The Spine Journal 19 (2019) 717–725

Clinical Study

Effect of narcotic prescription limiting legislation on opioid utilization following lumbar spine surgery

Daniel B.C. Reid, MD, MPH[a,*], Kalpit N. Shah, MD[a], Jack H. Ruddell, BA[b], Benjamin H. Shapiro, MS[b], Edward Akelman, MD[a], Alexander P. Robertson, MD[a], Mark A. Palumbo, MD[a], Alan H. Daniels, MD[a]

[a] *Department of Orthopaedic Surgery, Warren Alpert Medical School of Brown University, Providence, RI, USA*
[b] *Warren Alpert Medical School of Brown University, Providence, RI, USA*
Received 5 August 2018; revised 10 September 2018; accepted 10 September 2018

Abstract

BACKGROUND CONTEXT: Prescription opioid abuse is a public health emergency. Opioid prescriptions for spine patients account for a large proportion of use. Some states have implemented statutory limits on prescribers, however it remains unclear whether such laws are effective.
PURPOSE: This investigation compares opioid prescription patterns for patients undergoing lumbar spine surgery before and after the passage of statewide narcotic-limiting legislation in Rhode Island.
STUDY DESIGN/SETTING: Retrospective review of prospectively-collected medical and pharmacologic data.
PATIENT SAMPLE: Two patient cohorts (*pre-law* January 1, 2016–June 31, 2016 and *post-law* June 1, 2017–December 31, 2017) that included all patients undergoing selected lumbar spine surgeries (lumbar discectomy, lumbar decompression without fusion, and posterior lumbar fusion).
METHODS: Demographic and surgical variables were collected from the patient's medical charts, and information on controlled substances was collected from the state prescription drug monitoring program database. Variables collected included the number of pills and total morphine milligram equivalents (MMEs) of the first prescription, number of prescriptions filled within 30 days of surgery, total MMEs filled in the 30-day postoperative period, and total MMEs filled from 30 to 90 days after surgery. For comparison of continuous variables, *t* test or Mann-Whitney *U* test were used as appropriate. Chi-squared analysis was utilized for comparison of categorical variables. Independent risk factors for prolonged postoperative opioid use were evaluated using logistic regression.
RESULTS: There were no significant differences between *pre-law* (n = 241) and *post-law* (n = 311) cohorts in terms of age, sex, preoperative opioid use, or preoperative anxiolytic use ($p > .05$). A greater than 50% decline was observed among all patients from the *pre-law* to the *post-law* period in terms of the number of pills (51.61 vs 23.60 pills, $p < .001$) and MMEs (525.56 vs 218.77 MMEs, $p < .001$) provided in the first postoperative opioid prescription. The mean total MMEs provided in the first 30 days decreased significantly (891.26 vs 628.63 MMEs, $p < .001$) despite an increase in the average number of opioid prescriptions filled (1.75 vs 2.04 prescriptions, $p = .002$) during this time. There was no significant difference in mean MMEs filled from 30 to 90 days. Upon subgroup analysis, there was a statistically significant decline in both the mean first prescription and total 30-day MMEs regardless of preoperative opioid status (all $p < .05$) or specific procedure performed (all $p < .05$). Preoperative opioid use was strongly associated with prolonged postoperative opioid requirements throughout the study period (OR 4.71, 95% CI 3.11–7.13, $p < .001$). There were no significant differences between cohorts in terms of emergency department (ED) visits or unplanned hospital readmissions at 30 and 90 days following surgery (all $p > .05$).

FDA device/drug status: Not applicable.

Author disclosures: ***DR:*** Nothing to disclose. ***KS:*** Nothing to disclose. ***JR:*** Nothing to disclose. ***BS:*** Nothing to disclose. ***EA:*** Nothing to disclose. ***AR:*** Nothing to disclose. ***MP:*** Consulting: Globus Medical (B), Spineart (C), Stryker (B). ***AD:*** Royalties: Springer (A); Consulting: Stryker (D), EOS (B), Spineart (C), Orthofix (D), Trans1 (None); Research Support - Staff and/or Materials: Orthofix (D, Paid directly to institution/employer); Fellowship Support: Orthofix (D, Paid directly to institution/employer).

* Corresponding author. Department of Orthopaedic Surgery, Warren Alpert Medical School of Brown University, 2 Dudley St, Providence, RI 02905. Tel.: 401-444-4030; fax: 401-444-6182.
E-mail address: danreid123@gmail.com (D.B.C. Reid).

https://doi.org/10.1016/j.spinee.2018.09.007

CONCLUSIONS: The institution of mandatory statewide opioid prescription limits has resulted in a significant reduction in initial and 30-day opioid prescriptions following lumbar spine surgery. Decreased opioid utilization was observed in all patients, regardless of preoperative opioid tolerance or procedure performed. No significant change in postoperative ED visits or unplanned hospital readmissions was seen following implementation of the legislation. This investigation provides preliminary evidence that narcotic limiting legislation may be effective in decreasing opioid prescriptions after lumbar spine surgery for both opioid-naïve and opioid-tolerant patients.

