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ORIGINAL ARTICLE

Regional anesthesia does not decrease opioid demand in pelvis and acetabulum fracture surgery

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Abstract

Introduction Patients with pelvic and acetabular fractures often have considerable pain in the perioperative period. Regional anesthesia (RA) including peripheral nerve blocks and spinal analgesia may reduce pain. However, the real-world impact of these modalities on inpatient opioid consumption and outpatient opioid demand is largely unknown. The purpose of this study was to evaluate the impact of perioperative RA on inpatient opioid consumption and outpatient opioid demand.

Methods This is a retrospective, observational review of inpatient opioid consumption and outpatient opioid demand in all patients ages 18 and older undergoing operative fixation of pelvic and acetabular fractures at a single Level, I trauma center from 7/1/2013–7/1/2018 ($n=205$). Unadjusted and adjusted analyses were constructed to evaluate the impact of RA on inpatient opioid consumption and outpatient opioid demand while controlling for age, sex, race, body mass index (BMI), smoking, chronic opioid use, ASA score, injury mechanism, additional injuries, open injury, and additional inpatient surgery.

Results Adjusted models demonstrated increases in inpatient opioid consumption in patients with RA (12.6 estimated OE's without RA vs 16.1 OE's with RA from 48 to 72 h post-op, $p<0.05$) but no significant differences at other timepoints (17.5 estimated OE's without RA vs 16.8 OE's with RA from 0 to 24 h post-op, 15.3 vs 17.1 from 24 to 48 h post-op, $p>0.05$). Estimated cumulative outpatient opioid demand was significantly higher in patients with RA at discharge to 90 days post-op (and 156.8 vs 207.9 OE's to 90 days, $p<0.05$) but did not differ significantly before that time (121.5 OE's without RA vs 123.9 with RA from discharge to two weeks, 145.2 vs 177.2 OE's to 6 weeks, $p>0.05$).

Discussion In pelvis and acetabulum fracture surgery, RA was associated with increased inpatient and outpatient opioid demand after adjusting for baseline patient and treatment characteristics. Regional anesthesia may not be beneficial for these patients.

Keywords Pelvis and acetabulum fracture surgery · Opioid · Regional anesthesia

Introduction

Fractures of the pelvis and acetabulum are major, often life-threatening, orthopedic injuries with considerable radiographic and clinical heterogeneity [1–4]. These fractures typically result from high energy impact and are associated with significant blood loss, morbidity, and mortality [5, 6]. The incidence of pelvic and acetabular fractures is relatively low (approximately 7.1 per 100,000 person years for acetabular fractures and 56 per 100,000 person years for pelvic fractures) [7], but is rising with increased incidence of motor vehicle accidents [8]. Patients with pelvic ring injuries often present with additional injuries and may require damage control resuscitation, procedures for hemorrhage control, and early stabilization of the fracture prior to definitive fixation [9]. Not only are fractures of the pelvis and acetabulum associated with high morbidity and mortality, but also significant acute and chronic pain [10, 11]. In patients with AO class A, B, and C pelvic fractures, the prevalence of persistent posttraumatic pelvic pain is 38%, 67%, and 90%, respectively [12]. Patients with acetabular fractures may go on to develop posttraumatic arthritis or heterotopic ossification, causing pain, and limitations in function [13, 14].

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Perioperative opioids are a mainstay in pain management for pelvic and acetabular fractures [15]. However, opioids are associated with significant risks. Up to 82% of patients experience moderate or severe opioid-related adverse effects [16]. These are dose dependent and include nausea, sedation, and respiratory depression [17]. Opioid use also increases the odds of poor orthopedic outcomes such as periprosthetic fracture, infection, and hardware loosening [18]. Additionally, persistent opioid use after surgery is a rising complication among both opioid naïve patients and those taking opioids preoperatively [19]. Chronic opioid use after acetabular fractures may be as high as 41% at 6 months and 33% at 12 months [20]. Fractures managed with external fixation are also associated with increased opioid demand up to a year postoperatively [21]. Further, patients with pre-existing mental health and opioid use disorders are at risk for increased postoperative opioid use [22–24]. These facts are especially concerning considering that 2/3 of prescription drug overdose deaths now involve an opioid [25]. Despite appropriate institutional, state, and federal efforts to limit opioid prescribing, long-term misuse continues to be problematic [26–32]. Developing perioperative opioid-sparing protocols that can adequately manage pain holds promise for reducing long-term opioid use [19, 33]. Consequently, a multimodal approach to analgesia has been advocated in the setting of orthopedic trauma.

Regional anesthesia (RA) has received increased attention in perioperative multimodal analgesia. RA, which has been used in orthopedic trauma, uses local anesthetics to prevent neural action potential propagation and the detection of nociceptive input by the central nervous system [34]. Various techniques have been developed to administer RA paravertebrally or in specific nerve distributions, and some modalities have demonstrated reductions in opioid consumption and adverse effects [35]. However, analgesic efficacy has been shown to vary across surgical procedures and the potential benefits of RA should be evaluated accordingly [36]. Only two studies have investigated the use of RA in pelvic and acetabular fractures with mixed results [37, 38], and the long-term impact of RA on opioid use in these patients remains to be elucidated. Given the knowledge gap regarding the impact of RA on longitudinal perioperative and postoperative opioid demand, the purpose of this study is to evaluate the impact of these modalities on inpatient opioid consumption and outpatient opioid demand in patients undergoing pelvis and acetabulum fracture surgery. The study hypothesis is that RA will be associated with a decrease in inpatient opioid consumption but have no impact on outpatient opioid demand.

Methods

Study design

This is a retrospective, observational study of inpatient opioid consumption and outpatient opioid demand in all patients age 18 years and older undergoing pelvis and acetabulum fracture surgery at a single institution from 7/1/2013–7/1/2018. This study is designed and reported in accordance with the STROBE statement on reporting observational studies [39].

