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ORIGINAL ARTICLE

Regional anesthesia improves inpatient but not outpatient opioid demand in tibial shaft fracture surgery

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Abstract

Background Patients undergoing operative treatment of tibial shaft fractures have considerable pain largely managed with opioids. Regional anesthesia (RA) has been increasingly used to reduce perioperative opioid use.

Methods This was a retrospective study of 426 patients that underwent operative treatment of tibial shaft fractures with and without RA. Inpatient opioid consumption and 90-day outpatient opioid demand were measured.

Results RA significantly decreased inpatient opioid consumption for 48 h post-operatively ($p = 0.008$). Neither inpatient use after 48 h nor outpatient opioid demand differed in patients with RA ($p > 0.05$).

Conclusions RA may help with inpatient pain control and reduce opioid use in tibial shaft fracture.

Level of evidence Level III, retrospective, therapeutic cohort study.

Keywords Regional anesthesia · Tibial shaft fracture surgery · Opioid demand · Nerve blockade · Pain

Introduction

The opioid epidemic is a major public health crisis, with multiple efforts nationwide to reduce opioid prescriptions and use [1, 2]. Prescription opioids are the leading cause of drug overdose deaths in the USA, and many patients are first exposed to opioids in the perioperative period [3]. Orthopedic surgeries are reported as extremely painful by patients, particularly when injury of the lower extremity is involved, and orthopedic surgeons are among the top prescribers of opioids nationwide [4–6]. Within orthopedic injuries and surgeries, tibial shaft fracture and surgical repair is particularly painful. These injuries often require a period of external fixation with increases opioid demand perioperatively [6], and 47.4% of patients suffer from anterior knee pain following tibial nailing [7]. The risk of nonunion is high and is associated with an increased likelihood of being prescribed long-term opioid therapy [8].

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Notably, opioid demand in the acute perioperative period is a predictor of long-term use and abuse [9], and various factors such as mental health and substance use impact perioperative opioid demand [10–12]. Pursuit of opioid-sparing pain management has received increased attention in orthopedic trauma, as this patient population is significantly more likely to use prescription opioids prior to injury, which in turn predicts post-operative opioid use and seeking narcotic prescriptions from multiple providers [13]. To this end, multimodal pain regimens are often used perioperatively.

Regional anesthesia (RA) has been increasingly incorporated into multimodal post-operative analgesia regimens, with some techniques demonstrating reductions in early perioperative opioid consumption and opioid-related side effects [14]. RA encompasses peripheral nerve blocks and paravertebral blocks and provides dynamic pain control targeted to the site of injury, an advantage over global anesthetics [15]. RA has shown promise in its ability to reduce acute pain in the early post-operative period following orthopedic surgery [16]. However, rebound pain—an acute increase in pain upon resolution of nerve blockade—has also been described as a potential detractor from to the overall clinical benefits of RA [17]. The long-term effects of RA on persistent post-operative pain and opioid demand have been understudied and are not yet clearly demonstrated [18].

While the impact of RA on pain and opioid consumption in orthopedic surgery has received growing attention in ankle, hip and distal radius fractures, less is known of its outcomes in tibial shaft fractures. These are particularly important injuries to consider, as the tibia is the most commonly fractured long bone and several factors may predispose these patients to increased opioid use [19]. It is critical to understand the impact regional anesthesia can have on longitudinal opioid demand in tibial shaft fractures; however, there is very limited evidence at present. The purpose of this study is to evaluate the impact of regional anesthesia modalities on inpatient opioid consumption and outpatient opioid demand in patients undergoing tibial shaft fracture surgery. The study hypothesis is that RA will be associated with a decrease in inpatient opioid consumption but will not have an impact on outpatient opioid demand.

Methods

Study design

The Institutional Review Board at our institution approved this retrospective, observational study of inpatient opioid consumption and outpatient opioid demand in all patients aged 18 years and older that underwent tibial shaft fracture surgery at a single institution from 7/1/2013 to 7/1/2018. This study is designed and reported in accordance with the STROBE statement on reporting observational studies [20].

Variables and data sources

Post-operative inpatient opioid consumption (0–24 h, 24–48 h, and 48–72 h post-operative) and outpatient opioid prescribing (discharge to 2-weeks, 6-weeks, and 90-days) in patients undergoing tibial shaft fracture surgery between 7/2013 and 7/2018 at a single, Level I trauma center (Current Procedural Terminology codes 27,758 or 27,759) that were ages 18 and older was recorded [21]. Opioids were converted to oxycodone 5-mg equivalents using conversion factors available through the CDC. Baseline and treatment characteristics including RA usage, age, sex, race, body mass index (BMI), smoking status, American Society of Anesthesiologists (ASA) score, injury mechanism, additional injuries, open fracture, pre-operative opioid prescribing within 6-months to 1-month pre-operative, and additional surgery were recorded through chart review. The definition of pre-operative opioid use was in line with the definition recommended by the Centers for Disease Control (CDC) [22]. General 90-day post-operative complications were also recorded through chart review including mortality, surgical site infection, acute compartment syndrome (ACS), loss of fixation, deep vein thrombosis (DVT), pulmonary embolism (PE), falls, delirium, and ileus. All patients had q4h compartment checks carried out for 24 h postoperatively.