Keywords: Crisis; Law; Legislation; Lumbar; Opioid; Public health; Spine.

Introduction

In October 2017, the opioid epidemic was officially declared a "public health emergency" and the executive government was directed to use "every appropriate emergency authority" to fight the crisis [1,2]. There is increasing recognition of the impact of prescription opioid overutilization as a key factor in the current opioid crisis. While there is limited research on surgeon prescribing patterns after lumbar spine surgery, there is some evidence that orthopedic and neurosurgical spine surgeons may be contributing to this epidemic. Opioids are the most frequently prescribed drug class for treatment of back pain in the US [3], and the health care expenditures on opioids for back pain have been rising [4]. A recent study notes a significant association between rates of opioid prescriptions by neurosurgeons and drug-related deaths per state [5]. Moreover, despite making up only 2.5% of US physicians, orthopedists are responsible for 7.7% of all narcotic prescriptions [6]. Spine surgery patients have a high incidence of preoperative opioid utilization and have been shown to be at risk of prolonged postoperative use [7,8]. Chronic opioid use has been independently associated with increased hospital length of stay, poorer overall health-related quality of life scores, increased in-hospital morbidity and mortality, and nonunion risk [9–15].

A number of state legislatures have passed statewide mandatory narcotic prescription limits; however, it remains unclear whether such legislations are effective. In June of 2016, the state of Rhode Island passed several policy measures designed to address the opioid epidemic. One such measure involving strict limits on narcotic prescriptions for prescribers and pharmacies was implemented in April of 2017. Opioid prescriptions of greater than 30 morphine milligram equivalents (MMEs) per day or more than 20 doses in the first prescription for opioid-naïve patients were prohibited. This study seeks to objectively investigate whether the statewide opioid prescription legislation has been effective in decreasing opioid utilization in the short and medium term following lumbar spine surgery.

Methods

After institutional review board approval, retrospective review of the medical charts and prescription histories of all patients undergoing three commonly performed lumbar spine surgeries (lumbar discectomy, lumbar decompression without fusion, and posterior lumbar fusion) was performed. Patients undergoing surgery during one of two specific time periods (*pre-law* January 1st, 2016–June 30th, 2016; *post-law* June 1st, 2017–December 31st, 2017) were eligible for collection. Patients undergoing secondary surgeries in addition to their primary lumbar discectomy or lumbar decompression without fusion were considered ineligible for study. Patients undergoing primary posterior lumbar fusion remained eligible for inclusion if they underwent a secondary posterior procedure, such as a decompression. All patients undergoing a combined fusion approach (eg, anterior-posterior) during the same hospital stay were excluded. Patients undergoing surgery for spinal emergencies including cauda equina and epidural abscess were also excluded from analysis.

The patients' medical charts were reviewed for collection of demographic and surgical data. The Rhode Island prescription drug monitoring program was reviewed for each patient to evaluate all controlled substances filled from 30 days prior to their procedures until 90 days afterwards. The database was also reviewed for any preoperative benzodiazepine prescriptions filled within 30 days of surgery. All oral formulations of morphine, hydrocodone, oxycodone, codeine, hydromorphone, and tramadol were collected and converted to MMEs [16]. Preoperative benzodiazepine prescriptions collected included alprazolam, chlordiazepoxide, clonazepam, clorazepate, diazepam, flurazepam, lorazepam, oxazepam, quazepam, temazepam, and triazolam. Patients were considered opioid-naïve if they did not receive any opioid prescriptions within the 30-day preoperative period.

The number of pills and total MMEs of each patient's first postoperative opioid prescription was examined. Additionally, the number of prescriptions and total MMEs filled within 30 days was calculated. A summation in MMEs of all opioid prescriptions filled 30 to 90 days after surgery was also collected. Patients requiring prolonged postoperative opioids were defined as those filling at least one opioid prescription 30 to 90 days after surgery. Prescriptions beyond 90 days were not collected in order to prevent bias from potentially unrelated injuries or surgeries requiring narcotic pain medications.

Table 1
Patient demographics compared between *pre-law* and *post-law* cohorts. Counts of patients undergoing each one of the included surgeries are listed by cohort

	All patients (N = 552)	Pre-law patients (n = 241)	Post-law patients (n = 311)	p value
Age, mean (95% CI)	59.65 (58.34–61.66)	59.20 (57.10–61.29)	59.99 (58.33–61.66)	.962
Sex (Female), n (%)	258 (46.74%)	116 (48.13%)	142 (45.66%)	.563
Opioid tolerant, n (%)	201 (36.41%)	85 (35.27%)	116 (37.30%)	.623
Recent benzodiazepine use, n (%)	90 (16.30%)	33 (13.69%)	57 (18.33%)	.144
Discharged home postoperatively, n (%)	417 (75.54%)	186 (77.18%)	231 (74.28%)	.431
Primary surgery, n	-	-	-	-
Lumbar decompression (without fusion)	186	77	109	-
Posterior lumbar fusion	234	104	130	-
Lumbar discectomy	132	60	72	-

Student *t* test or Mann-Whitney *U* test were used as appropriate for comparison of continuous variables. Independent predictors of prolonged postoperative opioid use were evaluated with multiple logistic regression. Microsoft Excel version 16.11.1 (Microsoft Corporation, 2017, Redmond, WA, USA) was used for data collection and visualization. All statistical analyses were performed using Stata 15.0 (StataCorp., 2017, College Station, TX, USA). Statistical significance was defined as $p < .05$ a priori.

