Impact of Policy Interventions on Postoperative Opioid Prescribing

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Abstract

Objective. To assess postoperative opioid prescribing in response to state and organizational policy changes. **Methods.** We used an observational study design at an academic medical center in the Northeast United States over a time during which there were two important influences: 1) implementation of state rules regarding opioid prescribing and 2) changes in organization policies reflecting evolving standards of care. Results were summarized at the surgical specialty and procedure level and compared between baseline (July–December 2016) and postrule (July–December 2017) periods. **Results.** We analyzed data from 17,937 procedures from July 2016 to December 2017, two-thirds of which were outpatient. Schedule II opioids were prescribed in 61% of cases and no opioids at all in 28%. The median morphine milligram equivalent (MME) prescribed at discharge decreased 40%, from 113 MME in the baseline period to 68 MME in the postrule period. Decreases were seen across all the surgical specialties. **Conclusions.** Postoperative opioid prescribing at the time of hospital discharge decreased between 2016 and 2017 in the setting of targeted and replicable state and health care organizational policies. **Policy Implications.** Policies governing the use of opioids are an effective and adoptable approach to reducing opioid prescribing following surgery.

Key Words: Postoperative Pain; Opioids; Drug Utilization; Surgical Procedures; Prescribing Patterns

Background

Over the past decade, the United States has been experiencing an increase in opioid misuse and opioid-related deaths [1]. Although specific regions of the United States have experienced a decrease in opioid prescribing, the national per capita prescription of opioids was 640 morphine milligram equivalents (MME) in 2015, about three times higher than in 1999 [2].

In an attempt to decrease the inappropriate prescription of pain medications, the Centers for Disease Control and Prevention (CDC) published prescribing guidelines for the use of opioids for chronic pain in 2016 [3]. As of 2017, 23 states have enacted rules governing the prescribing and monitoring of opioids in specific acute or chronic circumstances [4]. Vermont, which is the setting for this study, has had prescribing rules governing chronic opioids since 2015, and in July 2017 strict rules

governing the use of opioids for acute pain were enacted. These rules include specific quantity and duration limits and mandate use of the state-administered online prescription drug monitoring program (PDMP) [5].

The effects of opioid prescribing policy changes have not been widely studied, and most studies have not distinguished between acute and chronic prescribing. A 2012 study in Washington showed a temporal association between stricter regulation and a decline in dosing of long-acting and high-dose opioids, and a 2014 Florida study attributed an observed 27% decline in overdose deaths to legislative and law enforcement actions, especially those targeted at drugs favored by pain clinics [6]. In Staten Island, New York, a combination of public health actions was associated with a 29% decrease in opioid analgesic-associated deaths [7], and an Indiana study showed decreases in overall opioids prescribed [8].

Postoperative opioid prescribing offers a good opportunity for the evaluation of policy changes because the range of patient experience after a specific operation is narrower than for conditions such as acute injuries or chronic pain. Additionally, recent studies have demonstrated not only variation in prescribing following surgical procedures, but also opportunities for dose reduction [9–17]. Two of these studies demonstrated that patients actually use only 30%–40% of the opioids prescribed after common surgical procedures [15,16]. This overprescribing gap offers an opportunity for updated prescribing targets and more widespread standardization.

It is challenging to determine the impact of specific initiatives directed at decreasing opioid prescribing given the continuing evolution of public health, law enforcement, and organizational policies. We took advantage of a recent confluence of state and organizational policy changes in Vermont to examine their effects on opioid prescribing. The specific goal of this study was to compare postoperative opioid prescribing between 2016 and 2017.