Pain protocol

Although pain management is not rigidly standardized, patients at our institution generally receive multimodal analgesia with oral opioids based on a 10-point pain scale and intravenous (IV) opioids provided for breakthrough pain. Patients routinely receive oral acetaminophen, but non-steroidal anti-inflammatory medications are not routinely used. The decision for including RA in the patient's perioperative pain regimen is made on a case-by-case basis by the surgeon and treating anesthesiologist. In general, patients are less likely to receive a block if they sustained a high-energy mechanism of injury, underwent surgery within 2 days of initial injury, or sustained an open fracture, due to concern for these patients to be at increased risk of ACS. Sciatic-popliteal, femoral, and/or adductor canal single-shot or continuous blocks are the most commonly used block location, though single-shot and continuous epidural are sometimes used as well. At time of discharge, most patients (390 of 426, 91.5%) received opioid prescriptions.

Missing data

For 7 of 433 (1.6%) patients, BMI could not be evaluated from the available data. Unadjusted analysis was found to be similar with and without them. These patients were excluded after unadjusted analyses to allow adjusted analyses to account for BMI. This left 426 patients for adjusted analysis.

Statistical analysis

Both unadjusted and adjusted statistical analyses were performed. Proportions with percentages and medians with quartiles were calculated. Fisher's exact test and Wilcoxon rank-sum were used to compare baseline characteristics and outcomes between patients with and without RA. Histograms of outcomes (opioid demand) were created and demonstrated positive skew, as would be expected with data that mirrors count data. Patients within the top 2% of 90-day opioid demand were excluded due to their outlier status. Generalized linear modeling with log link function and negative binomial distribution was planned. Since treatment was not randomly assigned, propensity score weighting was carried out on RA versus no RA, and this analysis included 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. Propensity score weighting is a method that closely matches patients based on similarities

on covariates provided to the model and allows direct comparison between two groups with non-equal covariates [23].

Adjusted analyses using generalized linear modeling incorporated the propensity score weighting and the baseline and treatment factors mentioned above, creating "doubly robust" analyses [24, 25]. Incident rate ratios from adjusted analyses were displayed, and RA versus no RA was simulated through the cohort to create effect estimates, which were derived from medians and 95% confidence intervals. Histograms were also used to display these treatment simulations. 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

Demographics

Patients without RA tended to be younger, male, non-Caucasian, and had higher rates of smoking, high-energy mechanisms, additional injuries, and open fractures (Table 1). There was no difference between groups in BMI, pre-operative opioid usage, ASA scores, or additional surgeries within either 7 or 90 days. Sciatic-popliteal (65%, 76 of 117), adductor canal (44.4%, 52 of 117), and femoral (17.9%, 21 of 117) nerve blocks were most common forms of RA. Six patients received more than one RA block. Single shot (44.4%, 52 of 117) and continuous (31.6%, 37 of 117) nerve blocks were the most common nerve block routes. Single shot (12.8% 15 of 117) and continuous (6.8%, 8 of 117) epidural analgesia were utilized less frequently than peripheral nerve block. A single patient received a combination of epidural anesthesia and RA.

Inpatient opioid use

After adjustment for baseline patient and treatment factors, RA was associated with significant decreases in opioid consumption from 0–24 to 24–48 h post-operatively (Table 2 and Fig. 1) of approximately 3.7 and 3.0 oxycodone 5-mg equivalents (OE's), respectively. However, RA had no significant impact on outpatient opioid demand (Table 3 and Fig. 2). RA was also not associated with significant changes in outpatient opioid fills and refills (Table 4).

Outpatient opioid use

As shown in Table 5, general 90-day outcomes did not differ significantly between groups. Rates of acute compartment syndrome (ACS) did not differ significantly between groups.

Independent predictors of opioid use

Appendix Tables 6, 7 and 8 display complete results of multivariable modeling. For inpatient opioid consumption, adjusted models demonstrated significant decreases with increased age and RA but significant increases with female sex, Caucasian race, increased BMI, smoking, increased ASA, high energy mechanism, open fracture, and additional surgery (Appendix Table 6). For outpatient opioid prescribing, adjusted models demonstrated significant decreases with increased age and increased ASA but significant increases with Caucasian race, increased BMI, smoking, pre-operative opioid usage, high energy mechanism, additional injury, and open fracture (Appendix Table 7). Likelihood of outpatient opioid prescription filling or refilling was significantly decreased with increased age (discharge to 2-week timeframe), while it was significantly increased with female sex, Caucasian race, increased BMI, smoking, pre-operative opioid usage, high energy mechanism, additional injuries, open fractures, additional surgery, increased age (6-week to 90-day timeframe). Unadjusted results for inpatient opioid consumption and outpatient opioid demand are shown in Appendix Tables 9, 10, 11.

Discussion

We here found use of RA following tibial shaft fracture and surgical repair significant decreases inpatient opioid consumption in the acute perioperative period but does not change outpatient opioid demand. Age, sex, race, BMI, smoking, pre-operative opioid usage, ASA, injury mechanism, additional injuries, open fracture, and additional surgery were independent significant drivers of inpatient and/or outpatient opioid demand metrics.

