

Discharge Prescribing and Subsequent Opioid Use After Traumatic Musculoskeletal Injury

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Physicians struggle with the challenge of managing acute pain while guarding against the risk of long-term use when prescribing opioids.¹ Recent policies have restricted the supply of opioids that physicians can prescribe based on study findings suggesting that reducing opioid supplies could mitigate subsequent use and dependence.²⁻⁵ These correlational studies may be prone to significant bias if patient or injury characteristics influence both discharge supplies and subsequent use. For example, if patients with more serious injuries receive higher supplies at discharge, their propensity to use opioids in the short and long term may reflect the severity of their injuries rather than the supplies of their initial prescriptions.

One study addressed this source of bias by examining the association between physician prescribing tendencies and patient outcomes in the emergency department (ED) setting, where patients may be naturally randomly assigned to physicians.⁶ For a general population of ED patients with relatively low rates of opioid medication receipt, that study found a very small increase (0.35 percentage points) in subsequent use associated with higher-intensity ED physician prescribing patterns and did not account for the contribution of a given patient's clinical needs to both the physician's prescribing tendency and subsequent use. Moreover, the long-term consequences of high opioid supplies for acute pain in clinical settings where opioids are often necessary, as opposed to discretionary, remain unclear.

In this study, we investigate the effects of discharge opioid supply on subsequent opioid use after surgery for musculoskeletal injury at 2 academic trauma centers. Traumatic injury is a clinical setting where opioid prescribing rates are high, opioid use is often unavoidable, and the opioid supply is consequently the relevant variable.⁷ Because a patient's assigned resident at a teaching hospital is determined by the idiosyncrasies of the monthly rotation schedule and daily on-call schedules, assignment to residents with variable prescribing tendencies creates a natural experiment in discharge opioid supplies. Thus, we use resident prescribing tendencies as a source of variation that should not be related to patient needs, and we employ methods that eliminate a given patient's contribution to the physician's prescribing profile. We also account for

ABSTRACT

OBJECTIVE: To investigate the effects of discharge opioid supply after surgery for musculoskeletal injury on subsequent opioid use.

STUDY DESIGN: Instrumental variables analysis of retrospective administrative data.

METHODS: Data were acquired on 1039 patients treated operatively for a musculoskeletal injury between 2011 and 2015 at 2 level I trauma centers. State registry data were used to track all postoperative opioid prescription fills. Discharge surgical resident was identified for each patient. We categorized residents in the top one-third of opioid prescribing as high-supply residents and others as low-supply residents, with adjustment for service attending physician and month. The primary outcome was subsequent opioid use, defined as new opioid prescriptions and cumulative prescribed opioid supply 7 to 8 months after injury.

RESULTS: On average, patients of high-supply residents received an additional 96 morphine milligram equivalents (MME) at discharge (95% CI, 29-163 MME; $P < .01$), or 16% more, compared with patients of low-supply residents, which is equivalent to an additional 2-day supply at a typical dosage. In the seventh or eighth month after surgery, patients of high-supply residents received a greater total MME volume than patients of low-supply residents (difference, 13.0 MME; 95% CI, 3.1-22.9 MME; $P < .01$) despite receiving a greater cumulative supply of opioid medications through the sixth month after surgery.

CONCLUSIONS: After surgery for musculoskeletal injury, patients discharged by residents who prescribe greater supplies of opioid pain medications received higher supplies of opioids 7 to 8 months after surgery than patients discharged by residents who tend to prescribe less. Thus, limiting postoperative supplies of opioid pain medication may help reduce chronic opioid use.

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variation between patients of different attending physicians that may not be attributable to the resident. This analysis identifies a group of “treated” patients of “high-supply” residents who are comparable to “control” patients of “low-supply” residents in all aspects other than the discharge opioid supply.

TAKEAWAY POINTS

We use surgical resident assignment as an instrumental variable for discharge opioid prescribing and estimate the impact of discharge opioid supply on subsequent use.

- ▶ Surgical trauma patients who receive higher opioid prescriptions at discharge have higher rates of subsequent use (supply of new opioids at 7-8 months).
- ▶ Limiting initial opioid prescription at discharge may reduce subsequent opioid use.
- ▶ Resident assignment in orthopedic trauma surgery can be used as an effective instrumental variable, or natural experiment, for discharge opioid prescribing.

