive surgical management, there was no assessment of pharmaceutical outcomes. Recent studies have utilized administrative claims data to assess narcotic use following surgery, a topic of great interest to patients, health care providers, and policy makers.⁶ We analyzed a large, recent patient cohort focusing on pharmaceutical outcomes and geographic variation in narcotic utilization. The relationship between arthrodesis and postoperative narcotic use is particularly important, given the substantial geographic variation in arthrodesis and the substantial geographic variation in prescription opioid use established in previous studies.⁷

Methods

Data source

We performed a retrospective study of patients in the United States who received spinal surgical procedures for lumbar spondylolisthesis between 2007 and 2014. We used inpatient and outpatient longitudinal data from the Thomson Reuters MarketScan Commercial Claims and Encounters database, and the Medicare Supplemental and Coordination of Benefits database. These databases include information from 100 payers on inpatient, outpatient, and pharmacy services.

Cohort definition

We developed our patient cohort by querying the MarketScan database for patients with Common Procedural Terminology (CPT) descriptors for lumbar laminectomy and arthrodesis and concurrent International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes for spondylolisthesis. Our cohort primarily represents patients with degenerative spondylolisthesis, given patient characteristics such as older age at time of surgery, though we cannot definitively exclude patients with isthmic spondylolisthesis, as the ICD-9 diagnosis codes utilized capture both entities. This cohort definition has been previously established in the literature.⁵ We excluded patients with ICD-9 or CPT codes for revision surgeries from the index cohort.

Outcomes

We investigated the relationship between arthrodesis and surgical complications, length of hospital stay, postoperative hospital readmission, revisions of the initial surgery, costs of care, and postoperative opioid use. Costs were computed as the sum of payments to the provider and hospital and calculated for both the index hospital stay and for two years following surgery. Index payments were excluded from consideration in two-year cumulative payment calculations. To better characterize the use of arthrodesis in the United States, we also ran a sensitivity analysis to determine whether orthopedic surgeons or neurosurgeons were more likely to employ the procedure in the setting of lumbar spondylolisthesis. Detailed information about outcome definitions, including narcotic outcomes, is provided in the Appendix Methods.

Statistical analysis

We used coarsened exact matching (CEM) to create an analytic sample balanced across procedure characteristics, patient demographics, and relevant comorbidities. CEM is similar to propensity score matching, in that it matches patients in the treatment group (those who underwent laminectomy with arthrodesis) with patients in the control group (those who underwent laminectomy without arthrodesis) who are most similar to each other across an array of covariates. However, unlike propensity score matching, CEM allows the level of covariate balance between the two groups to be specified prior to matching; it ensures a minimum degree of balance within the analytic sample. In addition to producing a more balanced sample, CEM reduces model dependence and estimation error compared to propensity score matching.⁸ All covariates that were unbalanced ($p < 0.05$) in bivariate analyses between patients receiving arthrodesis and patients receiving laminectomy without arthrodesis were included in the matching procedure. CEM balanced the sample across the following variables: age; sex; single vs. multiple laminectomy; preoperative diagnosis of CHF, MI, osteoporosis, obesity, or diabetes; and geographic region of residence. Following CEM, we used logistic regression to analyze all binary outcomes (complications, readmissions, revisions), and linear regression to analyze continuous outcomes (days spent in hospital, costs of care, postoperative prescription of MMEs). These regression models included year of surgery as a continuous variable in addition to the variables listed in Table 1. Models of postoperative opioid prescription additionally adjusted for preoperative use of benzodiazepines, antipsychotics, and opioid use.

Results

Cohort overview

Our sample consists of 73,176 patients with lumbar spondylolisthesis who underwent laminectomy between 2007 and 2014. Of these patients, 67,262 (91.9%) received laminectomy with arthrodesis, and 62,613 (93.1%) of the patients receiving arthrodesis underwent an arthrodesis with instrumentation. 68,292 patients (93.3%) were successfully matched into the analytic sample; it was possible to balance the sample across the covariates listed in Table 1 while dropping relatively few patients because CEM achieves balance by re-weighting observations in the sample according to their covariates in addition to trimming observations that cannot be matched. Orthopedic surgeons were more likely than neurosurgeons to employ arthrodesis in conjunction with a laminectomy (OR=2.00, $p<0.01$), although both orthopedic surgeons and neurosurgeons used arthrodesis in the vast majority of their procedures (94.8% and 90.2%, respectively).