Our results show that RA was associated with decreased inpatient opioid consumption from 0 to 48 h after surgical management of tibial shaft fracture. This is likely indicative of superior pain control in patients with RA in the initial post-operative period, as has been demonstrated in prior research. Elkassabany et al. found that peripheral nerve blocks in patients with tibia fractures significantly decreased both pain and frequency of patient-controlled analgesia use up to 24 h post-operatively [26]. They did not report on overall amount of analgesia used. Low pain scores up to 40 h post-operatively have also been documented in a case report of a patient receiving RA after tibial nailing [27]. However, to our knowledge, no previous studies have quantified the impact of RA on post-operative opioid use in tibial shaft fractures.

While information on the effects of RA on opioid consumption in tibial fractures is scarce, our results are consistent with studies of RA in other lower extremity fractures.

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

Factors	Without RA ($n=309$)	With RA ($n=117$)	p-value
Age (years)	42 (28.6, 56.9)	45.4 (31.9, 63.2)	**0.016**
Female sex	101/309 (32.7%)	56/117 (47.9%)	**0.005**
Caucasian race	137/309 (44.3%)	72/117 (61.5%)	**0.002**
BMI (kg/m^2)	27.7 (23.6, 31.3)	28.1 (24.8, 32.6)	0.175
Smoking	87/301 (28.9%)	17/116 (14.7%)	**0.004**
Pre-operative opioid usage	29/309 (9.4%)	10/117 (8.5%)	0.85
ASA score			
ASA 3 or greater	122/309 (39.5%)	50/117 (42.7%)	0.58
ASA 1	53/309 (17.2%)	21/117 (17.9%)	0.89
ASA 2	134/309 (43.4%)	46/117 (39.3%)	0.51
ASA 3	104/309 (33.7%)	46/117 (39.3%)	0.31
ASA 4	18/309 (5.8%)	4/117 (3.4%)	0.46
Injury mechanism			
High energy mechanism	202/294 (68.7%)	52/105 (49.5%)	**< 0.001**
High energy mechanism			
Crush injury	7/309 (2.3%)	0/117 (0%)	0.198
Fall from height	33/309 (10.7%)	14/117 (12%)	0.73
GSW	27/309 (8.7%)	1/117 (0.9%)	**0.002**
MVC	109/309 (35.3%)	32/117 (27.4%)	0.134
MVC vs ped	26/309 (8.4%)	5/117 (4.3%)	0.21
Low energy mechanism			
Assault	7/309 (2.3%)	1/117 (0.9%)	0.45
Ground level fall	74/309 (23.9%)	35/117 (29.9%)	0.22
Pathologic	1/309 (0.3%)	1/117 (0.9%)	0.47
Sporting injury	8/309 (2.6%)	6/117 (5.1%)	0.22
Stress fracture	2/309 (0.6%)	10/117 (8.5%)	**< 0.001**
Unknown energy mechanism			
Not documented	3/309 (1%)	4/117 (3.4%)	0.094
Other	12/309 (3.9%)	8/117 (6.8%)	0.21
Additional injury	144/309 (46.6%)	39/117 (33.3%)	**0.016**
Open fracture	115/309 (37.2%)	17/117 (14.5%)	**< 0.001**
Additional surgery within 7-days	21/309 (6.8%)	6/117 (5.1%)	0.54
Additional surgery within 90-days	36/309 (11.7%)	9/117 (7.7%)	0.23
RA characteristics			
RA or EA	0/309 (0%)	117/117 (100%)	n/a
No Epidural	309/309 (100%)	94/117 (80.3%)	n/a
Epidural- continuous	0/309 (0%)	8/117 (6.8%)	n/a
Epidural- single shot	0/309 (0%)	15/117 (12.8%)	n/a
No RA	309/309 (100%)	22/117 (18.8%)	n/a
RA- continuous	0/309 (0%)	37/117 (31.6%)	n/a
RA- multiple	0/309 (0%)	6/117 (5.1%)	n/a
RA- single shot	0/309 (0%)	52/117 (44.4%)	n/a
RA (number)	0 (0, 0)	1 (1, 2)	n/a

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

Bold coloring highlights statistical significance

BMI body mass index, *ASA* American Society of Anesthesiologists score, *GSW* gunshot wound, *MVC* motor vehicle crash, *MVC Versus ped* motor vehicle versus pedestrian crash, *RA* regional anesthesia, *EA* epidural anesthesia

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	14.6 (11.8, 18.4)	10.9 (8.8, 13.7)	**0.75 (0.66, 0.84; *p* = < 0.001)**
24–48 h post-op	14.7 (11.3, 19.3)	11.7 (9, 15.5)	**0.8 (0.68, 0.94; *p* = 0.008)**
48–72 h post-op	12.5 (8.3, 17.7)	10.8 (7.1, 15)	0.86 (0.69, 1.07; *p* = 0.167)

