Who Hurts More? A Multicenter Prospective Study of In-Hospital Opioid Use in Pediatric Trauma Patients in the Midwest

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BACKGROUND: Despite increased national attention on misuse of prescription and nonprescription opioids for adolescents and children, little is known about opioid use in a pediatric population during hospitalization for injury. The purpose of this investigation is to describe opioid administration and magnitude of opioid exposure in the first 48 hours of hospitalization in a pediatric trauma population.

STUDY DESIGN: This is a secondary analysis of data collected for a randomized, prospective intervention study at 4 Midwestern children's trauma centers. Participants included children ages 10 to 17 years old, admitted to the hospital for unintentional injury. Descriptive statistics and multivariable modeling were used to characterize demographic factors and measure prevalence and magnitude of opioid use within the first 48 hours of hospitalization.

RESULTS: Among 299 participants, 82% received at least 1 opioid administration. Children had increased odds of receiving an opioid (odds ratio [OR] 4.25; 95% CI 2.16 to 8.35) for every log increase of Injury Severity Scores (ISS), yet the majority of children with minor injury (61%) also received an opioid. Children with fractures and older children had higher odds of receiving an opioid. Amount of opioid, expressed as morphine milligrams equivalent (MME), significantly increased with child age, ISS, and fracture.

CONCLUSIONS: Most pediatric trauma patients received an opioid in the first 48 hours of hospitalization, although prevalence and exposure varied by age, injury, and acuity. Aggressive pain management can be appropriate for injured pediatric patients; however, study results indicate areas for improvement, specifically for children with minor injuries and those receiving excessive opioid amounts. (J Am Coll Surg 2019;229:404–414. © 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Support: This work was supported by the Patient-Centered Outcomes Research Institute (CER-1306-02918).

Clinical trial registration identification number: NCT02323204

Presented at the Iowa Committee on Trauma Resident Research Competition, Iowa City, IA, September 2018; the Region VII Advances in Trauma 41st Annual Meeting, Kansas City, MO, December 2018 (winner); and the 42nd Annual Residents Trauma Papers Competition during the American College of Surgeons Committee on Trauma Annual Meeting, Chicago, IL, March 2019 (First Place, Clinical Research).

Received May 8, 2019; Accepted May 8, 2019.

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https://doi.org/10.1016/j.jamcollsurg.2019.05.021
ISSN 1072-7515/19

Abbreviations and Acronyms

ACS	= American College of Surgeons
AIC	= Akaike information criterion
ED	= emergency department
IQR	= interquartile range
ISS	= Injury Severity Score
MME	= morphine milligrams equivalent
OR	= Odds ratio
TBI	= traumatic brain injury

Rates of opioid-related hospitalization and death are increasing, particularly among children,[1-3] and significant national attention is focused on opioid misuse. Previous studies have shown that opioid addiction frequently begins in adolescence or young adulthood,[4] and one-quarter to one-third of young adults who report nonmedical prescription opioid use had an earlier history of prescribed medical opioid use.[5-7]

Unintentional injury is the leading cause of death and disability among children, with more than 8 million children treated for injury in emergency departments (ED) each year.[8-10] Many of these children experience moderate to severe pain after trauma, and opioids are one way that pain is treated.[11-17] Inadequately managed pain can lead to significant long-term consequences, such as post-traumatic stress and substance abuse[7,18-22]; however, early exposure to opioids has also been linked to similar outcomes.[4,23,24]

Opioids are often first-line treatment for moderate and acute pain after trauma, yet many trauma centers lack clear guidelines for when opioids are indicated in the pediatric trauma population and for the maximum cumulative amount of opioid to administer to pediatric patients. Although there is some guidance for managing pain in children treated in the ED,[25] children with chronic pain,[17] and children with acute postoperative pain,[26] to our knowledge there are no published, evidence-based, pediatric-specific guidelines for pain management after pediatric trauma. The CDC recommends that health care providers exercise caution when administering more than 50 morphine milligrams equivalent (MME) per day; however, this recommendation pertains to chronic pain in adults.[27] By this same recommendation, excessive exposure is considered administration of more than 90 MME per day. We are not aware of any maximum opioid dosing recommendations for acute pain in adult or pediatric trauma patients.