No funding was obtained for this study.

Results

Patient population

A total of 552 patients met inclusion criteria (241 *pre-law*, 311 *post-law*). There were no significant preoperative demographic differences between cohorts ($p > .05$) (Table 1). Additionally, similar proportions of patients in each cohort were noted to have utilized opioids (35.27% vs 37.30%, p = .623) or benzodiazepines (13.69% vs 18.33%, p = .144) within 30 days of surgery.

30-day postoperative period

Compared to the *pre-law* period, a significant decline in the number of pills in the first postoperative prescription was seen in the *post-law* period (51.61 vs 23.60 pills, $p < .001$). A corresponding decrease in the first prescription's total MMEs was similarly observed (525.56 vs 218.77 MMEs, $p < .001$) (Table 2, Fig. 1). While the total number of opioid prescriptions filled within 30 days did increase slightly in the *post-law* group (1.75 vs 2.04 prescriptions, p = .002), the mean MMEs filled during this time nevertheless decreased by nearly 30% *post-law* (891.26 vs 628.63 MMEs, $p < .001$) (Table 2, Fig. 2). No significant difference between *pre-law* and *post-law* cohorts was observed after 30 days ($p > .05$).

Subgroup analysis by procedure revealed a significant decrease for all procedures in terms of the first prescriptions' number of pills and total MMEs (all $p < .001$) (Table 2). The total MMEs filled within 30 days of surgery similarly declined among all surgeries evaluated (all $p < .01$).

A *post-law* decrease in the total MMEs in the first prescription was noted among both opioid-naïve (469.10 vs 149.56 MMEs, $p < .001$) and opioid-tolerant (629.18 vs

Table 2
Detailed comparisons of opioid prescriptions for all included patients and segregated by procedure performed. Comparisons made between *pre-law* and *post-law* cohorts

		All patients (N = 552)	Lumbar decompression without fusion (n = 186)	Posterior lumbar fusion (n = 234)	Lumbar discectomy (n = 136)
Mean no. pills in first script	Pre-law	51.61	50	50.36	55.87
	Post-law	23.60	23.08	23.33	24.86
	p value	<.001	<.001	<.001	<.001
Mean MME first script	Pre-law	525.56	480.1	565.17	515.25
	Post-law	218.77	237.06	199.32	226.22
	p value	<.001	<.001	<.001	<.001
Mean no. scripts 30 days	Pre-law	1.75	1.51	2.18	1.30
	Post-law	2.04	1.98	2.41	1.44
	p value	.002	.010	.121	.146
Mean MME 30 days	Pre-law	891.26	717.08	1,157.21	653.79
	Post-law	628.63	662.84	746.56	363.89
	p value	<.001	.003	.001	<.001
Mean MME 30–90 days	Pre-law	428.72	424.95	608.68	121.63
	Post-law	450.96	640.98	527.33	25.42
	p value	.097	.374	.117	.899

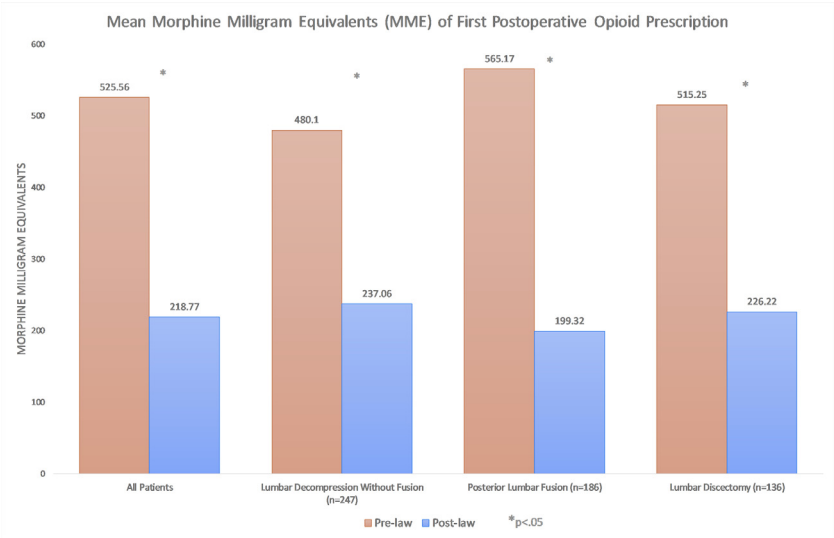

Fig. 1. Effect of narcotic limiting legislation on the MMEs prescribed in the first prescription after lumbar spine surgery.