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

Bold coloring highlights statistical significance

RA regional anesthesia

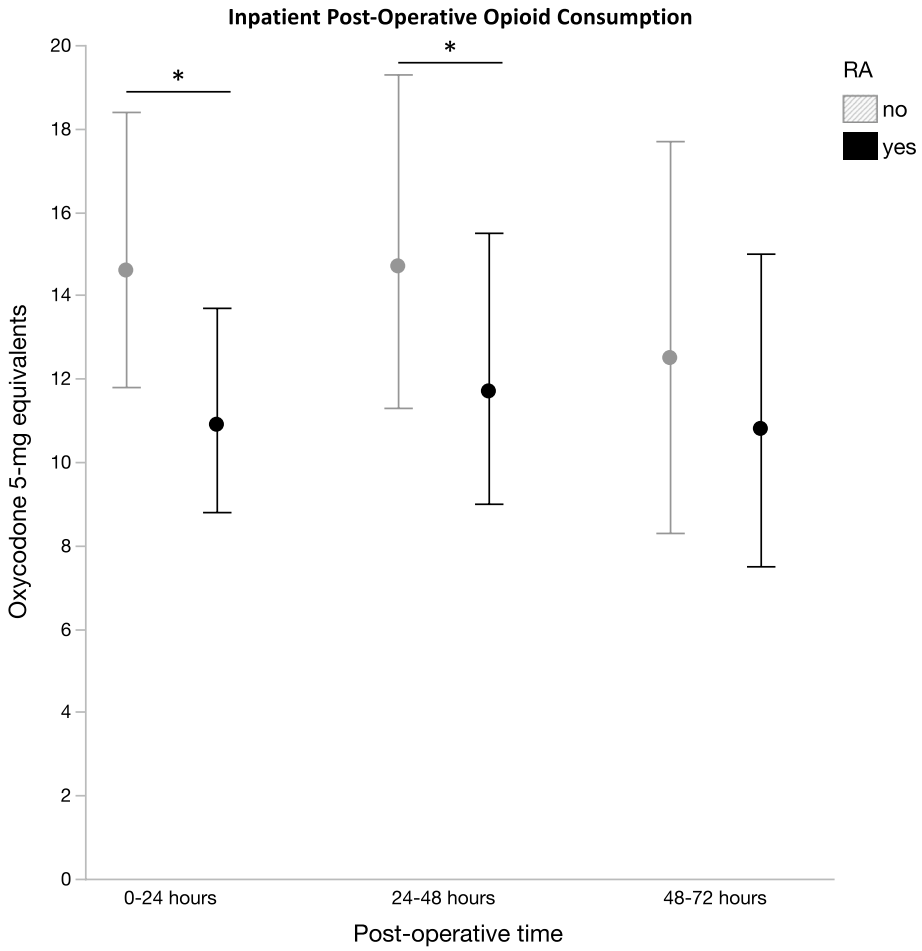

Fig. 1 Inpatient oxycodone 5-mg equivalent consumption in patients with and without RA anesthesia. *Indicates significant difference at $p < 0.05$ between patient with and without RA at that time point

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)
DC—2 weeks	116.7 (92, 146.7)	106.9 (84.2, 134.2)	0.92 (0.81, 1.04; *p* = 0.173)
DC to 6 weeks	142 (114.1, 175.4)	134 (107.7, 165.7)	0.94 (0.84, 1.07; *p* = 0.34)
DC to 90 days	156.9 (124.1, 193)	152.7 (120.5, 188.4)	0.97 (0.86, 1.11; *p* = 0.67)