Methods

Study Design and Intervention

We used an observational study design to assess changes in opioid prescribing at an academic medical center in the Northeast United States. The time period was chosen in order to assess the effect of several interventions that were taking place in our environment. The first of the influences was the implementation of state opioid prescribing rules. In 2015, Vermont adopted rules governing opioid prescribing for chronic noncancer pain that require use of treatment agreements, patient written informed consent, and querying the state prescription drug monitoring program [5,18]. These rules were largely relevant to primary care and pain management specialties, which are more likely to manage patients on chronic therapy. Additional rules governing prescribing for acute pain were developed under the supervision of the Commissioner of Health in consultation with a wide group of stakeholders and were adopted on July 1, 2017. The Department of Health notified prescribers through a variety of alerts and optional educational sessions delivered by content experts and Health Department staff and posted frequently asked questions documents. These rules recommend specific quantity and duration limits according to the anticipated level of pain and require that any patient prescribed more than 10 pills be looked up on the PDMP by the prescriber or a delegate [5,18]. The specific limits are as follows: for Minor Pain (such as wisdom tooth extraction or sprains), no opioids are recommended; for Moderate Pain (such as noncompound bone fractures and most soft tissue surgeries), an average daily dose of 24 MME for up to five days is the maximum

recommended; for Severe Pain (such as many nonlaparoscopic surgeries and joint replacement), an average daily dose of 32 MME for up to five days is the maximum recommended; and for Extreme Pain, an average daily dose of 50 MME for a total of seven days is the maximum recommended. Exceptions are allowable based on the clinical judgement of the prescriber. The consequences for not following the rules are under the purview of the Vermont Board of Medical Practice, with action taken based on filed complaints or investigation rather than specific surveillance by the Department of Health [18]. These controlled substance prescribing rules are among the strictest in the country.

The second influence on prescribing during the study period occurred at the institution level. A local research project was implemented between July 2016 and February 2017, the results of which showed that patients consumed only 30% of the opioid medications prescribed at hospital discharge [16]. These results were presented at departmental conferences and were used in the development of hospital-level policies and procedures governing opioid prescribing over the course of 2017. These organizational policies were largely focused on educating prescribers and staff on the upcoming Department of Health rules, including the proposed quantity and duration limits. The results from the internal research project were used to help prescribers understand their procedure-specific prescribing patterns and the observed gap between what was prescribed and what was consumed by patients.

Setting and Subjects

We included patients age 18 years and older who were discharged to home after undergoing a surgical procedure at the University of Vermont Medical Center, a 400-bed academic medical center in Burlington, Vermont. For this study, we included all inpatient and outpatient procedures from five surgical services: General Surgery, Orthopedics, Gynecology, Urology, and Vascular Surgery. Patients discharged to a skilled nursing or rehabilitation facility were excluded because their pain medication would be managed at the receiving facility rather than home.

For each patient discharged, we extracted the following data from the Epic-based electronic medical record: patient age, sex, and insurance; procedure name and CPT code; attending name and specialty; prescription date, medication name, strength, and quantity for all Schedule II–IV opioids (including tramadol). We analyzed data from 15,374 patients who underwent 17,961 procedures between July 1, 2016, and December 31, 2017.

Given that patients may have been referred for surgery from outside organizations, we were not able to reliably ascertain preoperative opioid treatment. We excluded 16 patients who were prescribed either methadone ($N=2$) or fentanyl ($N=14$) at discharge because these patients

were likely to be on chronic opioid therapy and not be representative of the typical postoperative experience. No patients received buprenorphine for postoperative pain management. All other subjects were retained in the analysis, including some who may have been on preoperative opioid therapy.

A potential unintended consequence of opioid reduction initiatives is an increase in the demand for pain medication in the weeks following surgery; to assess for this, we analyzed any additional opioid prescriptions written in the 30 days after surgery.

Measurements

Opioids prescribed at discharge were summed and converted to MME according to the Center for Disease Control and Prevention [19] and then categorized by procedure and by surgical specialty. Patients who received no opioid at discharge were assigned a value of zero MME.

Analytic Plan

We summarized MME using medians given the presence of outlier prescriptions that may reflect opioid tolerance among patients on opioids preoperatively. Patients receiving no opioids at discharge were included in the computation of the median MME at the time of discharge to appropriately reflect what a typical patient received.