Variables and data sources

Patients ages 18 and older with operatively treated pelvis and acetabular fractures (CPT codes 27215, 27216, 27217, 27218, 27226, 27227, 27228) at a single, Level I trauma center between 7/1/2013 and 7/1/2018 were included. Inpatient opioid consumption (0–24 h, 24–48 h, and 48–72 h post-op) and outpatient opioid prescribing (discharge to 2 weeks, 6 weeks, and 90 days) were recorded in oxycodone 5-mg equivalents (OE's) [40]. Additional baseline and operative characteristics include RA usage, age, sex, race, body mass index (BMI), smoking status, American Society of Anesthesiologists (ASA) score (measure of operative risk based on patient physiologic status [41]), injury mechanism, additional injuries, open fracture, additional surgery. Preoperative opioid usage, which was defined as patients with 1 or more opioid prescriptions within 6-months to 1-month preoperative, was also recorded, in line with the definition recommended by the Centers for Disease Control (CDC) [42]. General 90 day postoperative complications were also recorded through chart review including mortality, surgical site infection, compartment syndrome, loss of fixation, deep vein thrombosis (DVT), pulmonary embolism (PE), falls, delirium, and ileus.

As shown in Table 1, patients without RA tended to be non-Caucasian and had higher rates of high energy mechanism of injury. Spinal analgesia in the form of continuous (34/67, 50.7%) and single-shot epidurals (5/67, 7.5%) was the most common type of block. Fascia iliaca (12/67, 17.9%) and femoral (8/67, 11.9%) blocks were the most common peripheral nerve blocks.

Pain protocol

Our institution's multimodal pain regimen generally includes oral opioids administered according to a visual analog scale (VAS) pain scale (generally 5–15 mg oxycodone every

Table 1 Baseline patient, injury, and treatment characteristics for patients with and without RA

Factors	Without RA ($n=138$)	With RA ($n=67$)	p-value
Age (years)	38.2 (26.7, 55)	43.4 (28.1, 55.6)	0.37
Female sex	46/138 (33.3%)	24/67 (35.8%)	0.75
Caucasian race	61/138 (44.2%)	44/67 (65.7%)	0.005
BMI (kg/m^2)	29.2 (24.8, 33.4)	28.4 (25.5, 34.8)	0.43
Smoking	35/132 (26.5%)	14/65 (21.5%)	0.71
Preoperative opioid usage	11/138 (8%)	6/67 (9%)	0.79
ASA score			
ASA 3 or greater	66/138 (47.8%)	33/67 (49.3%)	0.88
ASA 1	15/138 (10.9%)	7/67 (10.4%)	1
ASA 2	57/138 (41.3%)	27/67 (40.3%)	1
ASA 3	50/138 (36.2%)	29/67 (43.3%)	0.36
ASA 4	16/138 (11.6%)	4/67 (6%)	0.32
Injury mechanism			
High energy mechanism	122/132 (92.4%)	51/64 (79.7%)	0.036
High energy mechanism			
Crush injury	5/138 (3.6%)	1/67 (1.5%)	0.67
Fall from height	24/138 (17.4%)	6/67 (9%)	0.141
MVC	84/138 (60.9%)	40/67 (59.7%)	0.88
MVC vs ped	9/138 (6.5%)	4/67 (6%)	1
Low energy mechanism			
Assault	0/138 (0%)	1/67 (1.5%)	0.33
Ground level fall	7/138 (5.1%)	8/67 (11.9%)	0.09
Sporting injury	3/138 (2.2%)	3/67 (4.5%)	0.39
Stress fracture	0/138 (0%)	1/67 (1.5%)	0.33
Unknown energy mechanism			
Not documented	3/138 (2.2%)	2/67 (3%)	0.66
Other	3/138 (2.2%)	1/67 (1.5%)	1
Additional injury	109/138 (79%)	45/67 (67.2%)	0.085
Open fracture	4/138 (2.9%)	1/67 (1.5%)	1
Additional surgery within 7 days	0 (0, 0)	0 (0, 0)	0.29
Additional surgery within 90 days	0 (0, 0)	0 (0, 0)	0.2
RA characteristics			
LRA or EA	0 / 138 (0%)	67/67 (100%)	n/a
Epidural route none	138/138 (100%)	28/67 (41.8%)	n/a
Epidural route continuous	0/138 (0%)	34/67 (50.7%)	n/a
Epidural route multiple	0/138 (0%)	0/67 (0%)	n/a
Epidural route not documented	0/138 (0%)	0/67 (0%)	n/a
Epidural route single shot	0/138 (0%)	5/67 (7.5%)	n/a
LRA route none	138/138 (100%)	38/67 (56.7%)	n/a
LRA route continuous	0/138 (0%)	6/67 (9%)	n/a
LRA route multiple	0/138 (0%)	0/67 (0%)	n/a
LRA route not documented	0/138 (0%)	0/67 (0%)	n/a
LRA route single shot	0/138 (0%)	23/67 (34.3%)	n/a
LRA (number)	0 (0, 0)	0 (0, 1)	n/a

Proportions (percentages) and medians (Q1, Q3) displayed. *P*-values from Fisher's exact test or Wilcoxon rank sum. Red coloring highlights statistical significance

4 h as needed for pain), intravenous (IV) opioids (typically hydromorphone) for breakthrough pain, and scheduled acetaminophen. Adjunctive oral and IV non-steroidal anti-inflammatory pain medications (NSAID's) are not frequently used after pelvis and acetabulum fracture surgery at our institution. Patients are considered for RA by their

treating anesthesiologist. Anesthetic treatment was performed by the anesthesiologist assigned to the individual case, which is generally provided by one of five core anesthesiologists within the regional anesthesia division. Discharge pain medications are prescribed by the treating team, and opioids are commonly prescribed. While the decision to discharge patients with opioids is made on a case-by-case basis by the primary team, 184 of 205 (89.8%) of patients in this series received a discharge opioid prescription.