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

DC discharge, *RA* regional anesthesia

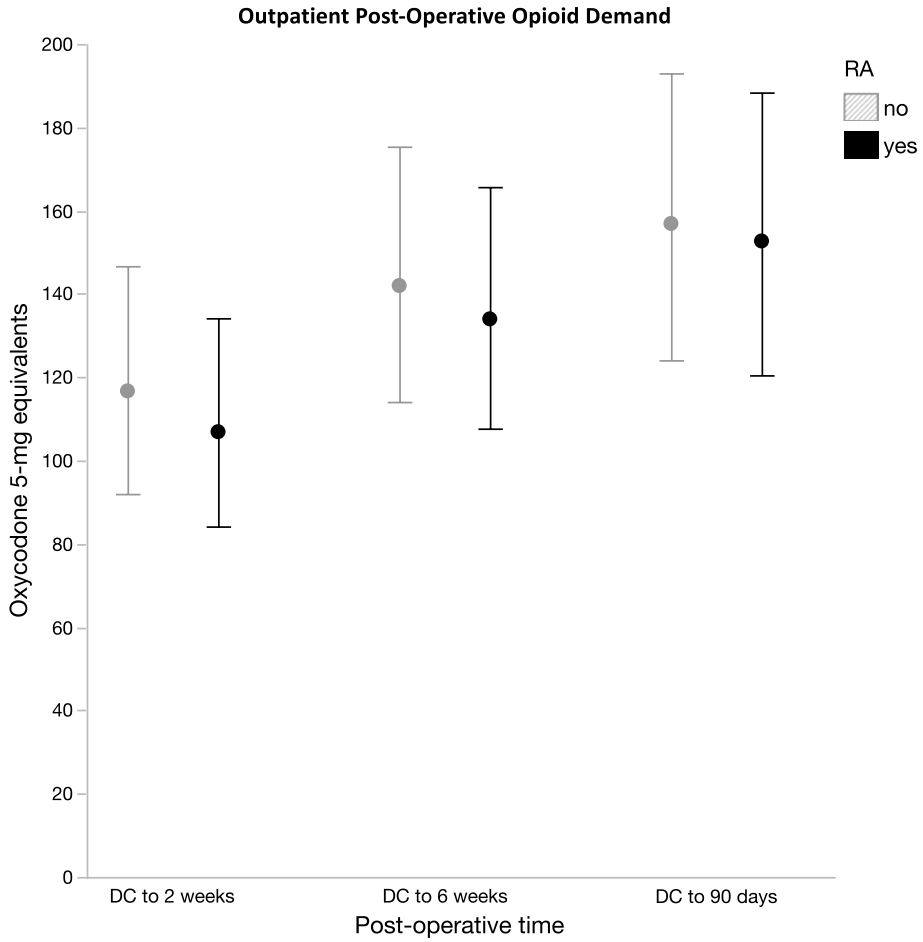

Fig. 2 Outpatient oxycodone 5-mg equivalent prescription demand in patients with and without RA anesthesia

Table 4 Adjusted odds of opioid fill and refill. Odds ratio (95% CI) displayed

Factors	Discharge to two week opioid refill	Two week to six week opioid fill	Six week to ninety day opioid fill
RA	1.11 (0.83, 1.49; $p=0.48$)	1.19 (0.87, 1.63; $p=0.27$)	0.88 (0.62, 1.26; $p=0.48$)

P-values from multivariable modeling. Complete model displayed in Appendix

Table 5 General 90-day perioperative complications

Outcomes	All subjects ($n=426$)	Without RA ($n=309$)	With RA ($n=117$)	*p*-value
Mortality	6 (1.4%)	6 (1.9%)	0 (0%)	0.195
SSI	42 (9.9%)	28 (9.1%)	14 (12%)	0.37
Mechanical failure	7 (1.6%)	6 (1.9%)	1 (0.9%)	0.68
DVT	1 (0.2%)	0 (0%)	1 (0.9%)	0.27
PE	7 (1.6%)	5 (1.6%)	2 (1.7%)	1
ACS	3 (0.7%)	2 (0.6%)	1 (0.9%)	1
Falls	16 (3.8%)	11 (3.6%)	5 (4.3%)	0.78
Delirium	2 (0.5%)	2 (0.6%)	0 (0%)	1
Ileus	6 (1.4%)	4 (1.3%)	2 (1.7%)	0.67

Proportions (percentages displayed). Unadjusted *p*-values from Fisher's exact test

N/c not calculable due to low event rate. *RA* regional anesthesia, *SSI* surgical site infection, *DVT* deep vein thrombosis, *PE* pulmonary embolism, *ACS* acute compartment syndrome

Christensen et al. found that regional anesthesia modalities significantly reduced 24 h post-operative opioid consumption compared to general anesthesia alone in ankle fracture patients [28]. In patients with talar and calcaneal fractures, continuous peripheral nerve block has been associated with a 30-fold decrease in opioid consumption on the first post-operative day compared to patient-controlled analgesia [29]. The current study agrees with prior research showing that RA is an effective acute analgesic for lower extremity fractures. However, this is the first study of its kind examining tibial shaft fractures. There may be location-specific differences in the effects of RA due to differences in fracture fixation methods, post-operative weight-bearing status, mechanism of injury and damage to surrounding structures, among others. The results from our large sample size add important new evidence of the impact of RA on immediate post-operative opioid demand in tibial shaft fractures.

In considering the potential analgesic and opioid sparing benefits of RA, it is important to account for rebound pain upon discontinuation of nerve blockade. The etiology of rebound pain remains to be fully elucidated, but is believed to be due to an unmasking of nociceptive input from the site of injury as the effects of RA diminish [30]. While duration of RA varies by block type, rebound pain in ankle fractures has been reported 12–24 h after administration and last for 3–6 h [31]. Further, meta-analysis of single-shot interscalene block for shoulder surgeries found an initial opioid-sparing effect up to 12 h, but greater pain 16–24 h post-operatively [32]. Rebound pain has been associated with high levels of opioid use, which may undermine the early clinical benefits of RA [33]. We were able to isolate these time frames of rebound pain by evaluating opioid consumption in 24-h blocks for up to 72 h postoperatively. RA did not lead to increased opioid consumption in the 24–48-h or 48–72-h blocks. This may be due to attenuation of rebound pain by pre-operative nerve blockade, continuous nerve catheter infusions, adjuvant medications or pre-emptive analgesia as previously described [34]. Scheduled acetaminophen is used in post-operative pain management at our institution, and it is possible this afforded pre-emptive analgesia before the blocks resolved. Additionally, RA protocols could not be standardized in this retrospective study and patients received a mix of single-shot and continuous blocks via either epidural or peripheral routes. Patients with continuous blocks may have experienced prolonged duration of analgesia and suppression of rebound pain, masking some patients with increased opioid use in the RA group.