As a first step, we created three six-month time periods, a baseline period (July–December 2016), an adoption period (January–June 2017), and a postrule period (July–December 2017). To visualize trends in opioid prescribing over time, we calculated the median MME prescribed per discharge prescribed during each week of the study period. We then fit smoothed trend lines to the median MME data using first-degree local polynomials [20]. Trend lines were superimposed on crude scatter plots of median MME prescribed per week of the study period, with vertical reference lines denoting the three study periods. For the comparison between the baseline and postrule periods, we used quantile regression to estimate differences in median MME prescribed and accompanying 95% confidence intervals [21]. To test whether there was a significant narrowing of the variability in prescribing, we used a robust test of variance, as described by Brown and Forsythe [22]. For one of the procedures analyzed (laparoscopic prostatectomy), the difference between the baseline and postrule periods was so large that it left insufficient overlap in MME distribution between eras to support a statistical model; the raw MME difference without confidence intervals is provided in this case. Subsequent 30-day opioid prescribing was summarized for the entire study population and for each procedure and specialty. The proportion of subjects receiving any 30-day subsequent opioid was compared across the study periods using chi-square analysis, and

Table 1. Characteristics of patients and surgical procedures, July 2016–December 2017

Patient Characteristic	Patients (N = 15,349)
Age, median (Q1–Q3), y	57 (43–68)
Female sex, No. (%)	8,731 (57)
Insurance type, No. (%)	
Commercial	7,485 (49)
Medicare	5,061 (33)
Medicaid	1,577 (10)
Other	1,227 (8)
Procedure Characteristic	Procedures (N = 17,937)
Specialty, No. (%)	
Orthopedic surgery	7,480 (42)
General surgery	4,340 (24)
Gynecology	2,476 (14)
Urology	2,445 (14)
Vascular	1,196 (7)
Outpatient procedure, No. (%)	11,348 (63)
Prescription combinations per procedure, No. (%)	
No opioid or tramadol	5,013 (28)
Schedule II opioid only	11,020 (61)
Tramadol only	635 (4)
Schedule II opioid and tramadol	1,269 (7)

the median subsequent MME prescribed was compared using a nonparametric test of trend.

Analyses were completed using Stata 15 (Stata Corp, College Station, TX, USA). The study was approved by the University of Vermont Committee on Human Research in Medical Settings.

Results

The characteristics of the patients, the surgical procedures, and the opioid prescribing at discharge are shown in Table 1. The highest volume of procedures was in orthopedic surgery, which comprised 42% of the 17,937 procedures. Two-thirds of the procedures were completed on an outpatient basis. No discharge opioids at all were prescribed for 28% of the procedures, a Drug Enforcement Agency (DEA) Schedule II opioid alone was prescribed for 61%, tramadol (DEA Schedule IV) alone was prescribed for 4%, and prescriptions for both an opioid and tramadol were prescribed for 7%.

Figure 1 shows a smoothed curve of the trend in opioid MME prescribed at discharge over the three study periods for the entire cohort. The median MME prescribed at discharge decreased from 113 MME in the baseline period (July–December 2016) to 90 MME in the adoption period (January–June 2017) to 68 MME in the postrule period (July–December 2017), with the steepest decline occurring over the six-month adoption period. The overall decline from the baseline to the postrule time period was –45 MME (95% confidence interval = –50 to –40), a relative drop of 40%. In addition, the degree of variation also narrowed considerably in the postrule period, as evidenced by 1) the narrowing of the scatter in

Figure 1. Trend in opioid prescribing for all specialties. The three time periods represent the baseline period, the adoption period during which state rules and organizational changes were being implemented, and the postrule period, representing the six months after the state rules took effect.

the postrule period (Figure 1) and 2) a decrease in the variance around the estimate (robust test statistic $P < 0.00$). There were no significant differences between the baseline and postrule periods in patient characteristics (age, sex, insurance category) or procedure characteristics (surgical specialty, outpatient vs inpatient).