335.12 MMEs, p < .001) patients (Table 3, Fig. 3). Similarly, the total MMEs filled in the first 30 postoperative days decreased in both opioid-naïve (726.27 vs 440.37 MMEs, p < .001) and opioid-tolerant (1,194.06 vs 945.09 MMEs, p < .001) patients (Table 3, Fig. 3).

Need for prolonged postoperative opioids

There was no significant difference between *pre-* and *post-law* cohorts in terms of MMEs filled during the 30 to 90-day postoperative period (Table 2). The proportion of patients who required prolonged postoperative opioids (more than 30 days postoperatively) was similar before and after passage of the law (36.10% vs 31.19%, p = .225).

After controlling for potential confounders including age, sex, preoperative benzodiazepine use, discharge disposition, legislative cohort, and surgical procedure, the factor most strongly predictive of the need for prolonged postoperative opioid requirements was preoperative opioid use (OR 4.71, 95% CI 3.11–7.13, p < .001, Table 4). Of those who filled opioids in the preoperative period, 53.73% (108/201) went on to fill subsequent opioid prescriptions more than 30 days postoperatively. In comparison, only 21.65% (76/351) of opioid-naïve patients required prolonged opioid treatment after surgery (p < .001). Age (p = .587), sex (p = .328), and preoperative benzodiazepine use (p = .282) were not significantly associated with prolonged opioid use (Table 4). Patients undergoing isolated lumbar decompressions (OR 3.81, 95% CI 1.96–7.39, p < .001) and posterior lumbar fusions (OR 5.06, 95% CI 1.82–4.53, p < .001) were significantly more likely to require prolonged opioids than those undergoing lumbar discectomy. Those discharged home in

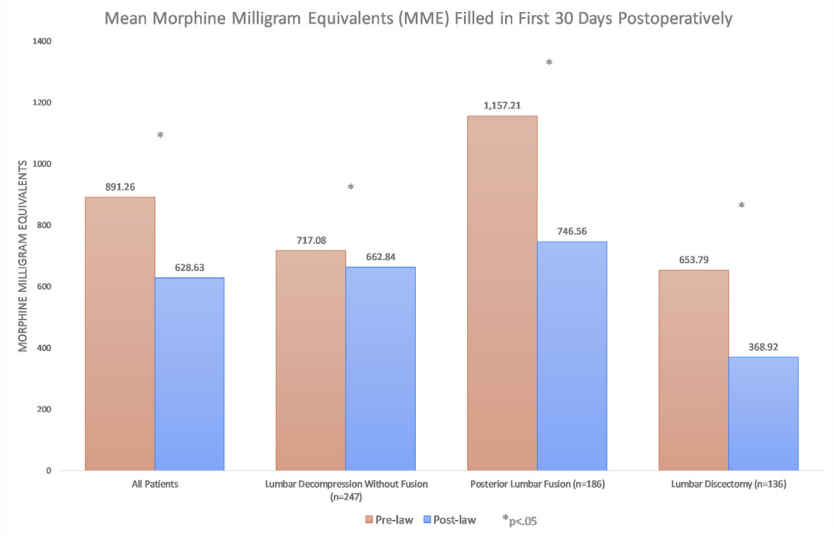

Fig. 2. Effect of narcotic limiting legislation on the MMEs prescribed in the first 30 days after lumbar spine surgery.

Table 3
Opioid prescriptions filled, stratified by preoperative opioid status

		All patients (N = 552)	Opioid tolerant (n = 201)	Opioid naïve (n = 351)
Mean no. pills in first script	Pre-law	51.61	55.41	49.54
	Post-law	23.6	31.16	19.10
	p value	< .001	< .001	< .001
Mean MME first script	Pre-law	525.56	629.18	469.10
	Post-law	218.77	335.12	149.56
	p value	< .001	< .001	< .001
Mean no. scripts 30 days	Pre-law	1.75	2.21	1.49
	Post-law	2.04	2.35	1.85
	p value	.002	.539	< .001
Mean MME 30 days	Pre-law	891.26	1,194.06	726.27
	Post-law	628.63	945.09	440.37
	p value	< .001	< .001	< .001
Mean MME 30–90 days	Pre-law	428.72	897.52	173.29
	Post-law	450.96	943.01	158.26
	p value	.097	.003	.799

the postoperative period were significantly less likely to require prolonged opioids than those discharged to medical facilities such as rehabilitation units or skilled nursing facilities (OR 0.56, 95% CI 0.35–0.90, p = .017, Table 4).

Subgroup analysis of patients discharged to home

Subgroup analysis including only those discharged to home after surgery (n = 417) was performed. A significant decline in both the number of pills (55.52 vs 24.29 pills, p < .001) and total MMEs (545.93 vs 205.45 MMEs, p < .001) filled in the first postoperative prescription was noted in this group (Table 5). Furthermore, the mean MMEs filled by 30 days following surgery declined from 860.12 to 565.25 (p < .001) in the *post-law* period. This pattern of findings was consistent regardless of surgical procedure evaluated (all p < .01, Table 5). No significant differences were seen after 90 days (all p > .05).