This study found no significant difference in outpatient opioid demand in patients with and without RA. Despite evidence that acute pain and opioid demand predict long-term pain and opioid use [35], our findings are consistent with several previous studies that suggest RA may not confer a long-term reduction in opioid use. In a large database study of patients undergoing abdominal surgery, Ladha et al. found that epidural analgesia was not protective against total 90-day opioid use [36]. Similar results have been reported in a large healthcare claims database study in orthopedic surgery. Mueller et al. determined perioperative nerve blockade was not associated with a reduced risk of persistent opioid use for patients undergoing shoulder arthroplasty [37]. To our knowledge, this is the first study to examine opioid consumption up to 12 weeks in patients with tibial shaft fractures. It is likely that while RA optimized early pain control, there was no significant lasting difference in levels of persistent pain between groups, and therefore, no difference in long-term opioid consumption. While chronic pain is common after tibial shaft fracture, we were unable to measure pain scores and compare differences between groups in this retrospective study. There is a need for high-powered, prospective, randomized studies to clarify the impact of RA on long-term opioid use following discharge after fracture fixation.

With little impact of RA on opioid use following discharge, it is important to acknowledge additional potential disadvantages to this form of analgesia. Nerve blockade prolongs perioperative time, incurs additional cost, and is an additional procedure with added risks for the patient. Furthermore, use of RA remains controversial in the setting of long bone fractures due to concern it may mask symptoms of acute compartment syndrome (ACS) [34]. While rates of all complications occurrence including ACS were similar between groups, diaphyseal fractures are a key risk factor for the development of ACS. A common clinical concern is that RA will delay diagnosis of ACS in tibial shaft fractures, as tibial shaft fractures are responsible for one-third of ACS cases [38]. A recent systematic review found the effect of RA on delayed diagnosis of ACS in tibial shaft fractures was limited to case reports, with limited evidence that the use of RA resulted in a clinically significant delay in ACS diagnoses [39]. In fact, studies in pediatrics have demonstrated no delay in ACS diagnoses in lower extremity fractures when nerve blocks were used [40]. One notable case report discusses a patient that received RA for surgical fixation of a tibial shaft fracture and went on to develop ACS. However, this was diagnosed quickly and resulted in no lasting neuromuscular damage [41]. There is growing evidence that RA may not mask ischemic pain, the hallmark of ACS, to the same degree as non-ischemic pain, although this too is limited to case reports [42, 43]. Despite the lack of clear evidence that RA may delay diagnoses of ACS, there is still significant concern within orthopedics that a peripheral nerve block may potentially mask early clinical signs of ACS. The hesitancy to utilize these blocks in many practices, and the subsequent paucity of evidence on this topic, present further challenges to surgeons in assessing the risks and benefits of RA in tibial shaft fractures.

There are a variety of options for RA in extremity fractures. The present study demonstrated the tendency toward either a single shot in the pre-operative area, designed to both reduce perioperative opioid use and provide postoperative analgesia, as well as use of an indwelling catheter for extended postoperative pain management. We were underpowered to evaluate differences between these groups. Prior research has shown that single shot blocks administered immediately pre-operatively reduced pain scores for at least 24 h after administration within tibial shaft and ankle fractures [26], and reduced opioid use for 24 h post-operatively [28]. Interestingly, indwelling catheters only reduced opioid use for 1 day post-operatively when compared with opioid patient-controlled analgesia (PCA), even when catheters remained in place for longer than 1 day [29]. This may suggest that a single shot block confers the same benefit to an indwelling catheter for postoperative analgesia. As single shot blocks are easier and cheaper to perform, future studies should closely evaluate differences between these forms of regional anesthesia.

There are several limitations to this study given its retrospective nature. First, the proportion of patients who experienced a high-energy injury mechanism and/or had multiple injuries was significantly higher in the non-RA group. This as expected as these patients are at higher risk for ACS and thus, less likely to be offered a block by anesthesia. We were able to control for this difference between groups by utilizing both a propensity score, and further including this score into a generalized linear model. These are well-established statistical methods to control for non-equal covariates between groups, and the difference in inpatient opioid consumption between RA and non-RA groups was significant in both these analyses. Second, adjunctive non-opioid perioperative analgesia was not evaluated as this was not standardized, and many non-opioid medications are provided PRN. Third, as this was a retrospective study, we were unable to evaluate pain scores. Despite this limitation, a prior prospective trial had not demonstrated consistent pain reductions with nerve blockade after 24 h, and it is unlikely that we would have discovered more significant differential pain reductions given our findings regarding opioid usage in this study [28]. Further, opioid prescribing rather than opioid consumption was measured in the outpatient setting. This was the most accurate, objective way to determine opioid use in the outpatient setting, as clinic notes regarding opioid use were inconsistent and patient reporting on opioid use is unreliable [44]. Lastly, our data included patients that received RA at a variety of anatomic locations and with varying medication type, rate, and quantity. This heterogeneity may decrease the specificity of our results to a single technique.

In conclusion, perioperative RA in tibial shaft fracture surgery was associated with reduced inpatient opioid consumption, but no significant change in outpatient opioid demand without notable increases in rates of perioperative complications. Regional anesthesia seems appropriate to utilize to reduce perioperative opioid demand in tibial shaft fracture surgery, but its role in outpatient opioid prescribing seems limited. Further research is needed to evaluate the mediating effect of pain scores and the role of continuous vs single-shot blocks on perioperative pain.