Complications, readmissions, and revisions of surgery

Patients who underwent laminectomy with arthrodesis were moderately more likely to experience a complication within 30 days of the procedure than patients who underwent laminectomy without arthrodesis (OR=1.15, $p=0.04$), but this risk was largely offset by the use of instrumentation in arthrodesis (OR=0.88, $p<0.01$). The increased risk of complications in fusion procedures appears to occur primarily among patients undergoing non-instrumented arthrodesis (Table 2). Neither arthrodesis nor instrumentation were associated with differences in 30-day readmission rates. However, patients who received arthrodesis were significantly less likely to have a record of any surgical revision in their follow-up period (OR=0.66, $p<0.01$) (Table 2).

Length of stay and cost

Patients who received arthrodesis spent approximately one day longer in the hospital following their procedure ($p<0.01$) (Table 3). Instrumentation was not associated with increase in length of hospital stay. Both arthrodesis and instrumentation resulted in significantly more expensive procedures (arthrodesis was nearly \$25,000 more expensive on average, $p<0.01$, and instrumentation was over \$10,000 more expensive on average, $p<0.01$). However, costs of care aside from the costs of the index procedure were significantly lower at the 2-year mark for patients who underwent arthrodesis and for patients who underwent instrumentation. These lower costs of care did not fully offset the higher procedural costs of arthrodesis; at the 2-year mark, patients who underwent arthrodesis still had overall costs that were approximately \$10,000 higher (Table 3).

Postoperative opioid use

We find evidence that undergoing laminectomy with arthrodesis is associated with more opioid use in the first two months following surgery compared to laminectomy without arthrodesis (Table 4). Patients who underwent arthrodesis received 288 ($p<0.01$) more MMEs in the first month following surgery, and 172 ($p<0.01$) more MMEs in the second month after their surgery compared to patients who underwent laminectomy alone. However,

this difference does not appear to persist beyond two months; arthrodesis patients did not receive significantly more opioids than laminectomy-only patients at any point between postoperative month 3 and postoperative month 24 (Figure 1). Additionally, patients who had received arthrodesis were not more likely to have stopped using opioids by 6 months after their procedure, nor were they more likely to meet the criteria for chronic opioid use in their postoperative period (Table 4).

Geographic variation in opioid use

We found substantial variation in opioid use between states (Figure 2). We limited our analysis of geographic variation to states with drug information from at least 100 patients in our dataset (43 states, excluding Alaska, Hawaii, North Dakota, Rhode Island, South Dakota, Vermont, Wyoming, and the District of Columbia). Opioid use prior to receiving laminectomy was common among all states in our dataset; at least 50% of patients receiving laminectomy were using opioids prior to their procedure in all states but two (New Mexico, 24%, and Nebraska, 47%). The prevalence of pre-operative opioid use was highest in Mississippi (73%). Preoperative use of benzodiazepines was also lowest in New Mexico, where 15% of patients used benzodiazepines prior to undergoing laminectomy, and highest in Connecticut, where 36% of patients had filled benzodiazepine prescriptions within the six months preceding their operation (Appendix Table 1).

Postoperative opioid use varies substantially between states (Figure 2). In most states, patients were prescribed less than 2,000 MMEs in the first 30 days after their procedure, with New Mexico prescribing the fewest on average. Patients were prescribed more than 2,000 MMEs in the 30 days following laminectomy in 10 states (Oregon, Minnesota, Arizona, Nevada, Washington, South Carolina, Oklahoma, New York, Utah, and Idaho, in order of increasing prescription). By 24 months after their laminectomy, patients in New Mexico had been prescribed 3753 MMEs (95% CI 1,856 – 5,649), while patients in Idaho had been prescribed 30,749 MMEs (95% CI 24,652 – 36,845).