METHODS

Study Data and Population

We identified 2645 patients with traumatic musculoskeletal injuries who were treated operatively within 14 days of initial presentation and discharged by a resident physician at Massachusetts General Hospital or Brigham and Women’s Hospital in Boston between 2011 and 2015. Detailed demographic and clinical data, including prescriber and discharge opioid prescription, were matched to each patient using the institutions’ shared Enterprise Data Warehouse (EDW). We excluded patients with multiple injuries and multiple traumatic events in a single episode. We also excluded patients who received a discharge opioid prescription exceeding 10,000 morphine milligram equivalents (MME; <1% of the population). We used hospital discharge summaries to link patients to their care team of resident and attending physicians at discharge. Resident and attending physician names were identified using an electronic parser coded in Python version 2.7 (Python Software Foundation).

Consistent with the acute nature of the injuries, 85% of patients (n = 2247) received an opioid at discharge. To track subsequent new prescriptions and represcriptions (including refills) of opioids throughout Massachusetts, we linked hospital data to the Prescription Drug Monitoring Program data of the Massachusetts Department of Public Health’s Public Health Data Warehouse (PHD) using patient name, address, race, and sex (91% match rate). Patients from the hospital data who could not be matched to the PHD data were removed from the analysis. To limit the analysis to opioid-naïve patients, we excluded patients who were prescribed an opioid in the 6 months before presentation based on their prescription history in the PHD or EDW, excluding 48% of the original sample and leaving us with 1051 patients. Finally, we excluded patients of residents and attendings who treated fewer than 5 patients in the sample (1% of the sample).

After applying these restrictions, the sample included 1039 orthopedic patients treated by 61 distinct residents and 34 distinct attending physicians. Attending physicians saw a mean of 69 patients (range, 3-131) and residents saw a mean of 22 patients (range, 5-42) meeting the inclusion criteria during the 4-year study period.

Study Variables

Discharge opioid prescription and resident dosing intensity.

We identified the discharge prescription as the first outpatient prescription within 30 days of initial injury. We used a 30-day window for initial prescription to ensure that we included patients with longer hospitalizations; we used the earliest prescription

to ensure that we captured the prescription closest to discharge. Discharge prescriptions were converted into total MME by applying standard conversion tables.⁸ The MME were summed in cases in which more than 1 opioid prescription was filled on the same day.

Outcomes. We examined use in each month after injury and the cumulative supply by the end of each month. We prespecified the primary outcome as subsequent opioid use 7 to 8 months after injury, defined as opioid prescription fills during those months, including new prescriptions and repeated prescriptions. We considered both the volume of opioid supply in MME and whether an opioid was received during this interval.

Covariates. We recorded patient age, sex, race, and insurance type. We also considered injury year, location, and severity (AO Foundation and Orthopaedic Trauma Association fracture classification). Comorbidity was defined as the count of unique medication classes prescribed in the 180 days before the index visit (previously validated in trauma populations).²

Statistical Analysis

We ran ordinary least-squares and 2-stage least-squares (2SLS) regressions to estimate the relationship between resident prescribing tendency and subsequent use. In the design, resident assignment acts as an instrument for discharge opioid prescription. Resident prescribing tendencies were adjusted for attending effects, as described later herein. The main analysis uses ordinary least-squares regression to estimate the direct relationship between resident prescribing tendency and subsequent opioid use.

Subsequent analyses use 2SLS (reported in [eAppendix Tables 1 and 2](#) [eAppendix available at [ajmc.com](#)]). In the design, 2SLS estimates the relationship between discharge opioid prescription (directly estimated from resident prescribing tendency) and subsequent opioid use. The first stage of the estimator is the relationship between resident prescribing tendency and patient discharge prescription. The reduced form of the estimator is the direct relationship between resident prescribing tendency and subsequent use. The 2SLS estimate is produced by dividing the reduced form coefficient by the first stage, hence scaling the relationship between resident prescribing tendency and long-run use by the degree by which resident prescribing tendency predicts discharge prescription.