We cannot begin to address the public health crisis of opioid abuse if we do not understand opioid prescribing patterns for hospitalized pediatric trauma patients, including prevalence of opioid use and potential differences in opioid administration based on factors such as age, sex, and injury. The purpose of this investigation is to describe opioid administration and magnitude of opioid exposure in the first 48 hours of hospitalization in a pediatric trauma population.

METHODS

Study population

This was a secondary analysis of baseline data collected for a 3-year randomized, prospective study evaluating an intervention to address child psychosocial functioning after unintentional trauma. Patients were admitted during the study period (February 2015 to July 2017) to 1 of 4 verified American College of Surgeon (ACS) pediatric trauma centers in the Midwest: Iowa City, IA (level I pediatric trauma center); Des Moines, IA (level II); Kansas City, MO (level I); and Minneapolis, MN (level I). Study procedures for the Iowa City and Kansas City sites were approved by the IRB at the University of Iowa, and study procedures for the other 2 sites were approved by the IRBs at those respective study hospitals.

Eligible participants included children ages 10 to 17 years, admitted to the hospital for unintentional injury. One parent enrolled in the study with each child participant and each parent and child participant was compensated $25 per questionnaire they completed at baseline and follow-up. Study exclusion criteria were hospital admission for intentional injuries or complications from a previous injury; a score of less than 55 on the modified Children's Orientation and Amnesia Test (COAT)[28]; significant psychiatric history; previous diagnosis of intellectual deficit or psychosis; suicide attempt in previous year; law enforcement involvement in incident; pregnancy; residential treatment or foster care; non-English speaking (parent or child); or injury that occurred more than 2 weeks before admission.

Study variables

Demographic variables were available from baseline survey responses, including child sex, ethnicity (Hispanic or non-Hispanic), race (white or non-white), date of birth, and annual family income. Patient variables abstracted from the trauma registries at each study hospital included transfer from outside hospital, operative procedure, mechanical ventilation, hospital and ICU length of stay, diagnosis, injured body region, Injury Severity Score (ISS), and mechanism of injury. Because ISS does not follow a normal distribution, it was log transformed for use in multivariate models. Log transformation included an adjustment of 1 unit to allow for inclusion of individuals with ISS = 0.

Mechanism of injury and diagnosis codes were recorded using both the ICD-9 and ICD-10. The Barrel matrix was used to classify the nature of injury for ICD-9 codes, and the CDC Injury Mortality Diagnosis Matrix was used to classify ICD-10 codes.[29,30] Diagnoses were grouped by nature of injury (fracture, internal, superficial, traumatic brain injury [TBI], open wound, dislocation, unspecified); categories were not mutually exclusive to allow for multiple injuries. Injured body region was noted if the body region (head, chest, abdomen, or extremity) severity was $\geq$2 in each respective region. Multiple injured body regions was defined as having more than 1 injured body region with severity $\geq$ 2 in each region. Minor injury was defined as ISS 0 to 3, indicating that no body region had a severity score greater than 1.

Through medical record review, we obtained total amount of opioid (fentanyl, hydrocodone, hydromorphone, methadone, morphine, nalbuphine, oxycodone, remifentanil, tramadol), sedative (dexmedetomidine, ketamine, propofol), and anxiolytic (diazepam, hydroxyzine, lorazepam, midazolam) medication administered in the first 48 hours after admission to the study hospital. This included medication received in the ED and during the inpatient stay, but excluded opioids administered in the operating room, during transport to the study hospital, or at the transferring hospital. In order to discuss the magnitude of opioid exposure across different medications, opioid administration was converted to MME using CDC guidelines[27] and an equivalent opioid calculator.[31] A high amount of opioid was defined as 100 MME or greater in a 48-hour period, and excessive exposure was defined as 180 MME or greater in a 48-hour period; both definitions were adapted from the CDC guideline for management of chronic pain in adults.[27]

Statistical method

Analyses were performed with SAS 9.4 (SAS Institute Inc). Descriptive statistics were examined and reported for continuous data as medians and interquartile ranges (IQR); categorical data were reported as counts and percentages. Chi-square tests with alpha 0.05 were used to compare frequencies of categorical variables, and Wilcoxon signed-rank tests were used to compare medians for continuous variables. Correlations between variables were assessed with Pearson correlation coefficients (r) with 2-tailed tests of significance.