Appendix

See Tables 6, 7, 8, 9, 10 and 11

Table 6 Adjusted inpatient opioid usage. Estimates (95% CI) and *p*-values from generalized linear model

Factors	0–24 h post-op	24–48 h oxycodone	48–72 h oxycodone
Age (years)	**0.97 (0.97, 0.98; $p = < 0.001$)**	**0.97 (0.96, 0.98; $p = < 0.001$)**	**0.98 (0.97, 0.98; $p = < 0.001$)**
Female sex	**1.34 (1.16, 1.53; $p = < 0.001$)**	1.18 (0.98, 1.43; $p = 0.085$)	1.23 (0.97, 1.56; $p = 0.091$)
Caucasian race	**1.48 (1.3, 1.69; $p = < 0.001$)**	**1.53 (1.28, 1.83; $p = < 0.001$)**	**1.29 (1.02, 1.62; $p = 0.03$)**
BMI (kg/m^2)	**1.01 (1, 1.02; $p = 0.003$)**	1 (0.99, 1.01; $p = 0.82$)	1 (0.99, 1.02; $p = 0.52$)
Smoking	**1.25 (1.07, 1.47; $p = 0.005$)**	**1.47 (1.19, 1.81; $p = < 0.001$)**	**1.56 (1.19, 2.06; $p = 0.002$)**
Pre-operative opioid usage	0.82 (0.65, 1.04; $p = 0.101$)	0.94 (0.71, 1.24; $p = 0.64$)	1.07 (0.75, 1.51; $p = 0.71$)
ASA 3 or greater	0.98 (0.83, 1.15; $p = 0.76$)	**1.29 (1.04, 1.59; $p = 0.019$)**	1.07 (0.81, 1.42; $p = 0.62$)
High energy mechanism	**1.25 (1.05, 1.48; $p = 0.01$)**	0.89 (0.71, 1.12; $p = 0.33$)	1.19 (0.88, 1.61; $p = 0.27$)
Additional injury	1.09 (0.95, 1.26; $p = 0.21$)	0.96 (0.8, 1.16; $p = 0.7$)	1.18 (0.93, 1.5; $p = 0.18$)
Open fracture	**1.33 (1.15, 1.54; $p = < 0.001$)**	**1.46 (1.21, 1.76; $p = < 0.001$)**	**1.63 (1.29, 2.06; $p = < 0.001$)**
Additional surgery within 7 days	**1.28 (1.09, 1.5; $p = 0.003$)**	1.16 (0.95, 1.41; $p = 0.147$)	**1.36 (1.09, 1.69; $p = 0.005$)**
RA	**0.75 (0.66, 0.84; $p = < 0.001$)**	**0.8 (0.68, 0.94; $p = 0.008$)**	0.86 (0.69, 1.07; $p = 0.167$)

Bold coloring highlights statistical significance

Table 7 Adjusted outpatient opioid usage. Estimates (95% CI) and *p*-values from generalized linear model

Factors	Discharge to 2 weeks	Discharge to 6 weeks	Discharge to 90 days
Age (years)	**0.99 (0.99, 1; *p* = < 0.001)**	**0.99 (0.99, 0.99; *p* = < 0.001)**	**0.99 (0.99, 1; *p* = < 0.001)**
Female sex	0.93 (0.81, 1.07; *p* = 0.3)	1.03 (0.91, 1.18; *p* = 0.61)	1.05 (0.92, 1.21; *p* = 0.47)
Caucasian race	**1.19 (1.04, 1.36; *p* = 0.01)**	**1.15 (1.01, 1.3; *p* = 0.032)**	**1.21 (1.07, 1.38; *p* = 0.004)**
BMI (kg/m^2)	1.01 (1, 1.02; *p* = 0.2)	**1.01 (1, 1.02; *p* = 0.011)**	**1.02 (1.01, 1.03; *p* = < 0.001)**
Smoking	**1.25 (1.07, 1.47; *p* = 0.005)**	**1.45 (1.25, 1.68; *p* = < 0.001)**	**1.64 (1.41, 1.92; *p* = < 0.001)**
Pre-operative opioid usage	1.22 (0.97, 1.55; *p* = 0.101)	**1.27 (1.02, 1.6; *p* = 0.033)**	1.26 (1, 1.61; *p* = 0.05)
ASA 3 or greater	0.88 (0.75, 1.03; *p* = 0.099)	**0.84 (0.73, 0.98; *p* = 0.026)**	0.86 (0.73, 1; *p* = 0.054)
High energy mechanism	**1.2 (1.02, 1.4; *p* = 0.025)**	**1.16 (1, 1.35; *p* = 0.049)**	1.05 (0.9, 1.23; *p* = 0.55)
Additional injury	1.11 (0.97, 1.28; *p* = 0.136)	**1.24 (1.09, 1.42; *p* = 0.001)**	**1.33 (1.16, 1.53; *p* = < 0.001)**
Open fracture	**1.42 (1.22, 1.65; *p* = < 0.001)**	**1.47 (1.27, 1.7; *p* = < 0.001)**	**1.63 (1.4, 1.9; *p* = < 0.001)**
Additional surgery within 7 days	1 (0.85, 1.19; *p* = 0.98)	1.09 (0.93, 1.28; *p* = 0.34)	1.17 (0.99, 1.39; *p* = 0.087)
RA	0.92 (0.81, 1.04; *p* = 0.173)	0.94 (0.84, 1.07; *p* = 0.34)	0.97 (0.86, 1.11; *p* = 0.67)