Resident prescribing tendencies. In the regressions, resident prescribing tendencies were identified using a “leave-one-out”

TABLE 1. Balance Check of Covariates Between Patients of High- and Low-Supply Residents

Covariate	Patients of low-supply residents	Patients of high-supply residents	Difference (SE)	P
Age in years	60.30	60.74	0.44 (1.17)	.71
Comorbidities	0.37	0.34	-0.034 (0.051)	.50
White, %	83.70	81.56	-2.11 (2.51)	.40
Female, %	52.75	53.88	1.15 (3.28)	.73
White and female, %	43.79	44.67	0.88 (3.27)	.79
Medicaid, %	8.24	8.25	0.12 (1.82)	.95
Self-pay, %	2.75	1.74	-1.02 (0.94)	.28
Leg, %	32.80	32.57	-0.23 (3.08)	.94
Pelvis, %	2.02	2.59	0.57 (1.01)	.57
Upper body, %	8.09	7.21	-0.89 (1.73)	.61
AO/OTA A, %	16.76	14.99	-1.78 (2.39)	.46
AO/OTA B, %	16.91	16.72	-0.19 (2.46)	.94
AO/OTA C, %	9.25	10.66	1.41 (1.99)	.48
Year of discharge, %				
2011	4.48	1.16	-3.33 (0.97)	<.001
2012	16.33	22.48	6.14 (2.65)	<.001
2013	22.40	31.70	9.30 (2.96)	<.001
2014	41.04	38.04	-3.00 (3.21)	<.001
2015	15.75	6.63	-9.12 (1.92)	<.001

AO/OTA, AO Foundation/Orthopaedic Trauma Association fracture classification.

method to adjust for heterogeneous features of attendings, attending panels, and patients.⁹ This approach allowed us to compare the MME quantity prescribed by each resident for a typical patient with those of other residents in similar settings. To estimate an attending effect on each prescription, we measured the mean discharge prescription MME by the attending physician's other residents, leaving out the prescriptions written by the patient's own resident so that the resident's prescribing tendencies do not enter into the attending effect. We then adjusted the resident prescription for each patient by the attending effect for each patient's attending physician. Therefore, the estimated resident prescribing tendency is demeaned by the attending effect. Adjusting resident prescribing practices for this attending effect was important to eliminate differences in residents' exposure to different attending physicians because although the resident assigned to a given patient should be random, assignment of surgical cases to different attending physicians may not be.

Then, the resident's prescribing tendency was defined as the mean discharge prescription (in MME) by the resident relative to all other residents, after adjusting for the attending effect and the clinical characteristics of the resident's patients. To ensure that the resident's prescribing tendency was independent of the patient's own characteristics, we excluded the patient's own prescription. Leaving out the patient's prescription was important to eliminate correlation between unobserved patient characteristics and the

estimated prescribing tendencies of the patient's resident. The resident prescribing tendency is therefore unique for each attending-patient combination. We defined high-supply residents as those in the top one-third of resident prescribing tendencies, with robustness to the top one-fourth and top one-fifth.

Analysis. To test the assumption that patients were naturally randomly assigned to residents, we checked whether patient characteristics were balanced across high- and low-supply residents. We also assessed the strength of the instrumental variable by estimating the association between the prescribing tendency of a patient's assigned resident and discharge supply.

For the main analysis, we estimated the direct (reduced form) relationship between resident prescribing tendency and long-run opioid use using ordinary least-squares regression. In 2SLS analyses reported in the eAppendix, we further adjusted the reduced form estimate with the relationship between resident tendency and patient discharge MME prescription (first stage), producing an estimate of the relationship between MME prescription at discharge and subsequent opioid use. All regressions used heteroskedasticity-robust SEs and were performed using SAS Studio version 3.5 (SAS Institute).

As a falsification test, we checked whether resident prescribing tendencies were predictive of patients' opioid use in the 7 to 8 months before surgery. Because treatment in the present should not affect opioid use in the past, uncovering such a relationship would suggest that an omitted factor such as chronic morbidity drove resident prescribing behavior and patient opioid use patterns. In contrast, a null result would support the study design because many omitted factors that would create a misleading relationship between resident prescribing tendencies and opioid use would also affect previous use.

This study was approved by the Massachusetts General Hospital Institutional Review Board (IRB), which determined that individual patient and prescriber consent was not required. The work in the PHD was mandated by law and conducted by a public health authority. The Massachusetts Department of Public Health was not engaged in human subjects research, and thus no IRB review was required. No patients were involved in determining the research question, outcome measures, or study design. There are no plans to involve patients in the dissemination of research findings.

RESULTS

Population Characteristics

Of 1039 opioid-naive patients, 347 were treated by high-supply residents and 692 were treated by low-supply residents. Both groups had similar observable patient and injury characteristics (Table 1), suggesting that unobserved characteristics were also likely comparable.