Postoperative emergency department visits and unplanned readmissions

There were no significant differences between the proportion of *pre-law* and *post-law* patients visiting and emergency department (ED) in the 30 day (10.79% *pre-law* vs 10.29% *post-law*, p = .850) and 30 to 90 day (7.88% *pre-law* vs 5.79% *post-law*, p = .329) postoperative periods (Table 6). Similarly, no difference in unplanned readmission rates at 30 days (4.98% *pre-law* vs 6.11% *post-law*,

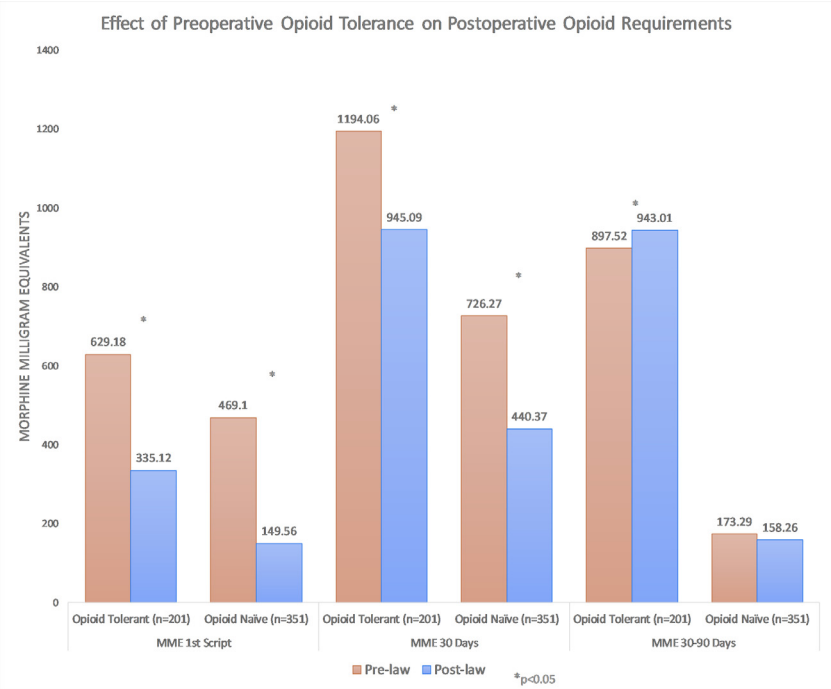

Fig. 3. Effect of preoperative opioid tolerance on postoperative opioid requirements following lumbar spine surgery.

Table 4
Multiple logistic regression evaluating independent risk factors for prolonged opioid utilization. Variables included in the model included patient demographics, preoperative opioid and benzodiazepine exposure, patient cohort, discharge disposition, and type of surgery

Variables	Odds ratio	Std. Err.	z	p value	95% CI	
Age	1.00	0.01	−0.54	.587	0.98	1.01
Male sex	0.82	0.17	−0.98	.328	0.55	1.22
Preoperative opioid use	4.71	1.00	7.33	<.001	3.11	7.13
Preoperative benzodiazepine use	1.33	0.36	1.08	.282	0.79	2.25
Discharge to home (vs facility)	0.56	0.14	−2.4	.017	0.35	0.90
Post-law	0.73	0.15	−1.54	.122	0.49	1.09
Specific surgery (lumbar discectomy = reference group)	-	-	-	-	-	-
Isolated lumbar decompression	3.81	1.29	3.95	<.001	1.96	7.39
Posterior lumbar fusion	5.06	1.82	4.53	<.001	2.51	10.22
Constant	0.20	0.12	−2.77	.006	0.07	0.63

p = .567) or 30 to 90 days (3.73% *pre-law* vs 3.86% *post-law*, p = .940) was observed (Table 6).

Discussion

This investigation provides early evidence supporting the potential effectiveness of mandatory narcotic prescription limiting legislation in decreasing opioid utilization in the early postoperative period. A significant reduction in the number of opioids filled in the first 30 days following spine surgery was observed after statewide mandatory opioid prescribing limits were implemented in Rhode Island. Specifically, a 58.4% reduction in MMEs provided in the first postoperative opioid prescription was seen. Furthermore, while the total number of individual opioid prescriptions provided within 30 days of surgery increased slightly after the law was implemented, each prescription averaged fewer total opioids, resulting in a significant 29.5% decline in 30-day MMEs.

When stratified by preoperative opioid status, previously opioid-naïve patients experienced a 68.1% reduction in the MMEs provided in the first postoperative prescription and a 39.4% total reduction in MMEs in the first 30 postoperative days. Interestingly, while the legislation specifically exempted opioid-tolerant patients from any mandatory prescribing limits, this group of patients nevertheless appears to have been affected by the legislation as well. Specifically, there was a 46.7% reduction in mean MMEs provided in the first prescription and a 20.9% reduction in total MMEs by 30 days among opioid-tolerant patients. It is possible that the law's mandates for opioid-naïve patients were adopted into general physician and pharmacy prescribing workflows. As prescription practices were standardized and new practice habits were formed following implementation of the new mandates, many prescribers likely adopted more restrictive narcotic prescribing patterns in the early postoperative period for all patients, regardless of preoperative opioid status.