This substantial variation in postoperative opioid use between states persists even after accounting for the patient and procedure characteristics that are associated with opioid use in our analyses. We conducted a sensitivity analysis that estimated the relationship between arthrodesis and postoperative opioid use while including a separate binary variable for every state, in addition to the covariates included in our primary model; a joint test of significance for all of the geographic binary variables in this model was strongly significant ($p < 0.01$), indicating that geographic variation in postoperative opioid use exists even after accounting for patient characteristics and characteristics of the laminectomy procedure that are likely to be associated with opioid use (e.g. employment of arthrodesis).

Discussion

This retrospective observational database study of 73,176 surgical patients with lumbar spondylolisthesis finds evidence that the incorporation of arthrodesis in patients undergoing laminectomy impacts an array of clinically significant outcomes, including costs of care, surgical revisions, complications in the post-operative period, and post-operative use of opioids. We find that arthrodesis is associated with reduced likelihood of surgical revision,

but is also associated with increased total costs, slightly longer hospital stays, increased likelihood of post-operative complications within 30 days of surgery (a finding largely driven by patients receiving non-instrumented arthrodesis), and increased use of opioids in the first two months following surgery. We also find tremendous variation in the degree of postoperative opioid use in different states, even after accounting for differences between patient populations between states.

We find evidence that patients undergoing laminectomy with arthrodesis fill significantly more opioid prescriptions in the first and second postoperative months compared to patients undergoing laminectomy alone. However, we do not find evidence that this higher use of opioids in the immediate postsurgical period is associated with longer term opioid use. Patients undergoing arthrodesis are no more likely to convert to chronic use of opioids within two years of surgery, nor are they more likely to be consuming higher doses of opioids in post-operative months 3–24. Arthrodesis appears unlikely to be a significant contributor to chronic opioid use in these patients. Conversely, addition of arthrodesis does not increase the likelihood that patients will be able to cease narcotic use in the post-operative period assessed in this analysis. Use of opioids between the fusion and non-fusion patient cohorts appear similar after the initial two months post-operatively.

While arthrodesis is a significant predictor of opioid use in the immediate postoperative period, a patient's state of residence is an even stronger predictor of opioid use. The state-by-state variation in postoperative opioid use observed is substantially greater than the average difference in opioid use between arthrodesis and laminectomy-alone patients. We find that similar patients undergoing similar procedures (e.g., patients with similar comorbidities who both undergo single-level laminectomy with or without arthrodesis) are likely to receive substantially different amounts of opioids postoperatively depending upon what state they live in. Our previous analysis of this dataset found that state of residence was an important predictor of whether patients received arthrodesis in conjunction with their laminectomy; in this analysis we find that arthrodesis is associated with increased opioid use, but that state of residence is a vital predictor of opioid use even after accounting for whether a patient receive arthrodesis. Patients with lumbar spondylolisthesis face dramatically different operative and postoperative courses depending upon their geography; similar patients in different states face different likelihoods of receiving arthrodesis when they undergo laminectomy for lumbar spondylolisthesis and also experience very different approaches for management of their postoperative pain. Further research should investigate whether this state variation in opioid use is similar in other surgical patient populations, and whether state-specific prescription modalities are associated with broader trends in opioid abuse.

Our results indicate that patient characteristics explain only some of the variation in surgical and postsurgical management of lumbar spondylolisthesis. Patient outcomes are associated with patient characteristics, but are also associated with the type of surgical procedure they underwent. Postoperative pain management is associated with patient characteristics and with type of surgical procedure, but is also strongly associated with geography. These findings are in line with the results of an earlier analysis conducted by this team, which noted substantial geographic variation in the employment of arthrodesis in patients

undergoing laminectomy for lumbar spondylolisthesis. We also note that employment of arthrodesis in laminectomy was associated with surgical specialty; orthopedic surgeons were approximately twice as likely to use arthrodesis in laminectomies compared to neurosurgeons (OR=2.00, $p<0.01$).