Bold coloring highlights statistical significance

Table 8 Adjusted odds of opioid fill and refill. Odds ratio (95% CI) displayed. *P*-values from multivariable modeling

Factors	Discharge to two week opioid refill	Two week to six week opioid fill	Six week to ninety day opioid fill
Age (years)	**0.99 (0.98, 1; *p* = 0.028)**	1 (0.99, 1.01; *p* = 0.87)	**1.02 (1.01, 1.03; *p* = < 0.001)**
Female sex	0.96 (0.7, 1.33; *p* = 0.82)	**1.57 (1.12, 2.22; *p* = 0.009)**	1.3 (0.89, 1.91; *p* = 0.175)
Caucasian race	1.1 (0.81, 1.49; *p* = 0.56)	0.91 (0.66, 1.26; *p* = 0.58)	**1.72 (1.18, 2.51; *p* = 0.005)**
BMI (kg/m^2)	0.99 (0.97, 1.02; *p* = 0.56)	**1.04 (1.02, 1.06; *p* = 0.001)**	1.02 (1, 1.05; *p* = 0.092)
Smoking	**1.57 (1.09, 2.25; *p* = 0.014)**	**3.02 (2.09, 4.4; *p* = < 0.001)**	**2.96 (1.94, 4.52; *p* = < 0.001)**
Pre-operative opioid usage	**2.59 (1.5, 4.51; *p* = < 0.001)**	1.11 (0.61, 1.99; *p* = 0.72)	**2.3 (1.26, 4.13; *p* = 0.006)**
ASA 3 or greater	0.86 (0.59, 1.24; *p* = 0.42)	0.92 (0.62, 1.37; *p* = 0.68)	0.86 (0.55, 1.34; *p* = 0.51)
High energy mechanism	**1.82 (1.26, 2.63; *p* = 0.001)**	1.23 (0.83, 1.83; *p* = 0.31)	0.75 (0.47, 1.18; *p* = 0.21)
Additional injury	**1.52 (1.1, 2.09; *p* = 0.01)**	**1.66 (1.19, 2.33; *p* = 0.003)**	**2.22 (1.51, 3.29; *p* = < 0.001)**
Open fracture	**2.33 (1.65, 3.31; *p* = < 0.001)**	**2.59 (1.81, 3.7; *p* = < 0.001)**	**2.46 (1.64, 3.7; *p* = < 0.001)**
Additional surgery within 7 days	0.66 (0.43, 1; *p* = 0.051)	**2.18 (1.41, 3.47; *p* = < 0.001)**	1.29 (0.81, 2.02; *p* = 0.26)
RA	1.11 (0.83, 1.49; *p* = 0.48)	1.19 (0.87, 1.63; *p* = 0.27)	0.88 (0.62, 1.26; *p* = 0.48)

Bold coloring highlights statistical significance

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

Outcomes	All subjects (*n* = 426)	Without RA (*n* = 309)	With RA (*n* = 117)	*p*-value
0–24 h post-op	12.7 (5.6, 20.6)	13.8 (7, 21.7)	8.9 (2, 14.6)	**< 0.001**
24–48 h post-op	11.3 (4.9, 20.4)	12 (6, 21)	8.4 (3, 14.7)	0.054
48–72 h post-op	10 (4, 19.7)	11 (4, 19.7)	8.3 (2, 18.3)	0.168

Median (Q1, Q3) displayed. *P*-values from Wilcoxon rank-sum test

Bold coloring highlights statistical significance.

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

Outcomes	All subjects (*n* = 426)	Without RA (*n* = 309)	With RA (*n* = 117)	*p*-value
Discharge to 2 weeks	100 (60, 160.8)	100 (60, 180)	90 (45, 122)	**0.005**
Discharge to 6 weeks	118.3 (60, 190)	120 (70, 200)	100 (60, 160)	**0.014**
Discharge to 90 days	120 (66.1, 209.6)	132 (80, 220)	100 (60, 170)	**0.013**

Median (Q1, Q3) displayed. *P*-values from Wilcoxon rank-sum test

Bold coloring highlights statistical significance

Table 11 Unadjusted rates of outpatient opioid fill and refill

Outcomes	All subjects ($n=426$)	Without RA ($n=309$)	With RA ($n=117$)	p-value
Discharge to two week opioid refill	186/426 (43.7%)	143/309 (46.3%)	43/117 (36.8%)	0.081
Two week to six week opioid fill	142/426 (33.3%)	107/309 (34.6%)	35/117 (29.9%)	0.42
Six week to ninety day opioid fill	97/426 (22.8%)	74/309 (23.9%)	23/117 (19.7%)	0.37

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

Bold coloring highlights statistical significance

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Declarations

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Ethical approval This study was approved by the institutional review board.

Informed consent Informed consent was not applicable for this retrospective review.

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