To highlight specific changes in opioid prescribing over the study period, we tabulated, for selected common procedures, the opioid prescribing in the baseline and postrule periods. Table 2 shows the proportion of subjects receiving any opioid at all, along with the median MME prescribed and the change in MME between the baseline and postrule periods. Notably, there were no procedures for which the median MME increased over the study period. The drop was statistically significant for most of the procedures, with the exception of some procedures with lower pain requirements such as mastectomy, hand and wrist surgery, and urethral sling procedures. The notable exception among the high-pain procedures was knee arthroplasty, which was essentially unchanged.

The specialty with the highest opioid dosing was orthopedics, especially for major surgery of the hip, knee, shoulder, and lumbar spine. Although relatively large decreases in prescribing were noted for hip and shoulder surgery, smaller decreases were noted for lumbar arthrodesis.

In the 30 days after hospital discharge, additional opioid prescriptions were written for 17.1% of subjects in the baseline period, 15.4% in the adoption period, and 13.1% in the postrule period (chi-square $P < 0.001$). The median 30-day MME prescribed also decreased across the three periods, from 141 MME in the baseline period

to 118 MME in the adoption period and 84 MME in the postrule period ($P < 0.001$).

Discussion

In this observational study of changes in opioid prescribing, we found a clinically important and statistically significant decrease in postoperative opioid prescribing after common surgical procedures. We believe that the strongest drivers of the observed changes were 1) the implementation of controlled substance prescribing rules at the state level and 2) policy changes within our health care organization. States are increasingly instituting quantity and duration limits on the use of opioids for acute pain. As of 2017, the National Conference of State Legislators reported that 23 states had implemented some limits on opioid prescribing [4]. It is likely that other states will follow suit in 2018 and beyond. Our findings provide evidence of the influence of such policies on postoperative prescribing.

There are likely other influences on opioid prescribing that we did not have the ability to measure in this study. Societal influences such as popular media and public health messaging are increasing patient awareness of the potential hazards of opioids. Given the relatively high-profile media coverage and community awareness of the opioid crisis [23] and statewide efforts to provide access to substance abuse treatment [24] in Vermont, it is plausible that patient expectations and attitudes may have contributed to the observed decrease in postoperative opioid prescribing.

How do these observed prescription amounts compare with national estimates? Wunsch and colleagues, using a

Table 2. Prescriptions at discharge after selected surgical procedures before and after organizational and policy changes

Specialty, Procedure	Baseline Period (July–December 2016)				Postrule Period (July–December 2017)				Difference in Median MME (95% CI)*
	Number of Procedures	Proportion with Any Opioid, %	MME Prescribed Median (Q1–Q3)		Number of Procedures	Proportion with Any Opioid, %	MME Prescribed Median (Q1–Q3)		
Overall	5,981	71	113 (0–240)		5,872	64	68 (0–150)		–45 (–50 to –40)
General surgery†	1,420	73	80 (0–160)		1,413	71	64 (0–80)		–16 (–24 to –8)
Appendectomy (laparoscopic)	108	94	106 (80–155)		67	78	64 (30–72)		–36 (–55 to –17)
Cholecystectomy (laparoscopic)	155	94	120 (80–160)		134	85	64 (45–80)		–56 (–73 to –39)
Colectomy, partial (laparoscopic or open)	69	77	160 (75–240)		82	68	80 (80–150)		–80 (–123 to –37)
Hernia (inguinal, ventral, incisional)	177	90	96 (64–160)		235	95	64 (48–80)		–32 (–44 to –20)
Mastectomy, partial	102	73	48 (0–80)		86	65	40 (0–72)		–8 (–21 to 6)
Gynecology	827	62	75 (0–200)		785	60	60 (0–80)		–15 (–29 to –1)
Hysterectomy (laparoscopic or vaginal)	114	92	225 (160–263)		132	91	75 (75–80)		–150 (–164 to –136)
Hysterectomy (open)	28	96	260 (225–320)		37	89	80 (75–150)		–200 (–241 to –159)
Laparoscopy	25	88	113 (75–120)		28	96	75 (38–75)		–38 (–61 to –14)
Urethral sling procedure	47	70	60 (0–113)		35	86	37.5 (32–75)		–23 (–49 to 4)
Orthopedic surgery	2,464	78	225 (75–450)		2,441	75	113 (50–300)		–112 (–133 to –92)
Carpal tunnel release	152	39	0 (0–100)		170	43	0 (0–50)		0 (–20 to 20)
Hip arthroplasty	144	88	594 (450–775)		154	84	375 (238–520)		–225 (–290 to –160)
Knee arthroplasty	146	77	523 (300–700)		119	91	500 (280–650)		–20 (–93 to 53)
Knee arthroscopy	98	97	155 (96–225)		136	91	67.5 (64–80)		–83 (–109 to –56)
Lumbar arthrodesis	40	77	513 (388–880)		40	90	450 (250–735)		–75 (–300 to 150)
Rotator cuff repair (arthroscopic)	42	100	533 (450–600)		33	100	268 (225–400)		–272 (–357 to –188)
Trigger finger release	33	27	0 (0–100)		38	29	0 (0–25)		0 (–12 to 12)
Urology	808	58	48 (0–113)		848	31	0 (0–60)		–48 (55 to –41)
Cystoscopy (± stent, biopsy, fulguration, resection)	347	52	38 (0–75)		338	16	0 (0–0)		–38 (–44 to –31)
Prostatectomy (laparoscopic)	56	100	160 (160–160)		49	88	80 (80–96)		–38†
Transurethral resection or laser vaporization of prostate	42	48	43 (0–75)		41	10	0 (0–0)		–45 (–66 to –24)
Vascular	399	73	64 (25–150)		385	52	25 (0–68)		–39 (–51 to –27)
Varicose vein surgery	98	77	50 (25–80)		99	86	38 (23–68)		–13 (–23 to –2)
Carotid endarterectomy	49	88	40 (38–80)		49	37	0 (0–38)		–40 (–59 to –21)
Bypass or aneurysm repair	32	72	160 (25–230)		30	70	80 (0–160)		–80 (–156 to –4)