Surgical technique

Open reduction and internal fixation of pelvis and acetabular injuries are complex and surgeon and case dependent. Generally, fixation of pelvic ring injuries is accomplished with percutaneously applied sacroiliac fixation using cannulated lag screws supplemented when needed by anterior symphyseal plating. Acetabular fracture fixation is largely dependent on fracture location and typically involves plate and screw fixation. Percutaneous acetabular fixation through appropriate osseous fixation pathways is sometimes utilized as an adjunct or as a stand-alone fixation strategy when indicated. There were four orthopedic traumatologists at our institution that performed pelvis and acetabular fracture fixation during the study time period. Operating times were case-dependent, and there were insufficient data to determine case times in this retrospective review.

Missing data

All patients ages 18 and older and undergoing the fracture fixation CPT's previously listed were considered for inclusion ($n=206$). For one patient of 206 (0.5%), BMI could not be determined. Overall results were evaluated with and without these patients and found to be similar. In order to adjust for the potential impact of this characteristic, this patient was excluded from the multivariable analyses leaving 205 patients for analysis. Pelvic external fixation is only performed as needed for pelvic and acetabular fractures. Patients were not excluded if they had previously received this treatment.

Statistical analysis

Medians with quartiles and proportions with percentages were used to display descriptive statistics. Fisher's exact test and Wilcoxon rank sum were used to evaluate unadjusted outcomes. When considering adjusted models, histograms were first created of study outcomes and demonstrated positive skew. The top 2% of opioid utilizers were excluded due to their outlier status. Since treatment with RA was not randomly assigned, the propensity to have received the treatment was considered. Propensity score weights were determined including age, sex, race, BMI, smoking, pre-op opioid usage, ASA score (binarized to 1 to 2 vs 3 or more), injury energy (binarized to high vs low energy), presence of additional injuries, open injury, and additional surgery within 7 days post-fracture surgery as model covariates. Generalized linear modeling including propensity score weighting and the factors listed above was then carried out in a "doubly robust" fashion [43, 44]. The negative binomial distribution and log link function were used based on the data distribution. Incident rate ratios from adjusted modeling for each outcome were obtained. The impact of treatment vs no treatment was simulated within the dataset to provide medians and 95% confidence intervals of simulated treatment effect. Histograms displaying the study outcomes were also created. R and R Studio (R: A Language and Environment for Statistical Computing, R Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2020) were used for statistical calculations. P-values less than 0.05 were considered significant.

Results

After adjustment for baseline patient and treatment factors, RA had no effect on opioid consumption at 0–24 h or 24–48 h but was associated with a significant increase in opioid consumption from 48–72 h post-op (Table 2 and Fig. 1). Similarly, RA was associated with increased outpatient opioid demand from discharge to 90 days post-op (Table 3 and Fig. 2). Adjusted analyses also demonstrated that RA was associated with increased opioid refills from two weeks to 90 days post-op (Table 4). As shown in Table 5, general 90-day outcomes did not differ significantly between groups between groups.

Table 2 Adjusted inpatient oxycodone 5-mg equivalents consumed in patients with and without RA

Timeframe	Oxycodone without RA (95% CI)	Oxycodone with RA (95% CI)	Incident rate ratios (95% CI, *p*-value)
0–24 h post-op	17.5 (13.3, 23)	16.8 (12.7, 21.9)	0.96 (0.81, 1.14; $p=0.62$)
24–48 h post-op	15.3 (10.9, 20.4)	17.1 (12.2, 22.7)	1.12 (0.93, 1.34; $p=0.23$)
48–72 h post-op	12.6 (9, 17.8)	16.1 (11.3, 22.6)	1.27 (1.04, 1.56; $p=0.02$)

Red coloring highlights statistical significance. Simulated estimates from multivariable model (95% CI) displayed. Incident rate ratios and *p*-values from multivariable model