These results demonstrate substantial heterogeneity in the management of a well-defined population of spine surgery patients in the United States. This heterogeneity exists even within the relatively homogeneous population used in this analysis, a population drawn from the MarketScan database of relatively younger, privately insured patients. This analytic approach necessarily eliminates variation based upon advanced patient age, through lack of Medicare beneficiaries. The analysis also fails to adequately capture variation in patient care based upon socio-economic status, through lack of inclusion of Medicaid and un-insured patients. While lack of these elements are limitations of our analytic approach, they might be expected to generate a more homogeneous patient population, with less variation in treatment protocols. This analysis failed to reveal homogeneity in treatment approaches in this population.

This study was subject to several additional limitations. Our outcomes in this study do not include clinical findings which may be relevant to patient care but which are not included in an administrative insurance database; it is likely that there are advantages (or disadvantages) to arthrodesis which are not reflected in complication rates and other relatively crude measures of procedure efficacy. Our clinical outcomes, specifically reoperation rates, are coarse. Similarly, our pharmacological data is a relatively crude measure of opioid use, since prescription of opioids may only approximate their use (some patients may not use the drugs they are prescribed, while others may find additional sources of opioids beyond their own prescriptions). We rely upon the accuracy of procedural and facility coding of the individual procedures and of patient comorbidities in this analysis; both may be subject to bias. The under-reporting of post-operative complications in administrative datasets has been well described, although by using longitudinal data we may obviate this concern.⁴

Conclusion

Narcotic use post-operatively varies more based upon geography than by choice of operative procedure in surgical treatment of lumbar spondylolisthesis. Narcotic use between fusion and non-fusion patient cohorts are similar. The use of arthrodesis in surgical management of lumbar spondylolisthesis varies markedly in the United States in ways that cannot be fully explained by variation in patient characteristics. Fully understanding the risks and benefits of arthrodesis is important for establishing best practices and for characterizing geographic variation in surgical outcomes, costs of lumbar spondylolisthesis, and postoperative opioid use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Opioid use over 24 postoperative months among patients undergoing laminectomy with and without arthrodesis for lumbar spondylolisthesis.

Figure 2. Mean opioid use in first postoperative month among patients receiving laminectomy for lumbar spondylolisthesis by state. Includes all states with at least 100 patients with pharmacological data. Opioid use adjusted for factors associated with postoperative opioid use as seen in Table 4.

Descriptive statistics for patients in the Truven Health Analytics MarketScan database undergoing laminectomy for lumbar spondylolisthesis, 2007–2014

Table 1

	Unmatched sample (N=73,176)				Matched sample (N=68,292)			
	Laminectomy without arthrodesis	Laminectomy with arthrodesis	N	%	Laminectomy without arthrodesis	Laminectomy with arthrodesis	N	%
Age, years								
<35	78	2265	1.3	3.4	77	1602	2.6	2.6
35–44	166	4987	2.8	7.4	162	4209	6.7	6.7
45–54	779	13993	13.2	20.8	774	12845	20.6	20.6
55–64	1957	26738	33.1	39.8	1945	25481	40.8	40.8
65+	2934	19279	49.6	28.7	2914	18283	29.3	29.3
Sex								
Male	2683	26002	45.4	38.7	2662	24071	38.6	38.6
Female	3231	41260	54.6	61.3	3210	38349	61.4	61.4
Multiple laminectomy								
No	3293	32850	55.7	48.8	3266	30632	49.1	49.1
Yes	2621	34412	44.3	51.2	2606	31788	50.9	50.9
Comorbidities								
Congestive heart failure	373	2951	6.3	4.4	344	1693	2.7	2.7
Chronic obstructive pulmonary disease	1330	14419	22.5	21.4	1312	12789	20.8	20.8
Myocardial infarction	295	2703	5	4	273	1343	2.2	2.2
Osteoporosis	1577	16880	26.7	25.1	1560	15030	24.1	24.1
Obesity	581	8097	9.8	12	553	5835	9.3	9.3
Diabetes	1419	14921	24	22.2	1394	12685	20.3	20.3
History of drug abuse	111	1428	1.9	2.1	107	1239	2.0	2.0
Census Region								
Northeast	944	10496	17.2	17.0	933	9540	16.5	16.5
Midwest	290	18163	23.5	29.4	1286	1661	28.8	28.8
South	1694	23269	30.8	37.6	1688	22123	38.3	38.3
West	1571	9922	28.6	16.0	1561	9480	16.4	16.4