Prescribing Behavior

As expected, most patients (85%) received an opioid prescription soon after injury. The patients received a mean discharge prescription

TABLE 2. Differences in Discharge MME and Short-Term and Subsequent Opioid Use Between Patients of High- and Low-Supply Residents^a

Variable	Patients of low-supply residents	Patients of high-supply residents	Before controls		After controls	
			Difference (SE)	P	Difference after controls (SE)	P
Mean MME at discharge	707.1	819.7	112.6*** [33.15]	<.001	96.09** [34.50]	.01
Mean MME 1-2 months after discharge	18.29	5.21	-13.1* [6.67]	.06	-13.6** [5.47]	.01
Mean MME 7-8 months after discharge	4.59	19.22	14.6** [5.57]	.01	13.0** [5.08]	.01
Patients with opioid 1-2 months after discharge, %	8.09	3.46	-4.63*** [1.43]	.002	-6.01*** [1.51]	<.0001
Patients with opioid 7-8 months after discharge, %	6.06	9.86	3.80** [1.85]	.05	2.66 [1.79]	.14

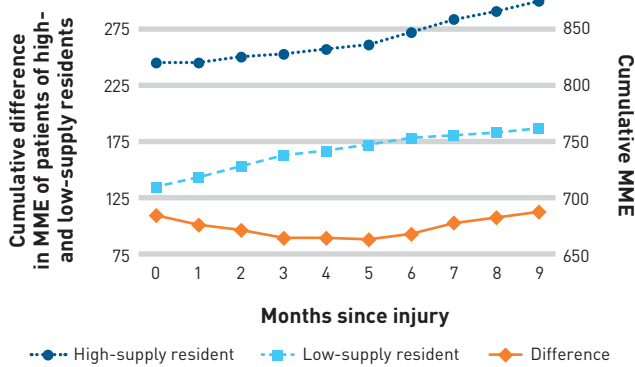
MME, morphine milligram equivalents.

P* < .05; *P* < .01; ****P* < .001.

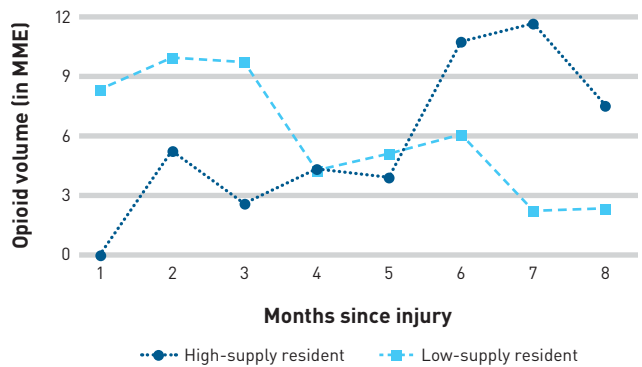
^aMME indicates total effective volume of opioids filled during the specified period. Controls include patient demographics—comorbidities, insurance status (Medicaid and self-pay vs the default of private insurance or Medicare), age and age squared, and indicators for being White, female, and White female—as well as descriptions of the injury—location (leg and upper body vs elsewhere on the body), type of fracture (based on AO Foundation/Orthopaedic Trauma Association classifications), and year of the injury. SEs that are robust to heteroscedasticity are in parentheses.

FIGURE 1. Opioid Prescribing Volumes After Musculoskeletal Trauma

A. Cumulative volume of opioid supply during the 8 months after injury^a



B. Opioid volumes prescribed in each month after injury^b



MME, morphine milligram equivalents.

^aIn part A, the top dotted dark blue line is the cumulative supply of opioids received by patients of high-supply residents in the months after their discharge; the lower dashed light blue line is the cumulative supply received by patients of low-supply residents. The solid orange line is the difference between these 2 cumulative supplies. There is initially a large gap in opioid supplies at discharge. This gap closes slightly in the first 5 months after injury because of the higher repeated prescriptions of the patients of low-supply residents. The initial gap grows wider 6 to 9 months after injury as the patients of high-supply residents once again receive higher supplies.