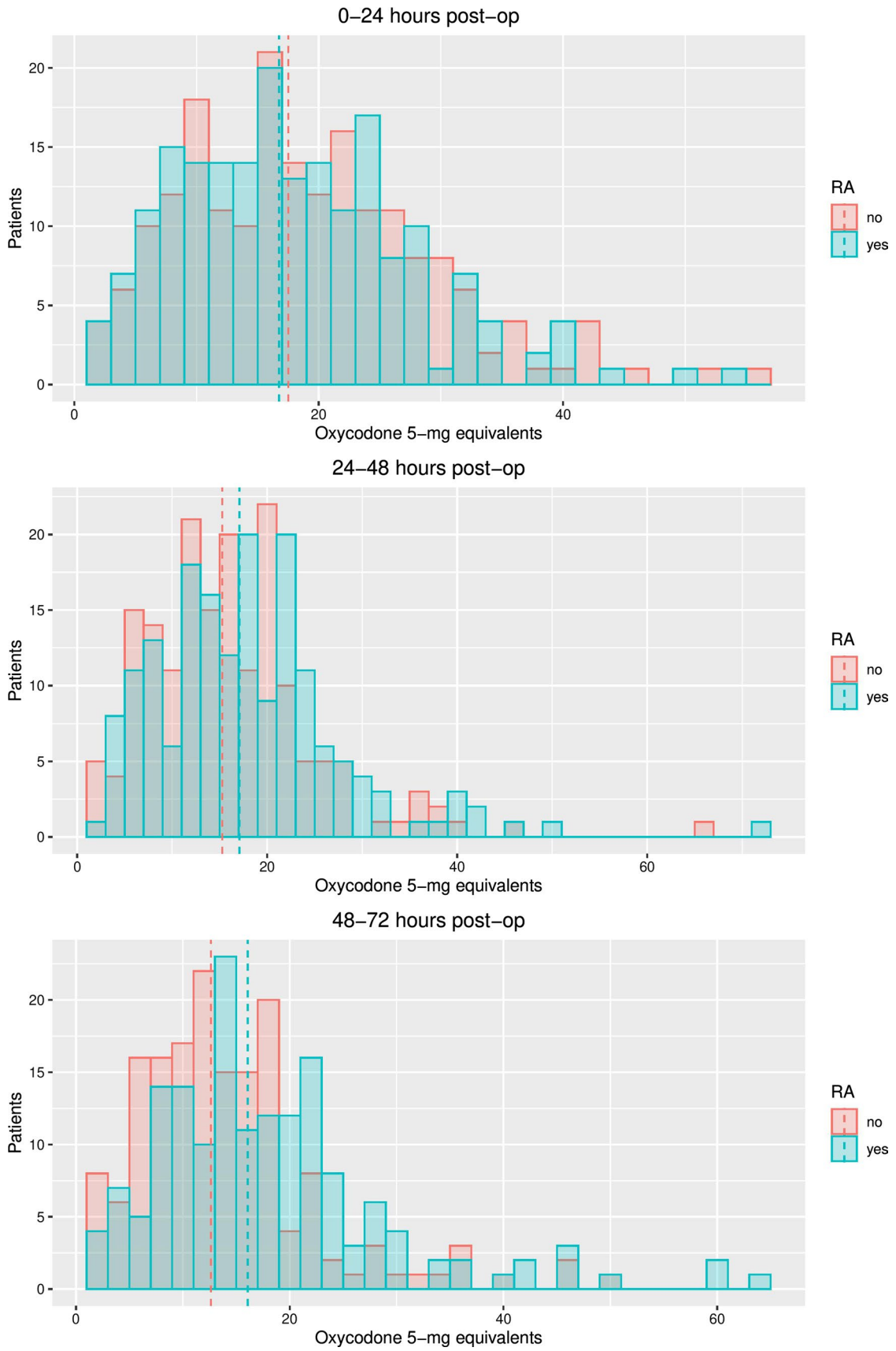

Fig. 1 Predicted inpatient opioid consumption histogram in patients with and without RA. Vertical bars represent mean consumption

Table 3 Adjusted outpatient oxycodone 5-mg equivalents prescribed in patients with and without RA

Timeframe	Oxycodone without RA (95% CI)	Oxycodone with RA (95% CI)	Incident rate ratios (95% CI, *p*-value)
Discharge to 2 weeks	121.5 (86.8, 181.1)	123.9 (88.5, 184.1)	1.02 (0.82, 1.27; $p=0.85$)
Discharge to 6 weeks	145.2 (98, 205.6)	177.2 (119.8, 253.2)	1.22 (0.99, 1.51; $p=0.056$)
Discharge to 90 days	156.8 (109.7, 229.2)	207.9 (145.3, 303.3)	1.33 (1.06, 1.65; $p=0.008$)

Red coloring highlights statistical significance. Simulated estimates from multivariable model (95% CI) displayed. Incident rate ratios and *p*-values from multivariable model

Appendix Tables 6, 7, 8 display complete results of multivariable modeling. For inpatient opioid consumption, adjusted models demonstrated significant decreases with increased age, female sex, and additional surgery (from 0 to 24 h post-op) and significant increases with increased BMI, smoking, increased ASA, high energy injury, additional injury, additional surgery (24–72 h post-op), and RA (Appendix Table 6). For outpatient opioid prescribing, adjusted models demonstrated significant decreases with increased age and significant increases with additional surgery and RA (Appendix Table 7). Odds of opioid fill or refill were significantly decreased with increased age, Caucasian race, increased ASA, and additional injury while it was significantly increased with unknown smoking status, open fracture, additional surgery, and RA.

As shown in Appendix Tables 9, 10, 11, there were no significant differences between groups in unadjusted analyses of inpatient opioid consumption, outpatient opioid demand, and rates of opioid fill and refill. As previously demonstrated in the adjusted models, age, sex, and additional surgery were important drivers of opioid demand.

Discussion

In this study of perioperative opioid demand in patients undergoing fixation of pelvis and acetabulum fractures with and without RA, there were significant increases in inpatient opioid consumption and outpatient opioid demand after adjusting for baseline patient characteristics. Age, sex, race, BMI, smoking, ASA score, additional injuries, open fracture, and additional surgery were significant drivers of inpatient and outpatient opioid demand metrics.

A limited number of prior studies have examined the effects of regional anesthesia in fractures of the acetabulum. Chelly et al. carried out a prospective case–control study with 26 patients to compare postoperative pain control with a continuous lumbar plexus block to patient-controlled morphine analgesia following surgical fixation of isolated acetabular fractures [38]. Patients in the lumbar plexus catheter group consumed significantly less morphine in the first 48 h postoperatively and were able to ambulate unassisted earlier. No significant differences in opioid-induced adverse effects or benefits associated with early ambulation, including mortality, were observed. Strauss et al. conducted a retrospective case–control study of 138 patients with surgically managed posterior wall fractures, comparing short-term outcomes in patients treated with a general anesthesia alone to those receiving a postoperative epidural catheter and general anesthesia [37]. There was no difference in postoperative pain scores or time to mobilization. However, pain scores were only analyzed until discharge from the post-anesthesia care unit and opioid use was not included in the outcome measures.