Table 2

Factors associated with 30-day complications, 30-day readmissions, and surgical revisions based on logistic regression models

	Any complication		Readmission		Any surgical revision	
	OR (95% C.I.)	p-value	OR (95% C.I.)	p-value	OR (95% C.I.)	p-value
Arthrodesis	1.145 (1.005 – 1.304)	0.041	1.056 (0.862 – 1.293)	0.601	0.663 (0.568 – 0.773)	<0.001
Instrumentation	0.877 (0.807 – 0.953)	0.002	0.963 (0.839 – 1.105)	0.589	1.008 (0.895 – 1.134)	0.898
Patient age (years)	1.014 (1.012 – 1.016)	<0.001	0.994 (0.991 – 0.998)	0.001	0.996 (0.993 – 0.999)	0.003
Male	0.958 (0.913 – 1.005)	0.078	1.168 (1.082 – 1.260)	<0.001	0.969 (0.910 – 1.032)	0.321
Year of operation	0.992 (0.981 – 1.004)	0.196	0.968 (0.951 – 0.985)	<0.001	0.801 (0.790 – 0.812)	<0.001
Multiple laminectomy	1.087 (1.038 – 1.137)	<0.001	1.178 (1.096 – 1.267)	<0.001	1.187 (1.117 – 1.261)	<0.001
Comorbidities:						
Congestive heart failure	1.224 (1.089 – 1.375)	0.001	1.207 (1.001 – 1.455)	0.048	1.017 (0.856 – 1.209)	0.848
Chronic obstructive pulmonary disease	1.120 (1.089 – 1.375)	<0.001	1.135 (1.042 – 1.237)	0.004	1.176 (1.093 – 1.266)	<0.001
Myocardial infarction	0.938 (0.816 – 1.079)	0.372	1.251 (1.011 – 1.548)	0.039	1.122 (0.930 – 1.355)	0.23
Osteoporosis	1.01 (0.957 – 1.066)	0.716	1.163 (1.068 – 1.266)	0.001	1.068 (0.992 – 1.150)	0.081
Obesity	1.138 (1.056 – 1.227)	0.001	1.499 (1.348 – 1.667)	<0.001	1.068 (0.958 – 1.189)	0.235
Diabetes	1.160 (1.100 – 1.224)	<0.001	1.447 (1.334 – 1.570)	<0.001	1.050 (0.976 – 1.131)	0.191
History of drug abuse	1.192 (1.025 – 1.385)	0.022	1.243 (0.995 – 1.554)	0.056	1.425 (1.166 – 1.742)	0.001
Census region (base=North)						
Midwest	0.909 (0.850 – 0.974)	0.006	0.802 (0.722 – 0.890)	<0.001	1.027 (0.933 – 1.130)	0.586
South	0.829 (0.778 – 0.883)	<0.001	0.859 (0.780 – 0.946)	0.002	1.093 (0.998 – 1.198)	0.056
West	0.890 (0.827 – 0.958)	0.002	0.681 (0.603 – 0.770)	<0.001	1.254 (1.132 – 1.388)	<0.001