^bIn part B, we consider the flow of new opioid supplies rather than the stock of cumulative supplies. We see that patients of high-supply residents receive lower volumes in the first few months after injury but then receive more in the ensuing months.

of 745 MME, which would be a 15-day supply at the standard of 50 MME per day.¹⁰ In unadjusted analysis, patients of high-supply residents received a mean of 820 MME compared with 707 MME among patients of low-supply residents, a difference of 113 MME or approximately 2 days of a typical supply (95% CI, 47.3-177.8 MME; *P* = .001) (Table 2). After adjustment for the set of covariates listed in Table 1, the estimated effect of resident prescribing tendencies on discharge supply remained stable (eAppendix Table 3). Specifically, in the first-stage specification, patients of high-supply residents received 96.1 MME more than patients of low-supply residents (95% CI, 28.4-163.7 MME; *P* = .006).

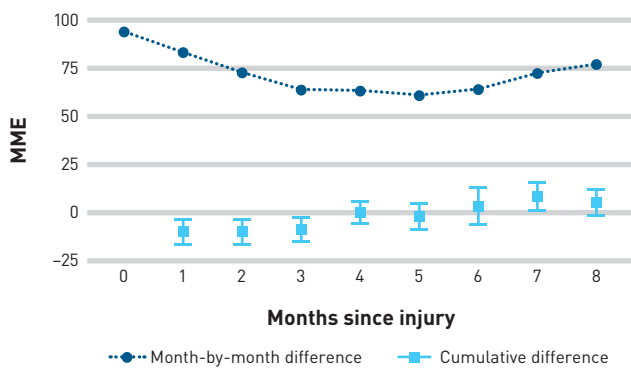
Evolution of cumulative supply of prescribed opioids after discharge.

Because of the higher opioid supply at discharge, patients of high-supply residents started with a higher volume of MME (Figure 1

[A]). This gap initially closed modestly as patients of high-supply residents received lower total volumes of opioids within the 5 months after injury, but the gap remained substantial over the entire period and began to widen starting in the sixth month after injury as patients of high-supply residents received higher volumes of newly prescribed opioids (Figure 1 [A and B]). We found the same pattern after adjusting for patient characteristics and the year of surgery. By 7 months after injury, patients of high-supply residents received significantly greater new supplies of opioids (Figure 2).

Short-term and subsequent opioid use. In the first 2 months after surgery, 3.5% of patients of high-supply residents received an opioid prescription compared with 8.1% of patients of low-supply residents (adjusted difference, 6.0 percentage points; 95% CI, -9.0 to -3.1 percentage points; *P* < .001) (Table 2). The opposite

FIGURE 2. Differences in MME for Patients of High- and Low-Supply Residents in the Months After Injury and Cumulative MME Controlling for Patient Differences^a



MME, morphine milligram equivalents.

^aWe show the cumulative differences in MME and the month-by-month differences between patients of high- and low-supply residents after adjusting for patient demographics—comorbidities, insurance status, age, race, and sex—as well as injury type—location, type of fracture, and the year of the injury. CIs reflect SEs that are robust to heteroscedasticity.

TABLE 3. Placebo Checks of Opioid Use 7 to 8 Months Before Injury^a

	Patients with opioid 7-8 months before injury, %	MME 7-8 months before injury
Difference between high-supply and low-supply groups (SE); <i>P</i> value	1.79 (1.63); <i>P</i> = .29	6.03 (4.80); <i>P</i> = .26
Mean (SD)	6.45 (24.6)	10.6 (72.3)
N	1039	1039

MME, morphine milligram equivalents.

^aThe past opioid use of patients of high-supply residents is compared with the past use of patients of low-supply residents. The difference between these groups is presented. The same controls used in Table 2 are used here; SEs that are robust to heteroscedasticity are in parentheses.

pattern emerged 7 to 8 months after discharge: 9.9% of patients of high-supply residents received an opioid prescription compared with 6.1% of patients of low-supply residents (adjusted difference, 2.7 percentage points; 95% CI, -0.7 to 6.2 percentage points; *P* = .13) (Table 2). Unadjusted estimates were similar (eAppendix Table 2).

In the first 2 months after injury, patients of high-supply residents received a mean of 5.2 MME and patients of low-supply residents received 18.3 MME (adjusted difference, -13.6 MME; 95% CI, -24.4 to -2.9 MME; *P* = .013) of opioid pain medications from new prescriptions. In the 7 to 8 months after surgery, patients of high-supply residents received 19.2 MME of newly prescribed opioid medication on average compared with 4.6 MME among patients of low-supply residents (adjusted difference, 13.0 MME; 95% CI, 3.1-22.9 MME; *P* = .011). Unadjusted estimates were similar (eAppendix Table 1). High-supply residents (top one-third of prescribing tendencies) tended to prescribe 190 MME more than

low-supply residents, suggesting that their patients would receive 26.9 MME less 1 to 2 months after discharge and 25.7 MME more 7 to 8 months after discharge.