This study is the first to our knowledge to examine the impact of RA in fractures of the pelvis in addition to the acetabulum. We found no significant difference in opioid consumption from 0 to 48 h postoperatively in patients receiving RA. While we could not measure pain in this study, VAS pain score has previously been found to predict postoperative opioid requirements [45] and this score is the basis for oral opioid dosing at our institution. Therefore, there was likely no difference in pain levels between groups. Fracture pain is largely due to afferent signals from the disrupted periosteum, which is innervated by nerves supplying the overlying muscles [46, 47]. The pelvis and acetabulum are mainly innervated by the lumbar plexus [38], though sacral rami may also contribute to postsurgical fracture pain, particularly if fixation of the sacroiliac joint is involved [48]. Consequently, some patients with pelvic fractures receiving RA targeted to branches of the lumbar plexus alone may have experienced incomplete analgesia. Given our larger sample size and greater number of longitudinal data points compared to prior studies, we must also consider that RA may not provide superior pain relief in patients with acetabular fractures. In addition to periosteal disruption, trauma to the labrum can contribute to pain in these fractures [49]. The extent to which RA targets labral free nerve endings is unknown, though infiltration of local anesthetics into the joint and surrounding soft tissues has been proposed [50]. Lastly, both pelvic and acetabular fractures are often associated with polytrauma. In this study, 75% of patients had at least one additional injury. It is possible that while RA provided adequate analgesia to the fracture sites studied, pain from other injuries led to no significant difference in opioid use overall. Previous studies of RA in acetabular fractures excluded patients with multiple fractures, nerve injuries, and

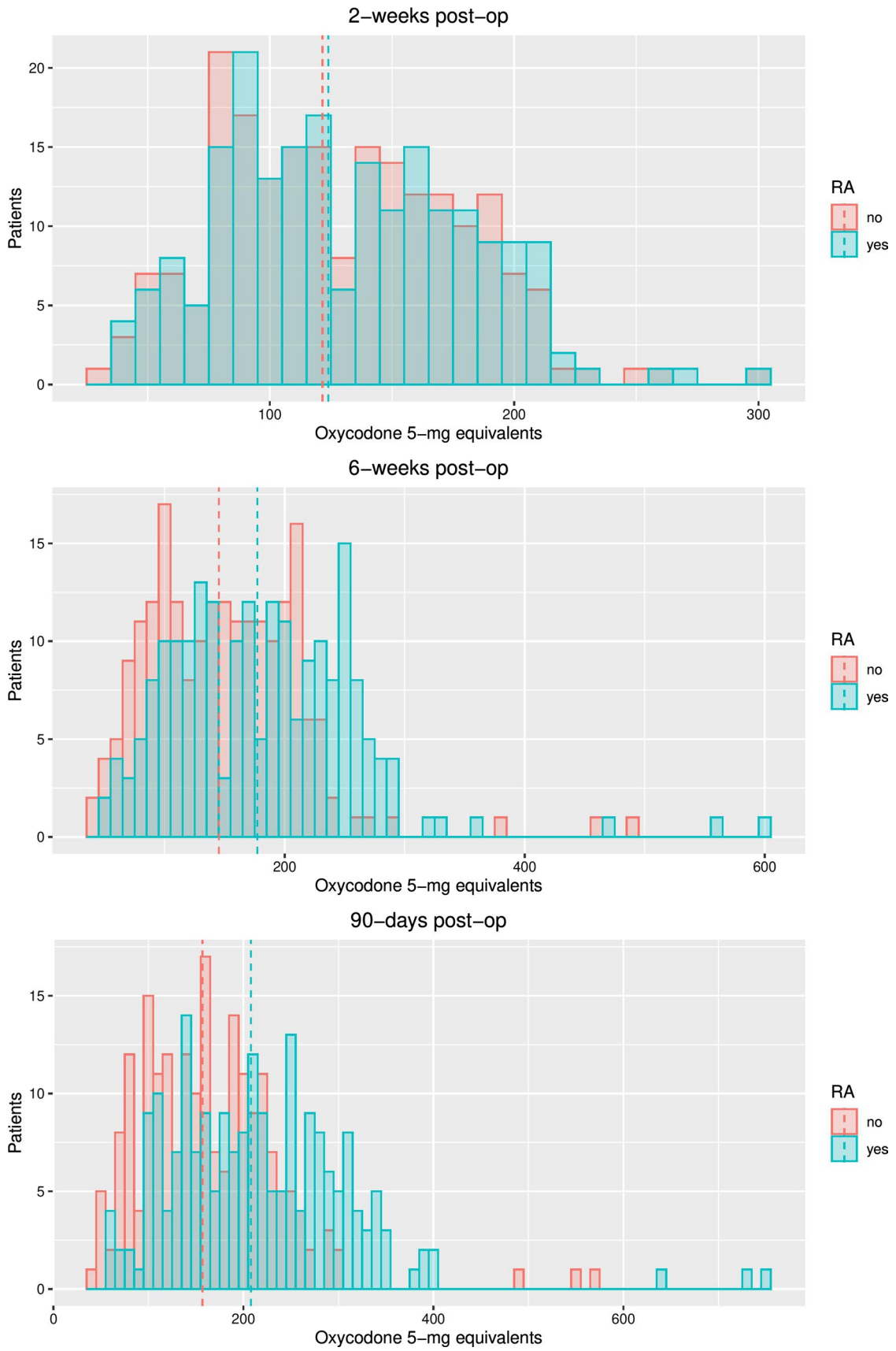

Fig. 2 Predicted outpatient opioid prescription histogram in patients with and without RA. Vertical bars represent mean prescription

Table 4 Adjusted odds of opioid fill and refill

Factors	Discharge to two week opioid refill	Two week to six week opioid fill	Six week to ninety day opioid fill
RA	0.99 (0.65, 1.51; $p=0.97$)	2.43 (1.55, 3.84; $p=<0.001$)	2.05 (1.24, 3.46; $p=0.006$)

Odds ratio (95% CI) displayed. *P*-values from multivariable modeling. Complete model displayed in Appendix