CI = confidence interval; MME = morphine milligram equivalents.

*Difference and 95% confidence interval determined by quantile regression.

†Totals for each specialty include all operations, not just the selected procedures shown.

‡Insufficient overlap in MME between eras to support a statistical mode, so no confidence interval is provided.

national database with more than 14 million commercially insured patients, described small increases in opioid prescriptions after four common surgeries between 2004 and 2012 [25]. Using their most recent data from 2012 for comparison, we found much lower median MME prescribed in our population's postrule period: cholecystectomy (64 vs 229 MME), inguinal hernia repair (64 vs 229 MME), knee arthroscopy (68 vs 289 MME), and carpal tunnel release (0 vs 221 MME). Likewise, a 2018 study by Hanson and colleagues reported a median discharge MME after cholecystectomy of 225 MME [26]. The similarity of our baseline period MME prescribing to these other studies provides encouragement that adoption of procedure-specific postoperative prescribing guidelines could have a broad national impact.

Although our study did not directly address the question of whether the policies described above caused an unintentional increase in unmanaged acute pain, we were reassured by the finding that the subsequent 30-day opioid prescribing decreased significantly across the three time periods. It is important to note that we did not expect the subsequent 30-day prescribing to be zero, as it includes, for example, opioids prescribed for chronic pain by primary care physicians and others. As another method of assessing for undertreatment of pain, we also discussed our findings with the relevant department chairs and other administrative leaders in quality and safety at our organization and were not made aware of any increase in patient complaints regarding undertreatment of pain.

It should be noted that surgeons are likely minor contributors to the supply of potentially diverted prescription opioids relative to primary care, as they primarily prescribe for brief postoperative episodes and not for chronic pain. A 2015 report from the Centers for Disease Control found that top-decile opioid prescribers are more likely to be general practice, family medicine, and internal medicine physicians [27]. As an example, an orthopedic surgeon performing 100 hip arthroplasty procedures per year and prescribing 375 MME per procedure would prescribe 37,500 MME annually; this is similar to the opioid volume prescribed for a single patient on a CDC-defined high-dose chronic daily therapy ($90 \text{ MME/d} \times 365 \text{ days} = 32,850 \text{ MME}$). If these policy changes have had an impact on acute postoperative prescribing, what lessons may be applicable to primary care prescribing for chronic conditions? In primary care, there are two opportunities to decrease opioid prescribing: 1) decrease the number of new chronic prescriptions and 2) taper the doses of current prescriptions where appropriate. We believe that the development of dosing standards, as has been done for acute postoperative prescribing, coupled with prescriber feedback and peer comparison, would be an effective first step. Of note is that we would not expect as steep a decline in prescribing for chronic conditions because of the complexity of chronic pain management and the need to taper opioid dosing over time.