Sensitivity Analysis

In the 6 months before injury, opioid use was zero for all patients by construction. In the 7 to 8 months before injury, there was no significant gap in opioid volumes between patients of high- and low-supply residents (difference, 1.8 MME; 95% CI, -3.4 to 15.4; *P* = .26) (Table 3). In addition, results were similar when using alternative definitions of high-supply residents (ie, top one-fourth or top one-fifth of prescribing tendencies). Adjusted and unadjusted results did not differ substantively.

DISCUSSION

We found that patients who received a higher initial supply of opioids were more likely to fill and receive higher volumes of opioids 7 or 8 months after surgery than patients discharged by residents with more judicious prescribing tendencies, despite receiving a substantially greater cumulative supply through the first 6 months after surgery. Although a higher discharge supply reduced represcription shortly after surgery, the increased subsequent opioid volumes 7 to 8 months later are suggestive of the development of misuse as a consequence of higher discharge quantities.

The present findings build on previous literature that has attempted to characterize the link between initial opioid supplies and subsequent use.^{1-3,5,6} Whereas those studies may have been prone to significant bias if patient or injury characteristics influenced both discharge supplies and subsequent use, we succeeded in identifying a natural source of prescribing variation that was unrelated to patients' observable clinical needs based on balance checks and the similarity of results with and without adjustment. Building on a previous study,⁶ we found that physician prescribing in terms of opioid supply was an important factor in subsequent use in clinical settings where opioids are often necessary and the standard of care for treatment of acute pain.

Reducing exposure to opioids, although emphasized in prescribing guidelines, is often challenging after musculoskeletal injuries because of patients' need for acute pain control.¹¹ Thus, the typical choice facing trauma care teams is not whether to prescribe an opioid but how much to prescribe. The present results suggest that some physicians may have a natural tendency to give higher initial opioid supplies, perhaps to reduce the short-term demand for opioid prescription renewals that discharging physicians may have to address before patients are able to see their surgeon or primary outpatient physician in follow-up. Indeed, we observed higher rates of new prescriptions initially after surgery for patients prescribed lower supplies at discharge. Taken together, these findings suggest that policies to lower discharge doses of opioid pain medication would reduce subsequent use but that limitations on discharge supply may need to be coupled with strategies to ensure adequate treatment of

short-term pain. Strategies might include improving postdischarge access to appropriate renewals and nonopioid pain medication via electronic or telephonic pain assessments and e-prescribing.^{12,13} Other areas for improvement include better training on the balance between pain management and the risk of elevated opioid use¹⁴ and techniques to identify high-risk individuals.¹⁵

Limitations

We may have underestimated the effect of opioid prescribing at discharge on subsequent use if patients sought subsequent opioid prescriptions outside of the state health care system (eg, via diversion from friends or family members) as a result of exposure to a higher initial supply, but we would not expect patients' procurement of opioids through other means to vary by resident prescribing tendencies. We could not assess the clinical consequences of a low initial opioid supply because we could not assess pain control, but this is an important area for future research. The period of the analysis (2011-2015) may not reflect more recent changes in opioid-prescribing norms; however, the available setting allowed for significant heterogeneity in prescribing behavior. The present results showed that patients of high-supply residents filled higher quantities of opioids 7 to 8 months after discharge, but our analysis of the percentage of those patients filling prescriptions failed to reject the null hypothesis, with large SEs. Mean patient volume filled is a combination of prescription intensity and number of patients; further work with larger samples could estimate this decomposition with precision (eAppendix Table 2). Finally, we used an electronic parser to identify resident and attending physicians and we may have failed to link some care teams due to data quality. We do not believe that this would bias the results because this failure was unlikely to occur in systematic fashion for specific attendings, residents, or patients.