Table 5 General 90-day perioperative complications

Outcomes	All subjects ($n=205$)	Without RA ($n=138$)	With RA ($n=67$)	*p*-value
Non-opioid outcomes				
Mortality	5/205 (2.4%)	3/138 (2.2%)	2/67 (3%)	0.66
SSI	7/205 (3.4%)	4/138 (2.9%)	3/67 (4.5%)	0.69
Mechanical failure	1/205 (0.5%)	1/138 (0.7%)	0/67 (0%)	1
DVT	2/205 (1%)	2/138 (1.4%)	0/67 (0%)	1
PE	11/205 (5.4%)	9/138 (6.5%)	2/67 (3%)	0.51
ACS	0/205 (0%)	0/138 (0%)	0/67 (0%)	n/c
Falls	1/205 (0.5%)	1/138 (0.7%)	0/67 (0%)	1
Delirium	7/205 (3.4%)	4/138 (2.9%)	3/67 (4.5%)	0.69
Ileus	3/205 (1.5%)	2/138 (1.4%)	1/67 (1.5%)	1

Proportions (percentages displayed). Unadjusted *p*-values from Fisher's exact test. Adjusted odds ratios (95% CI) with p-values from multivariable modeling. "N/c" = not calculable due to low event rate

those requiring laparotomy or intubation. By including patients with additional injuries, we were able to capture data across a range of injury severity that more closely replicates the actual clinical effects of RA in these fractures.

The significant increase in opioid demand at 48–72 h postoperatively in this study likely reflects the occurrence of rebound pain. This phenomenon that has been described with RA use for other fractures as the nerve block dissipates and has been associated with high levels of opioid use [51–53]. While the pathophysiology of rebound pain remains debated, theories include hyperalgesia [54–56], anesthetic-induced nerve damage [57], and upregulation of inflammatory mediators secondary to the presence of local anesthetics [58, 59]. The onset of rebound pain varies with block technique and the type and concentration of local anesthetic used. Prior studies have reported rebound pain 12–24 h after administration of single-shot blocks [51, 60, 61]. Continuous RA catheters have been shown to delay and attenuate rebound pain, with reported onset at 24–59 h after initiation of the block [62–64]. In the present study, 60% of patients received continuous RA catheters, likely delaying the onset of rebound pain. Further, the heterogeneity in block locations and local anesthetics in this study could account for a longer time to observed onset of rebound pain.

While RA has the theoretical potential to prevent the development of chronic pain by blocking early nociceptive input, evidence supporting the long-term benefits of RA is weak at present. A recent systematic review reported moderate and low-quality evidence that RA could reduce chronic postoperative pain after non-orthopedic surgeries [65]. However, the conclusions were based on a limited number of small studies and these findings cannot be extended to other surgical interventions. Evidence from prior retrospective studies has indicated that RA may not reduce chronic postoperative opioid use. In patients undergoing abdominal surgery, total knee arthroplasty, and shoulder arthroplasty, no association has been found between use of RA and the risk of persistent postoperative opioid use [66–68].

With respect to the long-term impacts of RA on opioid use in pelvic and acetabular fractures, we found that RA was associated with increased outpatient opioid demand. This difference was evident at 90 days postoperatively but not at the earlier cumulative timepoints, suggesting that pain was high for longer in the RA group while it diminished over time in the group without RA. Patients treated with RA also had significantly higher odds of opioid refill from two weeks to 90 days postoperatively, further suggesting prolonged postsurgical pain in this group. It is possible that these results represent the consequences of postoperative rebound pain. Several studies have demonstrated that acute postoperative pain and opioid demand predict the development of long-term pain and opioid use [19, 69, 70]. Given the finding of increased opioid consumption at 48–72 h in patients with RA, it would stand to reason these patients experienced an acute rise in postoperative pain, leading to increased likelihood of developing prolonged postsurgical pain. Persistent neuropathic pain might also contribute to these findings, as it is one of the proposed mechanisms behind rebound pain and a cause of persistent maladaptive plasticity [69]. However, these inferences are limited by our inability to measure pain retrospectively and warrant further investigation.

Considering that RA is associated with increased postoperative and long-term opioid use, the potential risks and benefits of

RA unique to the pelvis and acetabulum merit discussion. The addition of epidural anesthesia (EA) to general anesthesia has been shown to significantly reduce intraoperative blood loss in total hip arthroplasty [71]. A small retrospective study by Acan et al. [72] and the aforementioned study by Strauss et al. [37] found similar results in acetabular fracture surgery. Minimizing intraoperative blood loss should be weighed against the risks from EA-induced hypotension. In particular, perineural lumbar plexus blocks carry the risk of accidental intrathecal injection or epidural spread and subsequent conversion to an epidural block, causing unanticipated hemodynamic instability [73]. While thoracic EA reduces both myocardial oxygen supply via hypotension and oxygen demand through blockade of cardiac sympathetic nerves, EA isolated to the lumbar plexus is unable to offset the reduced supply with a lower oxygen requirement [74]. Thus, lumbar epidural analgesia alone can be especially problematic in procedures with high intraoperative blood loss. Patients anticoagulated with low molecular weight heparin are also at increased risk for developing an epidural hematoma after EA administration [75]. Additionally, pre-existing nerve damage may predispose to further anesthesia-related nerve injury [76]. This is an important as 12.2% of acetabular fracture patients may have injury to the sciatic nerve, particularly in fracture dislocations of the affected hip [6].

Several additional clinical considerations apply to the use of RA in fractures of the pelvis and acetabulum. The location and severity of these fractures often prevent patients from RA administration outside of the operating room. Early administration of RA would be expected to block peripheral pain signals from reaching the spinal cord, decreasing central sensitization to pain. As definitive fixation is secondary to resuscitation and stabilization, patients with pelvic and acetabular fractures are more likely to receive RA at a later timepoint and not obtain this benefit. Additional benefits of EA, including blunted sympathetic and neuroendocrine stress responses, may not be seen when implemented postoperatively [77]. While rare, complications of RA procedures include peripheral nerve injury, infection, and local anesthetic systemic toxicity [78]. Finally, nerve blockade often adds time to the perioperative experience for the patient, surgeon, and anesthesiologist, incurs additional cost to the healthcare system, and represents an additional procedure for the patient.