Table 3

	Days in hospital following procedure		Total cost of procedure paid by insurer		Costs in first two years, aside from procedure	
	Coefficient (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value
Arthrodesis	1.062 (0.845 – 1.280)	<0.001	24126.62 (22,666.57 – 25,586.67)	<0.001	–14667.22 (–25,970.35 – –3,364.08)	0.011
Instrumentation	–0.101 (–0.300 – 0.098)	0.320	10231.33 (9,003.58 – 11,459.08)	<0.001	–1488.28 (–2,997.88 – 21.33)	0.053
Patient age (years)	0.016 (0.014 – 0.018)	<0.001	–316.73 (–351.06 – –282.39)	<0.001	143.01 (95.98 – 190.05)	<0.001
Male	0.236 (0.190 – 0.282)	<0.001	–890.47 (–1,611.73 – –169.20)	0.016	–312.67 (–1,158.31 – 532.96)	0.469
Year of operation	–0.075 (–0.084 – –0.065)	<0.001	2436.00 (2,268.14 – 2,603.86)	<0.001	–1552.49 (–1,722.44 – –1,382.53)	<0.001
Multiple laminectomy	0.208 (0.159 – 0.257)	<0.001	2299.43 (1,655.78 – 2,943.09)	<0.001	1863.14 (1,117.74 – 2,608.53)	<0.001
Comorbidities:						
Congestive heart failure	0.417(0.269 – 0.565)	<0.001	365.58 (–1,733.48 – 2,464.64)	0.733	10826.66 (7,552.08 – 14,101.24)	<0.001
Chronic obstructive pulmonary disease	0.143(0.091 – 0.195)	<0.001	–357.52 (–1,172.80 – 457.77)	0.390	5060.00 (4,044.26 – 6,075.74)	<0.001
Myocardial infarction	0.217(0.083 – 0.352)	0.002	114.05 (–2,026.51 – 2,254.60)	0.917	6090.48 (3,051.18 – 9,129.77)	<0.001
Osteoporosis	–0.006 (–0.058 – 0.047)	0.834	1415.67 (600.44 – 2,230.91)	0.001	3732.06 (3,051.18 – 9,129.77)	<0.001
Obesity	0.125 (0.059 – 0.191)	<0.001	773.44 (–336.48 – 1,883.36)	0.172	2792.29 (1,433.10 – 4,151.49)	<0.001
Diabetes	0.178 (0.128 – 0.228)	<0.001	1188.43 (381.32 – 1,995.54)	0.004	5234.81 (4,181.36 – 6,288.25)	<0.001
History of drug abuse	0.295 (0.155 – 0.436)	<0.001	196.15 (381.32 – 1,995.54)	0.874	10272.70 (6,933.95 – 13,611.45)	<0.001
Census region (base=North)						
Midwest	–0.256 (–0.348 – –0.163)	<0.001	–6421.88 (–7,545.74 – –5,298.02)	<0.001	–2547.93 (–3,713.92 – –1,381.93)	<0.001
South	–0.393 (–0.483 – –0.303)	<0.001	–3006.01 (–3,997.24 – –2,014.78)	<0.001	–1299.28 (–2,382.24 – –216.32)	0.019
West	–0.209 (–0.303 – –0.114)	<0.001	5270.05(4,016.41 – 6,523.70)	<0.001	1902.11 (499.17 – 3,305.04)	0.008

Table 4
Factors associated with postoperative opioid use based on linear and logistic regression models