CONCLUSIONS

After surgery for musculoskeletal injury, patients discharged by residents who prescribe greater supplies of opioid pain medications received higher volumes of new prescriptions for opioids 7 or 8 months after surgery than patients discharged by residents with more judicious prescribing tendencies, despite receiving a greater cumulative supply through the first 6 months after surgery. Based on this finding, to minimize the risk of subsequent use while managing acute pain, our findings would support a strategy of low opioid supplies at discharge with a coordinated pain management plan in place to ensure adequate treatment of short-term pain. ■

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eAppendix Table 1. Effect of Discharge Supply on Short-Term and Subsequent Opioid Volume

	<i>MME 1-2 Months After Discharge (OLS)</i>	<i>MME 1-2 Months After Discharge (IV)</i>	<i>MME 7-8 Months After Discharge (OLS)</i>	<i>MME 7-8 Months After Discharge (IV)</i>
<i>Discharge Supply</i>	6.21	-14.2**	0.29	13.5**
<i>in 100 MME</i>	(6.55)	(5.7)	(0.352)	(5.28)
<i>Age</i>	0.824	3.11*	0.0446	-2.00**
	(1.15)	(1.69)	(0.48)	(0.94)
<i>Comorbidities</i>	5.65	5.67	0.14	0.108
	(4.93)	(4.92)	(2.77)	(2.79)
<i>White</i>	6.34	20*	3.14	-8.93
	(7.86)	(10.3)	(5.11)	(6.94)
<i>Female</i>	-1	-4.86	5.4	9.06
	(8.32)	(8.6)	(9.17)	(9.48)
<i>White & Female</i>	2.68	-7.35	-7.8	0.965
	(12.4)	(12.7)	(9.66)	(9.86)
<i>Medicaid</i>	-10.3	3.75	4.56	-7.86
	(8.29)	(8.55)	(9.06)	(8.58)
<i>Self Pay</i>	-4.46	7.62	-5.22	-16.1***
	(14.5)	(14.1)	(3.23)	(5.4)
<i>AO/OTA A</i>	39.1	-4.96	-14.7***	24.7*
	(43.8)	(38.3)	(5.02)	(13.1)
<i>AO/OTA B</i>	55.5	17.7	-4.89	28.8**
	(61.3)	(55.9)	(5.17)	(14.2)
<i>AO/OTA C</i>	25.5	-11.6	-8.54**	24.6**
	(33.9)	(30.1)	(4.27)	(12.5)
<i>Leg</i>	-41.8	-37.9	0.654	-2.86
	(48.2)	(47.4)	(3.41)	(3.78)
<i>Pelvis</i>	-53.1	-40.3	-4	-15.4**
	(44.8)	(42.3)	(3.99)	(6.5)
<i>2011</i>	-28.4	-21.4	-3.48	-9.67***
	(24.2)	(22.9)	(2.37)	(3.56)
<i>2012</i>	-29.8	-5.76	-4.03**	-25.4***
	(26)	(22.6)	(1.81)	(8.87)
<i>2013</i>	7.66	20.9	25.5***	13.8***
	(25.4)	(24.4)	(7.29)	(4.96)
<i>2014</i>	-24.2	-25.8	4.45**	5.94**
	(27)	(27.3)	(2.26)	(2.42)
<i>Dependent Mean</i>	13.92	13.92	9.53	9.53
<i>N</i>	1,039	1,039	1,022	1,022

eAppendix Table 2. Effect of Discharge Supply on Short- and Subsequent Opioid Receipt