Table 5
Subgroup analysis of only patients discharged home postoperatively. Comparisons of opioid prescriptions filled were made between *pre-law* and *post-law* cohorts

		All patients discharged home (N = 417)	Lumbar decompression without fusion, discharged home (n = 140)	Posterior lumbar fusion, discharged home (n = 234)	Lumbar discectomy, discharged home (n = 136)
Mean no. pills in first script	Pre-law	55.52	54.27	56.37	55.80
	Post-law	24.29	22.33	25.79	24.86
	p value	<.001	<.001	<.001	<.001
Mean MME first script	Pre-law	545.93	519.92	594.15	516.36
	Post-law	205.45	172.62	220.38	226.22
	p value	<.001	<.001	<.001	<.001
Mean no. scripts 30 days	Pre-law	1.66	1.56	2.04	1.31
	Post-law	1.91	1.96	2.29	1.44
	p value	.005	.019	.213	.159
Mean MME 30 days	Pre-law	860.12	765.97	1,117.83	657.25
	Post-law	565.25	523.89	794.04	363.89
	p value	<.001	.001	.005	<.001
Mean MME 30–90 days	Pre-law	348.87	345.49	547.17	123.69
	Post-law	288.87	331.02	488.3	25.42
	p value	.176	.581	.169	.868

Table 6
Proportion of patients returning to emergency department (ED) or requiring unplanned readmission at 30 and 90 days postoperatively, stratified by timepoint and procedure. Comparisons were made between *pre-law* and *post-law* cohorts

		All patients (N = 552)	Lumbar decompression without fusion (n = 186)	Posterior lumbar fusion (n = 234)	Lumbar discectomy (n = 132)
ED visit within 30 days of discharge, n (%)	Pre-law (n = 241)	26 (10.79%)	8 (10.39%)	15 (14.42%)	3 (5.00%)
	Post-law (n = 311)	32 (10.29%)	11 (10.09%)	15 (11.54%)	6 (8.33%)
	p value	.850	.947	.512	.449
ED visit 30–90 days following discharge, n (%)	Pre-law (n = 241)	19 (7.88%)	5 (6.49%)	13 (12.50%)	1 (1.67%)
	Post-law (n = 311)	18 (5.79%)	10 (9.17%)	5 (3.85%)	3 (4.17%)
	p value	.329	.508	.014	.404
Unplanned readmission within 30 days of discharge, n (%)	Pre-law (n = 241)	12 (4.98%)	4 (5.19%)	7 (6.73%)	1 (1.67%)
	Post-law (n = 311)	19 (6.11%)	8 (7.34%)	11 (8.46%)	0 (0.00%)
	p value	.567	.558	.622	.271
Unplanned readmission 30–90 days following discharge, n (%)	Pre-law (n = 241)	9 (3.73%)	1 (1.30%)	8 (7.69%)	0 (0.00%)
	Post-law (n = 311)	12 (3.86%)	7 (6.42%)	5 (3.85%)	0 (0.00%)
	p value	.940	.090	.202	1.000

Post-law, a 262.6 MME reduction per patient in the 30-day postoperative period was seen compared to the *pre-law* cohort. This is equivalent to a reduction of 35.0 oxycodone tablets per patient and 10,890 fewer oxycodone pills dispensed than expected in the 311 patient *post-law* cohort. While no difference in the proportion of patients requiring prolonged opioid treatment or the total MMEs filled after 30 days was observed after the law's implementation, the substantial decrease in opioids dispensed in the first 30 days may have important implications for public health. Specifically, a reduction in opioids dispensed into the community may reduce the risk of opioid diversion. Opioid diversion describes the transfer of prescription opioids from patients for whom they were legally prescribed to other persons for illegal or recreational use. Opioid diversion has been shown to be an important contributing factor in the current opioid epidemic. In a recent study, 54.4% of those using prescription opioids for nonmedical use reported obtaining them from a friend or relative for free, and over 15% reported either buying or stealing opioids from a friend or relative. In contrast, less than 5% of recreational users bought their prescription opioids from a drug dealer or some other stranger [17].

This study is the first to objectively evaluate the effect of mandatory narcotic-restricting legislation on postoperative prescribing practices among spine surgeons. The results demonstrate early evidence of success in terms of decreasing opioid utilization in the early postoperative period after lumbar spine surgery, although no significant difference between *pre*-law and *post-law* cohorts was appreciated after 30 days. Thus, while this legislation may be effective in decreasing early opioid dispensation after lumbar spine surgery, prolonged use of narcotic medication in this population remains unchanged. The problem of chronic opioid utilization for back pain and after lumbar spine surgery continues to be a critical issue. Further research efforts are currently underway evaluating demographic, medical, and surgical risk factors for prolonged and chronic opioid dependence in this important patient cohort. The development of effective policies and clinical strategies to reduce long-term opioid use both before and after lumbar spine surgery is of paramount importance. In this analysis, the preoperative variable most predictive of prolonged postoperative opioid use was preoperative opioid tolerance. This is consistent with recent research implicating preoperative opioid use as a risk factor for prolonged use after anterior cruciate ligament (ACL) reconstruction [12], knee arthroscopy [9], total knee arthroplasty [10,11], shoulder arthroplasty [18], and spine surgery [14,19,20].