	Patient has stopped using opioids by 6 months following procedure			Patient meets the criteria for chronic opioid use			MMEs, postoperative month 1			MMEs, postoperative month 2		
	OR (95% C.I.)	p-value	OR (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value	Coefficient (95% C.I.)	p-value
Arthrodesis	0.901 (0.790 – 1.028)	0.121	0.992 (0.830 – 1.186)	0.933	288.471 (164.502 – 412.439)	<0.001	172.123 (69.715 – 274.532)	<0.001	172.123 (69.715 – 274.532)	0.001		
Instrumentation	1.133 (1.035 – 1.240)	0.007	0.968 (0.857 – 1.094)	0.605	133.247 (47.396 – 219.097)	0.002	–29.385 (–104.340 – 45.570)	0.002	–29.385 (–104.340 – 45.570)	0.442		
Patient prescribed none of the following medications within 6 months preceding surgery:												
Opioids	3.017 (2.871 – 3.170)	<0.001	0.142 (0.129 – 0.157)	<0.001	–685.243 (–728.799 – –641.688)	<0.001	–581.995 (–610.287 – –553.702)	<0.001	–581.995 (–610.287 – –553.702)	<0.001		
Benzodiazepines	0.672 (0.640 – 0.706)	<0.001	1.734 (1.531 – 1.842)	<0.001	318.103 (259.422 – 376.784)	<0.001	258.826 (214.624 – 303.027)	<0.001	258.826 (214.624 – 303.027)	<0.001		
Antipsychotics	0.630 (0.549 – 0.723)	<0.001	1.788 (1.534 – 2.085)	<0.001	412.668 (211.826 – 613.510)	<0.001	519.080 (321.678 – 716.483)	<0.001	519.080 (321.678 – 716.483)	<0.001		
Patient age (years)	1.004 (1.002 – 1.007)	<0.001	0.982 (0.979 – 0.985)	<0.001	–26.379 (–28.671 – –24.087)	<0.001	–13.792 (–15.545 – 12.040)	<0.001	–13.792 (–15.545 – 12.040)	<0.001		
Male	0.934 (0.890 – 0.979)	0.005	1.042 (0.978 – 1.111)	0.200	–81.201 (–133.558 – –28.845)	0.002	9.607 (–27.718 – 46.933)	0.002	9.607 (–27.718 – 46.933)	0.614		
Year of operation	1.159 (1.147 – 1.171)	<0.001	0.884 (0.872 – 0.897)	<0.001	49.548 (37.660 – 61.436)	<0.001	–14.896 (–22.983 – –6.809)	<0.001	–14.896 (–22.983 – –6.809)	<0.001		
Multiple laminectomy	0.913 (0.873 – 0.955)	<0.001	1.079 (1.017 – 1.146)	0.012	45.743 (–3.631 – 95.117)	0.069	25.765 (–10.062 – 61.593)	0.069	25.765 (–10.062 – 61.593)	0.159		
Comorbidities:												
Congestive heart failure	0.814 (0.701 – 0.944)	0.007	1.287 (1.061 – 1.560)	0.010	–15.129 (–160.231 – 129.974)	0.838	43.689 (–55.852 – 143.230)	0.838	43.689 (–55.852 – 143.230)	0.390		
Chronic obstructive pulmonary disease	0.821 (0.777 – 0.867)	<0.001	1.333 (1.243 – 1.430)	<0.001	70.000 (6.590 – 133.410)	0.030	107.373 (59.842 – 154.904)	0.030	107.373 (59.842 – 154.904)	<0.001		
Myocardial infarction	0.825 (0.704 – 0.967)	0.018	1.118 (0.903 – 1.384)	0.307	26.682 (–146.521 – 199.886)	0.763	74.248 (–46.458 – 194.953)	0.763	74.248 (–46.458 – 194.953)	0.228		
Osteoporosis	0.949 (0.897 – 1.003)	0.063	1.035 (0.961 – 1.114)	0.368	–3.931 (–62.611 – 54.749)	0.896	–18.028 (–59.112 – 23.056)	0.896	–18.028 (–59.112 – 23.056)	0.390		
Obesity	0.960 (0.884 – 1.042)	0.330	0.964 (0.865 – 1.075)	0.512	–3.533 (–104.657 – 97.590)	0.945	1.786 (–65.962 – 69.535)	0.945	1.786 (–65.962 – 69.535)	0.959		
Diabetes	0.892 (0.847 – 0.940)	<0.001	1.132 (1.050 – 1.221)	0.001	–58.187 (–115.569 – –0.805)	0.047	–33.045 (–72.299 – 6.210)	0.047	–33.045 (–72.299 – 6.210)	0.099		
History of drug abuse	0.618 (0.534 – 0.716)	<0.001	2.600 (2.219 – 3.048)	<0.001	1384.858 (1087.958 – 1681.758)	<0.001	1307.125 (1038.358 – 1575.892)	<0.001	1307.125 (1038.358 – 1575.892)	<0.001		
Census region (base=North)												
Midwest	0.968 (0.901 – 1.039)	0.370	0.881 (0.800 – 0.969)	0.009	–154.023 (–233.626 – –74.419)	<0.001	–155.095 (–217.655 – –92.534)	<0.001	–155.095 (–217.655 – –92.534)	<0.001		
South	0.914 (0.854 – 0.979)	0.010	1.001 (0.914 – 1.097)	0.980	–260.933 (–339.531 – 182.334)	<0.001	–161.420 (–223.817 – –99.023)	<0.001	–161.420 (–223.817 – –99.023)	<0.001		
West	0.837 (0.774 – 0.906)	<0.001	1.088 (0.980 – 1.209)	0.114	490.424 (382.565 – 598.284)	<0.001	80.549 (4.441 – 156.658)	<0.001	80.549 (4.441 – 156.658)	0.038		