This study has several limitations. First, adjunctive non-opioid perioperative analgesia was not evaluated. However, it is unlikely that the adjunctive pain management strategies differed between groups. Secondly, as this was a retrospective study, we did not evaluate pain, since this would have been collected at non-standardized time intervals. Further, opioid prescribing rather than opioid consumption was measured in the outpatient setting given the retrospective nature of the study. However, we included information on opioid refills which correlates well to patient opioid demand. Of note, our study only evaluated adult patients and cannot provide insight into cases of pediatric pelvis and acetabulum trauma, which is rare and may have unique challenges with regard to pain control and operative treatment [79]. Lastly, our data included patients that received RA at a variety of anatomic locations and with varying medication type, rate, and quantity. While this heterogeneity may decrease the specificity of our results to one particular technique, we believe that analyzing the data in this fashion broadens their clinical interpretation since it more closely matches the scenario encountered in clinical practice.

In conclusion, perioperative RA in pelvis and acetabulum fracture surgery was associated with small increases in inpatient opioid consumption and outpatient opioid demand. This is important information when considering the utility of perioperative nerve blockade in this patient population.

Appendix 1

See Table 6.

Table 6 Adjusted inpatient opioid usage

Factors	0–24 h post-op	24–48 h oxycodone	48–72 h oxycodone
Age (years)	0.98 (0.97, 0.99; $p = < 0.001$)	0.97 (0.97, 0.98; $p = < 0.001$)	0.97 (0.97, 0.98; $p = < 0.001$)
Female sex	0.69 (0.57, 0.84; $p = < 0.001$)	0.79 (0.64, 0.98; $p = 0.029$)	0.59 (0.47, 0.75; $p = < 0.001$)
Caucasian race	1.01 (0.84, 1.23; $p = 0.88$)	1.05 (0.86, 1.29; $p = 0.63$)	1.07 (0.85, 1.35; $p = 0.55$)
BMI (kg/m^2)	1.02 (1.01, 1.03; $p = < 0.001$)	1.02 (1, 1.03; $p = 0.008$)	1.01 (1, 1.03; $p = 0.065$)
Smoking	1.35 (1.09, 1.67; $p = 0.005$)	1.19 (0.96, 1.48; $p = 0.121$)	1.18 (0.93, 1.51; $p = 0.178$)
Preoperative opioid usage	1.18 (0.8, 1.73; $p = 0.4$)	1.14 (0.76, 1.71; $p = 0.53$)	1.73 (1.06, 2.82; $p = 0.027$)
ASA 3 or greater	1.2 (0.98, 1.46; $p = 0.072$)	1.3 (1.06, 1.61; $p = 0.012$)	1.41 (1.12, 1.77; $p = 0.003$)
High energy mechanism	1.46 (1.01, 2.09; $p = 0.043$)	1.4 (0.95, 2.07; $p = 0.093$)	1.5 (0.94, 2.41; $p = 0.091$)
Additional injury	1.37 (1.06, 1.76; $p = 0.015$)	0.86 (0.66, 1.13; $p = 0.29$)	0.95 (0.68, 1.31; $p = 0.74$)
Open fracture	1.4 (0.8, 2.46; $p = 0.24$)	1.54 (0.87, 2.73; $p = 0.136$)	1.11 (0.59, 2.09; $p = 0.74$)
Additional surgery within 7 days	0.43 (0.26, 0.72; $p = 0.001$)	1.76 (1.07, 2.9; $p = 0.027$)	2.54 (1.49, 4.35; $p = < 0.001$)
RA	0.96 (0.81, 1.14; $p = 0.62$)	1.12 (0.93, 1.34; $p = 0.23$)	1.27 (1.04, 1.56; $p = 0.02$)

Estimates (95% CI) and *p*-values from generalized linear model

Appendix 2

See Table 7.

Table 7 Adjusted outpatient opioid usage

Factors	Discharge to 2 weeks	Discharge to 6 weeks	Discharge to 90 days
Age (years)	0.98 (0.97, 0.99; $p = < 0.001$)	0.98 (0.97, 0.99; $p = < 0.001$)	0.98 (0.97, 0.99; $p = < 0.001$)
Female sex	1 (0.78, 1.28; $p = 0.99$)	0.9 (0.71, 1.15; $p = 0.39$)	0.84 (0.66, 1.08; $p = 0.163$)
Caucasian race	1 (0.8, 1.26; $p = 0.98$)	0.94 (0.74, 1.18; $p = 0.56$)	0.9 (0.71, 1.13; $p = 0.36$)
BMI (kg/m^2)	1.01 (0.99, 1.02; $p = 0.39$)	1 (0.99, 1.02; $p = 0.8$)	1 (0.98, 1.01; $p = 0.64$)
Smoking	1.09 (0.84, 1.43; $p = 0.5$)	1.05 (0.81, 1.37; $p = 0.7$)	0.98 (0.75, 1.28; $p = 0.86$)
Preoperative opioid usage	1.26 (0.83, 1.97; $p = 0.26$)	1.11 (0.74, 1.72; $p = 0.6$)	1.31 (0.88, 2.01; $p = 0.186$)
ASA 3 or greater	0.9 (0.71, 1.14; $p = 0.41$)	0.98 (0.78, 1.24; $p = 0.88$)	1.03 (0.81, 1.31; $p = 0.8$)
High energy mechanism	1.12 (0.74, 1.68; $p = 0.58$)	1.07 (0.71, 1.59; $p = 0.74$)	1.14 (0.75, 1.7; $p = 0.54$)
Additional injury	0.82 (0.61, 1.1; $p = 0.2$)	0.88 (0.66, 1.18; $p = 0.4$)	0.91 (0.67, 1.22; $p = 0.55$)
Open fracture	0.67 (0.33, 1.54; $p = 0.28$)	0.71 (0.36, 1.61; $p = 0.35$)	0.58 (0.29, 1.34; $p = 0.149$)
Additional surgery within 7 days	1.62 (0.9, 3.17; $p = 0.116$)	2.35 (1.31, 4.6; $p = 0.004$)	2.59 (1.42, 5.15; $p = 0.002$)
RA	1.02 (0.82, 1.27; $p = 0.85$)	1.22 (0.99, 1.51; $p = 0.056$)	1.33 (1.06, 1.65; $p = 0.008$)