Child demographic and injury characteristics most likely to result in the prescribing of an opioid were evaluated using a logistic model. Children who received mechanical ventilation were excluded from the model because pain management for intubated children often requires continuous intravenous opioid and sedative infusions; patients with mechanical ventilation received more MME than patients not receiving mechanical ventilation ($t = -2.52$, $p = 0.03$). Variables were included in a stepwise logistic model to determine the odds of being administered an opioid, with Akaike information criterion (AIC) used to determine the most appropriate model. The AIC is a measure of how well predictors fit the data, while penalizing for the numbers of predictors in the model.[32] The resulting model balances bias and variance. With the large number of candidate variables included in this analysis, the use of AIC allowed for the identification of predictive variables while also considering parsimony of the model. The final model was evaluated for collinearity by regressing the covariates in the final model with each other. When 2 variables correlated by more than 50%, 1 predictor was kept in the model based on which of the possible models resulted in the lowest AIC. Results are presented with odds ratios (OR) and CI.

Prediction of MME amount was completed using the same procedures with linear regression; children who received mechanical ventilation were excluded from the model because sedation and analgesia protocols often use continuous opioid infusion. A natural log transformation was applied to total MME to account for non-normality. The model predicted a linear increase in log MME for each of the covariates. To account for the log transformation of opioid amount, the coefficients in the predictive model were exponentiated to calculate the difference in the actual opioid amount resulting from the variable. A normal distribution of the coefficient was assumed to create a confidence interval of the difference based on standard error of the coefficient. Child sex was not an important predictor of MME amount, despite being an important predictor of opioid administration, but was forced into the final log MME model to determine the difference in MME between females and males. Finally, when accounting for amount of opioid administered, there were 2 possible outcomes variables: total MME or total MME controlling for child weight (MME/kg). Children less than 50 kg are typically administered opioids with weight-based dosing,[33] but 60% of children in the study weighed more than 50 kg. Therefore, the model predicting total opioid amount was calculated for total MME amount, but additional models were run accounting for child weight (MME/kg).

RESULTS

Of 1,688 pediatric trauma patients screened for study eligibility, 868 (51%) children did not meet inclusion criteria, 243 (14%) were missed recruits, 263 (16%) declined participation, 15 (1%) withdrew from the study,

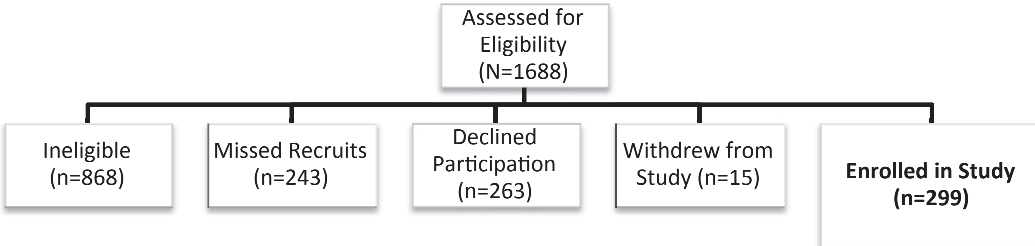

Figure 1. Flow chart for the study sample.

and 299 (18%) enrolled in the study (Fig. 1). As shown in Table 1, the majority of children were male (63%), white (85%), and non-Hispanic (93%). One-quarter of the sample had an annual family income under $40,000. Age was distributed as follows: 10 to 12 years (36%), 13 to 15 years (39%), and 16 to 17 years (24%). Fifty-two percent of children were transferred to the study hospital from another facility, and 51% of children received an operative procedure during hospitalization. Figure 2 illustrates the opioids administered during the study period. Of the 244 children who received an opioid, 77% received more than 1 different type of opioid. The most frequently administered opioids were morphine (54%), fentanyl (53%), and hydrocodone (39%).