Limitations

Our study has several limitations. First of all, the observational study design does not allow us to exclude the possible impact of other unmeasured factors. We feel this is relatively unlikely given the short duration of the study and our familiarity with the prescribing environment. Although a comparative trial would offer a stronger level of evidence, such a trial comparing policies at the state level would be difficult to execute in a rapidly evolving policy environment. Use of administrative prescribing data (such as from prescription drug monitoring programs) to compare prescribing rates in response to policy changes would be limited by the absence of linkage to the specific surgical procedures [6,27].

Second, although our pragmatic study design does not allow us to determine the relative impact of state-level vs organizational-level policy changes on opioid prescribing, we were able to assess the cumulative effects of a suite of practical and replicable strategies that could be adopted by other health care organizations or other states. Third, given that this is a single-institution study in an academic health center, our results may not generalize to other hospitals or health systems. On the other hand, our observed prescribing and opioid utilization patterns are similar to other academic institutions in our region [15–17]. Finally, our analysis is based on medication orders in the medical record and not filled prescriptions, so our findings may overestimate the actual volume of opioids picked up or ultimately used by the patient.

Our study has several implications for future research and health care policy. Given the known variability in opioid prescribing [27], our findings should be replicated in other settings and in response to other policy changes (or absence thereof). There is evidence that simple educational programs can have an impact on postoperative prescribing [28]. Absent a clinical trial with specific measurement of patient experience, the median opioid prescribed for these common procedures in the postrule period may be a reasonable starting point for a standard recommendation for opioid prescribing for patients discharged to home. Ultimately, surgical societies or other responsible entities could consider the development of procedure-specific guidelines for the management of typical patients after common procedures.

Public Health Implications

Postoperative opioid prescribing at the time of hospital discharge decreased between 2016 and 2017 in the setting of targeted and replicable state and health care organizational policies.