Estimates (95% CI) and *p*-values from generalized linear model

Appendix 3

See Table 8.

Table 8 Adjusted odds of opioid fill and refill

Factors	Discharge to two week opioid refill	Two week to six week opioid fill	Six week to ninety day opioid fill
Age (years)	0.97 (0.95, 0.98; $p = < 0.001$)	0.98 (0.96, 0.99; $p = 0.005$)	0.99 (0.97, 1.01; $p = 0.26$)
Female sex	1.03 (0.64, 1.65; $p = 0.92$)	0.68 (0.4, 1.13; $p = 0.139$)	0.88 (0.49, 1.55; $p = 0.66$)
Caucasian race	0.85 (0.54, 1.34; $p = 0.48$)	0.69 (0.42, 1.12; $p = 0.132$)	0.52 (0.3, 0.91; $p = 0.022$)
BMI (kg/m^2)	1.01 (0.98, 1.04; $p = 0.69$)	1.03 (0.99, 1.06; $p = 0.108$)	0.93 (0.89, 0.97; $p = < 0.001$)
Smoking	1.37 (0.82, 2.3; $p = 0.23$)	1.05 (0.61, 1.79; $p = 0.87$)	1.18 (0.65, 2.09; $p = 0.58$)
Preoperative opioid usage	1.37 (0.61, 3.07; $p = 0.44$)	0.52 (0.17, 1.33; $p = 0.195$)	1 (0.34, 2.62; $p = 1$)
ASA 3 or greater	0.54 (0.33, 0.87; $p = 0.011$)	0.84 (0.5, 1.42; $p = 0.52$)	0.9 (0.5, 1.62; $p = 0.74$)
High energy mechanism	1.23 (0.53, 2.91; $p = 0.63$)	0.51 (0.2, 1.28; $p = 0.147$)	1.5 (0.56, 4.39; $p = 0.44$)
Additional injury	0.53 (0.28, 0.96; $p = 0.04$)	1.69 (0.88, 3.34; $p = 0.124$)	0.91 (0.46, 1.84; $p = 0.79$)
Open fracture	0.83 (0.13, 3.87; $p = 0.82$)	7.15 (1.68, 40.9; $p = 0.012$)	n/c
Additional surgery within 7 days	2.11 (0.61, 8.13; $p = 0.25$)	13.55 (3.52, 78.88; $p = < 0.001$)	4.37 (1.29, 15.28; $p = 0.017$)
RA	0.99 (0.65, 1.51; $p = 0.97$)	2.43 (1.55, 3.84; $p = < 0.001$)	2.05 (1.24, 3.46; $p = 0.006$)

Odds ratio (95% CI) displayed. *P*-values from multivariable modeling

Appendix 4

See Table 9.

Table 9 Unadjusted inpatient oxycodone 5-mg equivalents consumed in patients with and without RA

Outcomes	All subjects ($n=205$)	Without RA ($n=138$)	With RA ($n=67$)	p-value
0–24 h post-op	13.3 (6.1, 25.7)	13.5 (7.6, 25.3)	12.7 (4, 27.2)	0.36
24–48 h post-op	14 (6, 24.1)	14.2 (6.2, 21.1)	12.7 (6, 26.3)	0.8
48–72 h post-op	10.7 (4.3, 23)	11 (5.3, 21)	10.2 (4, 23.5)	0.98

Red coloring highlights statistical significance. Median (Q1, Q3) displayed. *P*-values from Wilcoxon rank-sum test

Appendix 5

See Table 10.

Table 10 Unadjusted outpatient oxycodone 5-mg equivalents prescribed in patients with and without RA

Outcomes	All subjects ($n=205$)	Without RA ($n=138$)	With RA ($n=67$)	p-value
Discharge to 2 weeks	100 (40, 196)	100 (46.3, 195)	100 (30, 200)	0.64
Discharge to 6 weeks	120 (50, 220)	108.3 (60, 210)	154 (36, 254.5)	0.24
Discharge to 90 days	140 (60, 240)	131.7 (60, 210)	168 (43.5, 290)	0.124

Red coloring highlights statistical significance. Median (Q1, Q3) displayed. *P*-values from Wilcoxon rank-sum test

Appendix 6

See Table 11.

Table 11 Unadjusted rates of outpatient opioid fill and refill

Outcomes	All subjects ($n=205$)	Without RA ($n=138$)	With RA ($n=67$)	p-value
Discharge to two week opioid refill	93/205 (45.4%)	64/138 (46.4%)	29/67 (43.3%)	0.77
Two week to six week opioid fill	68/205 (33.2%)	40/138 (29%)	28/67 (41.8%)	0.082
Six week to ninety day opioid fill	42/205 (20.5%)	26/138 (18.8%)	16/67 (23.9%)	0.46

Proportion (percentage) displayed. *P*-value from Fisher's exact test

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Declarations

Conflict of interest The author declares that they have no competing interest.

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