	<i>% with Opioid 1-2 Months After Discharge (OLS)</i>	<i>% with Opioid 1-2 Months After Discharge (IV)</i>	<i>% with Opioid 7-8 Months After Discharge (OLS)</i>	<i>% with Opioid 7-8 Months After Discharge (IV)</i>
<i>Discharge Supply</i>	0.0587	-6.25***	0.317	2.77
<i>in 100 MME</i>	(0.142)	(1.57)	(0.234)	(1.87)
<i>Age</i>	0.0861	1.06***	0.19	-0.188
	(0.254)	(0.369)	(0.201)	(0.339)
<i>Comorbidities</i>	0.45	0.458	-0.144	-0.151
	(0.966)	(0.95)	(1.11)	(1.11)
<i>White</i>	-1.75	4.05	-0.146	-2.36
	(3.12)	(3.4)	(2.81)	(3.26)
<i>Female</i>	1.13	-0.513	0.696	1.39
	(3.97)	(3.96)	(3.56)	(3.6)
<i>White & Female</i>	0.545	-3.73	1.66	3.27
	(4.18)	(4.33)	(3.94)	(4.09)
<i>Medicaid</i>	-4.39**	1.6	0.649	-1.65
	(2.05)	(2.48)	(2.86)	(3.38)
<i>Self Pay</i>	2.17	7.32	-5.68***	-7.66***
	(5.11)	(5.25)	(1.63)	(2.17)
<i>AO/OTA A: Extra articular</i>	-0.522	-19.3***	-2.3	4.97
	(3.1)	(5.13)	(4.02)	(6.59)
<i>AO/OTA B: Partial articular</i>	-4.57	-20.7***	-2.88	3.33
	(2.84)	(4.98)	(3)	(5.49)
<i>AO/OTA C: Intra articular</i>	-3.67	-19.5***	-2.33	3.78
	(2.82)	(4.99)	(2.75)	(5.24)
<i>Leg</i>	1.58	3.24	-1.45	-2.1
	(2.52)	(2.48)	(2.92)	(2.97)
<i>Pelvis</i>	-1.07	4.38	-0.899	-3.01
	(4.93)	(5.04)	(5.49)	(5.86)
<i>2011</i>	-4.62**	-1.64	5.16	3.99
	(1.82)	(1.86)	(4.94)	(5.04)
<i>2012</i>	-1.37	8.86***	2.35	-1.64
	(2.17)	(3.15)	(2.33)	(3.67)
<i>2013</i>	11.1***	16.7***	13.1***	10.9***
	(2.78)	(3.37)	(2.57)	(2.93)
<i>2014</i>	-0.486	-1.15	2.29	2.54
	(1.91)	(1.93)	(1.65)	(1.69)
<i>Dependent Mean</i>	6.54%	6.54%	7.34%	7.34%

eAppendix Table 3. First Stage of Resident Prescribing Tendency on Discharge Supply in MME

	<i>Discharge MME</i>	<i>Discharge MME</i>	<i>Discharge MME</i>	<i>Discharge MME</i>
<i>Resident L10 Top 3rd</i>	112.55*** (33.15, p-value = 0.0007)	109.03*** (31.60, p-value = 0.0006)	105.24*** (29.70, p-value = 0.0004)	96.09** (34.50, p-value = 0.0055)
<i>Comorbidities</i>		-1.09 (16.74)	-30.37*** (13.85)	1.58 (16.26)
<i>White</i>		100.67* (60.65)	61.07 (55.30)	101.09* (60.01)
<i>Female</i>		-13.671 (63.30)	-52.45 (58.48)	-18.07 (62.99)
<i>White, female</i>		-80.45 (71.40)	-20.06 (65.70)	-77.46 (71.53)
<i>Medicaid</i>		76.62 (88.40)	75.30 (83.60)	92.70 (89.15)
<i>Self-pay</i>		60.66 (131.82)	172.37 (135.58)	88.07 (132.88)
<i>Leg (Relative to Upper Body)</i>		24.52 (47.85)	5.78 (46.49)	23.27 (46.99)
<i>Pelvis (Relative to Upper Body)</i>		75.21 (89.02)	31.75 (87.07)	76.02 (89.91)
<i>AO/OTA A</i>		-309.84*** (63.57)	-10.79 (69.71)	-292.86*** (62.88)
<i>AO/OTA B</i>		-283.02*** (52.79)	15.88 (60.82)	-254.38*** (50.44)
<i>A/OTAC C</i>		-273.15*** (52.59)	-11.64 (58.28)	-253.08*** (51.90)
<i>Age and Age^2</i>		X	X	X
<i>Attending FE</i>			X	
<i>2011</i>				53.48 (78.10)
<i>2012</i>				139.42** (59.26)
<i>2013</i>				65.66 (60.34)
<i>2014</i>				-24.80 (53.17)
<i>N</i>	1039	1039	1039	1039
<i>Dependent Mean</i>	744.69	744.69	744.69	744.69
<i>R^2</i>	1.22%	15.83%	33.77%	17.40%

We demonstrate how the raw difference in discharge supplies between patients of high and low-supply residents is affected by the inclusion of controls for patient and service characteristics. In the second column, the inclusion of our baseline covariates does not change the estimated effect of resident prescribing behavior significantly, despite the dramatic improvement in model fit. Patients with fractures, particularly of more minor varieties, tended to receive smaller supplies of opioids at discharge. In the third column, the inclusion of attending fixed effects, has little impact on the coefficient of interest, suggesting our double-difference design effectively isolated the component of prescriptions that could be attributed to resident prescribing tendencies. The last column includes controls for the year of the surgery, which more meaningfully (although not statistically significantly) changes the coefficient of interest, as some of the variation in prescribing behavior of residents is due to changes in prescribing over time.