Despite the substantial reduction in postoperative opioid utilization, no associated change in ED visits or unplanned hospital readmissions was seen within the 90-day postoperative period. This is particularly important given considerable concern among medical professionals and the population at large [21,22] regarding the potential for undertreatment of pain with restrictive opioid prescription laws. While these findings suggest indirectly that undertreatment of pain in relation to such laws may not be a major problem in this population, further studies focusing on direct measures of postoperative pain, patient satisfaction, overall cost of care, and long-term health related quality of life are indicated and may further elucidate this important question.

Because this quasi-experimental study design utilized the real-world implementation of narcotic-limiting legislation to test its hypothesis, it allowed for a natural experiment evaluating the effectiveness of this new policy. This may improve the ecological validity of the study results. Furthermore, there were no significant preoperative demographic differences between *pre*-law and *post*-law cohorts, providing evidence that these were similar populations, except for presence or absence of the law. Unique strengths of this study include the granular demographic and surgical data collected from medical charts as well as the state prescription drug monitoring program database. This database of all controlled substances dispensed in Rhode Island and

the surrounding states allows for accurate evaluation of all outpatient controlled substance prescriptions. Opioids prescribed by any healthcare provider, not just from the treating surgeon, were included in the analysis. Thus, narcotic prescriptions from other providers such as fellows, residents, physicians' assistants, nurse practitioners, ED physicians, and primary care providers were not missed.

Potential limitations of this study include our inability to analyze inpatient opioid prescription patterns. While all prescriptions filled at outpatient pharmacies were included in the analysis, the database unfortunately does not include opioid prescription information during inpatient hospital stays or at skilled nursing and rehabilitation facilities. This may be particularly relevant for geriatric patients and in those with significant functional deficits requiring rehabilitation after surgery. To control for this limitation, subgroup analysis of only patients discharged home was performed, with similar findings compared to the overall group. Additionally, all ED visits and unplanned readmissions in the 90-day postoperative period were tracked, and no significant difference was noted between the *pre-law* and *post-law* cohorts in terms of ED visits or readmission rates. While we were able to accurately summate the total opioids filled at outpatient pharmacies, we are unable to determine how many pills patients actually consumed. Thus, it is possible the mean MMEs taken may be less than those filled at pharmacies. As a retrospective examination of prospectively collected data, this study is at risk of the biases inherent to all retrospective research. While our *pre-law* and *post-law* groups were similar demographically, it is possible that there are subtle population differences which were not appreciated. It is important to note that this study took place during a period of increasing awareness by patients, providers, hospital-systems, lawmakers, and society at large regarding the potential harms of opioids. It is possible that national trends in practice management may have contributed in part to the observed decrease in opioid utilization postoperatively. Thus, causation between mandatory narcotic-limiting legislation and decreasing opioid utilization in the postoperative period following lumbar spine surgery cannot be definitively established with this study methodology. However, it is unlikely that such epidemiologic trends alone can account for the particularly steep decline in postoperative opioid utilization seen shortly after implementation of the law. Finally, this is a single state and single institution study. Thus, any practice changes observed after passage of this specific legislation may be different with differing legislation, at various institutions, and in other states. Any generalization of this data to larger cohorts should be interpreted with caution. Further research comparing national trends in opioid utilization patterns as well as prescription patterns in similar states with and without such legislation over time may help answer this important question. However, this study provides preliminary evidence for the effectiveness of the legislation in question and may serve a starting point for future research.

Conclusion

After statewide mandatory opioid prescribing limits were implemented in Rhode Island, a significant reduction in the 30-day postoperative opioids prescribed following lumbar spine surgery has been observed. Further research is still needed evaluating the effects of this legislation on postoperative pain control and ED visits. Additionally, studies evaluating such legislation in different populations and in different geographic regions are still needed. This investigation, however, is the first of its kind and provides early evidence that legislation designed to reduce opioid prescriptions through mandatory caps may be effective in decreasing early postoperative opioid utilization after lumbar spine surgery.

Acknowledgment

Institutional Review Board Approval was obtained at all participating institutions for collection and analysis of patient data. No funding was required for this study.

References

[1] Johnson J, Wager J. Trump declares the opioid crisis a public health emergency. Washington Post 2017.

[2] Christie C, Baker C, Cooper R, Kennedy P, Madras B, Bondi P. The President's commission on combating drug addiction and the opioid crisis. 2017.

[3] Ivanova JI, Birnbaum HG, Schiller M, Kantor E, Johnstone BM, Swindle RW. Real-world practice patterns, health-care utilization, and costs in patients with low back pain: the long road to guideline-concordant care. Spine J 2011;11:622–32. doi: 10.1016/j.spinee.2011.03.017.