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References

- Rudd RA, Aleshire N, Zibbell JE, Gladden RM. Increases in drug and opioid overdose deaths—United States, 2000–2014. *MMWR Morb Mortal Wkly Rep* 2016;64(50–51):1378–82.
- Guy GP Jr, Zhang K, Bohm MK, et al. Vital signs: Changes in opioid prescribing in the United States, 2006–2015. *MMWR Morb Mortal Wkly Rep* 2017; 66(26):697–704.
- Dowell D, Haegerich TM, Chou R. CDC guideline for prescribing opioids for chronic pain—United States, 2016. *JAMA* 2016;315(15):1624–45.
- National Conference of State Legislators. Prescribing policies: States confront opioid overdose epidemic. 2017. Available at: <http://www.ncsl.org/research/health/prescribing-policies-states-confront-opioid-overdose-epidemic.aspx> (accessed February 20, 2018).
- State of Vermont. Rule governing the prescribing of opioids for pain. 2017. Available at: <https://www.sec.state.vt.us/media/818457/rules-governing-the-prescribing-of-opioids-for-pain-chapter-2-alcohol-and-drug-abuse.pdf> (accessed February 3, 2018).
- Johnson H, Paulozzi L, Porucznik C, et al. Decline in drug overdose deaths after state policy changes—Florida, 2010–2012. *MMWR Morb Mortal Wkly Rep* 2014;63(26):569–74.
- Paone D, Tuazon E, Kattan J, et al. Decrease in rate of opioid analgesic overdose deaths—Staten Island, New York City, 2011–2013. *MMWR Morb Mortal Wkly Rep* 2015;64(18):491–4.
- Al Achkar M, Grannis S, Revere D, et al. The effects of state rules on opioid prescribing in Indiana. *BMC Health Serv Res* 2018;18(1):29.
- Bates C, Laciak R, Southwick A, Bishoff J. Overprescription of postoperative narcotics: A look at postoperative pain medication delivery, consumption and disposal in urological practice. *J Urol* 2011; 185(2):551–5.
- Rodgers J, Cunningham K, Fitzgerald K, Finnerty E. Opioid consumption following outpatient upper extremity surgery. *J Hand Surg Am* 2012;37(4):645–50.
- Bartels K, Mayes LM, Dingmann C, et al. Opioid use and storage patterns by patients after hospital discharge following surgery. *PLoS One* 2016;11(1):e0147972.
- Kim N, Matzon JL, Abboudi J, et al. A prospective evaluation of opioid utilization after upper-extremity surgical procedures: Identifying consumption patterns and determining prescribing guidelines. *J Bone Joint Surg Am* 2016;98(20):e89.
- Feinberg AE, Chesney TR, Srikantharajah S, Acuna SA, McLeod RS. Opioid use after discharge in postoperative patients: A systematic review. *Ann Surg*. In press.
- Maughan BC, Hersch EV, Shofer FS, et al. Unused opioid analgesics and drug disposal following outpatient dental surgery: A randomized controlled trial. *Drug Alcohol Depend* 2016;168:328–34.
- Hill MV, McMahon ML, Stucke RS, Barth RJ Jr. Wide variation and excessive dosage of opioid prescriptions for common general surgical procedures. *Ann Surg* 2017;265(4):709–14.
- Fujii MH, Hodges AC, Russell RL, et al. Post-discharge opioid prescribing and use after common surgical procedure. *J Am Coll Surg*. In press.
- Sabatino MJ, Kunkel ST, Ramkumar DB, Keeney BJ, Jevsevar DS. Excess opioid medication and variation in prescribing patterns following common orthopaedic procedures. *J Bone Joint Surg Am* 2018;100(3):180–8.
- Vermont Department of Health. Opioid resources for patients and providers. 2017. Available at: <http://www.healthvermont.gov/alcohol-drugs/professionals/resources-patients-and-providers> (accessed February 3, 2018).
- Center for Disease Control and Prevention. Analyzing Prescription Data and Morphine Milligram Equivalents. 2017. Available at <https://www.cdc.gov/drugoverdose/resources/data.html> (accessed October 23, 2018).
- Fan J, Gijbels I. *Local Polynomial Modelling and Its Applications*. 1st ed. London: Chapman & Hall; 1996.
- Koenker R, Hallock K. Quantile regression. *J Econ Perspect* 2001;15(4):143–56.
- Brown MB, Forsythe AB. Robust test for the equality of variances. *J Am Stat Assoc* 1974;69(346):364–7.
- Simpatico TA. Vermont responds to its opioid crisis. *Prev Med* 2015;80:10–1.
- Brooklyn JR, Sigmon SC. Vermont hub-and-spoke model of care for opioid use disorder: Development, implementation, and impact. *J Addict Med* 2017;11(4):286–92.
- Wunsch H, Wijeyesundera DN, Passarella MA, Neuman MD. Opioids prescribed after low-risk surgical procedures in the United States, 2004–2012. *JAMA* 2016;315(15):1654–7.
- Hanson KT, Thiels CA, Polites SF, et al. The opioid epidemic in acute care surgery—characteristics of overprescribing following laparoscopic cholecystectomy. *J Trauma Acute Care Surg*. In press.
- Paulozzi LJ, Strickler GK, Kreiner PW, Koris CM; Centers for Disease Control and Prevention (CDC). Controlled substance prescribing patterns—prescription behavior surveillance system, eight states, 2013. *MMWR Surveill Summ* 2015;64(9):1–14.
- Stanek JJ, Renslow MA, Kalliainen LK. The effect of an educational program on opioid prescription patterns in hand surgery: A quality improvement program. *J Hand Surg* 2015;40(2):341–6.