[4] Martin BI, Deyo RA, Mirza SK, Turner JA, Comstock BA, Hollingworth W, et al. Expenditures and health status among adults with back and neck problems. JAMA 2008;299:656. doi: 10.1001/jama.299.6.656.

[5] Khalid SI, Adogwa O, Lilly DT, Desai SA, Vuong VD, Mehta AI, et al. Opioid prescribing practices of neurosurgeons: analysis of medicare part D. World Neurosurg 2018;112:e31–8. doi: 10.1016/j.wneu.2017.12.011.

[6] Volkow ND, McLellan TA, Cotto JH, Karithanom M, Weiss SRB. Characteristics of opioid prescriptions in 2009. JAMA 2011;305:1299–301. doi: 10.1001/jama.2011.401.

[7] Deyo RA, Hallvik SE, Hildebran C, Marino M, O'Kane N, Carson J, et al. Use of prescription opioids before and after an operation for chronic pain (lumbar fusion surgery). Pain 2018;159:1147–54. doi: 10.1097/j.pain.0000000000001202.

[8] Brummett CM, Waljee JF, Goesling J, Moser S, Lin P, Englesbe MJ, et al. New persistent opioid use after minor and major surgical procedures in US adults. JAMA Surg 2017;152:e170504. doi: 10.1001/jamasurg.2017.0504.

[9] Steiner SRH, Cancienne JM, Werner BC. Narcotics and knee arthroscopy: trends in use and factors associated with prolonged use and postoperative complications. Arthrosc J Arthrosc Relat Surg 2018;34:1931–9. doi: 10.1016/j.arthro.2018.01.052.

[10] Namba RS, Singh A, Paxton EW, Inacio MCS. Patient factors associated with prolonged postoperative opioid use after total knee arthroplasty. J Arthroplasty 2018. doi: 10.1016/j.arth.2018.03.068.

[11] Bedard NA, Pugely AJ, Westermann RW, Duchman KR, Glass NA, Callaghan JJ. Opioid use after total knee arthroplasty: trends and risk factors for prolonged use. J Arthroplasty 2017;32:2390–4. doi: 10.1016/j.arth.2017.03.014.

[12] Anthony CA, Westermann RW, Bedard N, Glass N, Bollier M, Hettrich CM, et al. Opioid demand before and after anterior cruciate ligament reconstruction. Am J Sports Med 2017;45:3098–103. doi: 10.1177/0363546517719226.

[13] Buchheit T, Zura R, Wang Z, Mehta S, Della Rocca GJ, Steen RG. Opioid exposure is associated with nonunion risk in a traumatically injured population: an inception cohort study. Injury 2018. doi: 10.1016/j.injury.2018.05.004.

[14] Jain N, Phillips FM, Weaver T, Khan SN. Pre-operative chronic opioid therapy: a risk factor for complications, readmission, continued opioid use and increased costs after one- and two-level posterior lumbar fusion. Spine 2018;1. doi: 10.1097/BRS.0000000000002609.

[15] Menendez ME, Ring D, Bateman BT. Preoperative opioid misuse is associated with increased morbidity and mortality after elective orthopaedic surgery. Clin Orthop Relat Res 2015;473:2402–12. doi: 10.1007/s11999-015-4173-5.

[16] Opioid Oral Morphine Milligram Equivalent (MME) Conversion Factors 2017. https://www.cms.gov/Medicare/Prescription-Drug-Coverage/PrescriptionDrugCovContra/Downloads/Opioid-Morphine-EQ-Conversion-Factors-Aug-2017.pdf (Accessed July 9, 2018).

[17] Jones CM, Paulozzi LJ, Mack KA. Sources of prescription opioid pain relievers by frequency of past-year nonmedical use United States, 2008-2011. JAMA Intern Med 2014;174:802–3. doi: 10.1001/jamainternmed.2013.12809.

[18] Rao AG, Chan PH, Prentice HA, Paxton EW, Navarro RA, Dillon MT, et al. Risk factors for postoperative opioid use after elective shoulder arthroplasty. J Shoulder Elb Surg 2018. doi: 10.1016/j.jse.2018.04.018.

[19] Pugely AJ, Bedard NA, Kalakoti P, Hendrickson NR, Shillingford JN, Laratta JL, et al. Opioid use following cervical spine surgery: trends and factors associated with long-term use. Spine J 2018. doi: 10.1016/j.spinee.2018.03.018.

[20] Schoenfeld AJ, Belmont PJ, Blucher JA, Jiang W, Chaudhary MA, Koehlmoos T, et al. Sustained preoperative opioid use is a predictor of continued use following spine surgery. J Bone Jt Surg 2018;100:914–21. doi: 10.2106/JBJS.17.00862.

[21] Ehley B. How the opioid crackdown is backfiring. POLITICO 2018.

[22] O'Donnell J, Chu J. Chronic pain patients, overlooked in opioid crisis, getting new attention from top at FDA. USA Today 2018.