Opioid use patterns

Overall, 244 (82%) children received at least 1 opioid administration in the first 48 hours of hospitalization. There were no significant differences in opioid administration across sex, study group, transfer status, or ICU stay (Table 1). Sixty-eight percent of Hispanic children received an opioid, compared with 82% of non-Hispanic children, but this difference was not statistically significant ($p = 0.10$). Older children were more likely to receive an opioid, with 72% of 10 to 12 year olds, 90% of 13 to 15 year olds, and 82% of 16 to 17 year olds receiving an opioid ($p = 0.003$). Children who experienced an operative procedure were more likely to receive an opioid than children who did not have an operative procedure. There were no differences in opioid administration between the 4 study sites ($p = 0.40$).

The most common mechanisms of injury were pedestrian, cyclist, or other transportation accidents (28%) and falls (27%); there was no association between mechanism of injury and opioid administration (Table 2). The most commonly injured body region was extremity (46%), and 96% of children with an extremity injury received an opioid. Forty-nine children had minor injury (ISS 0 to 3), and 61% of those children received an opioid. Children with fractures were more likely to receive an opioid than children without fractures (88% vs 70%, $p < 0.001$). Conversely, children with TBI were less likely to receive an opioid than children without TBI (63% vs 89%, $p < 0.001$). We found no association between opioid administration and injuries in multiple body regions.

Prediction of opioid administration

A predictive model was built to identify factors associated with children receiving an opioid in the first 48 hours of hospitalization; the final model excluded children receiving mechanical ventilation and included child age, sex, log ISS, fracture, open wound, chest body region, and TBI (Table 3). Controlling for other variables in the model, females were more likely to receive an opioid than males (odds ratio [OR] 2.60, 95% CI 1.09 to 6.17), and children with a higher ISS were also more likely to receive an opioid (OR 4.25, 95% CI 2.16 to 8.35 per log increase in ISS). Opioids were administered more frequently for older children, with 13 to 15 year olds being most likely to be administered an opioid. A child with a fracture had greater likelihood of opioid administration; chest injury and TBI resulted in a lesser likelihood of opioid administration. Patients with open wounds had 3 times greater odds of receiving an opioid; however, 80% of patients with open wounds (45 of 56) had concomitant injuries.

Prediction of magnitude of opioid exposure

Figure 3 illustrates total MME administered in the first 48 hours of hospitalization; this figure excludes children who received mechanical ventilation. Of the 232 children without mechanical ventilation who received an opioid, median MME over the 48-hour period was 56 (IQR 26, 118). One-third of children ($n = 82$) received a high amount of opioid ($\geq$ 100 MME) and 12% ($n = 29$) of children received an excessive amount of opioid ($\geq$ 180 MME) in the first 48 hours of hospitalization.

The final model predicting amount of opioid administered included child age, sex, log ISS, fracture, open wound, chest body region, and TBI (Table 4). Traumatic brain injury was associated with the lowest amount of log MME ($\beta = -0.61$, standard error $= 0.18$); children with TBI received 46% less MME than those without a TBI when

Table 1. Patient Characteristics by Opioid Use (n = 299)

Characteristic	All patients (n = 299)*	No opioid (n = 55)†	Opioid (n = 244)†	p Value
Sex, n (%)				0.90
Male	188 (63)	35 (19)	153 (81)	
Female	111 (37)	20 (18)	91 (82)	
Age, n (%)‡				0.003
10–12 y	109 (36)	30 (28)	79 (72)	
13–15 y	118 (39)	12 (10)	106 (90)	
16–17 y	72 (24)	13 (18)	59 (82)	
Ethnicity, n (%)				0.10
Hispanic	22 (7)	7 (32)	15 (68)	
Non-Hispanic	272 (91)	48 (18)	224 (82)	
Refused/unknown	5 (2)	0 (0)	5 (100)	
Race, n (%)				0.68
White	253 (85)	43 (17)	210 (83)	
Nonwhite	30 (10)	6 (20)	24 (80)	
Refused/unknown	16 (5)	6 (38)	10 (63)	
Family income, n (%)‡				0.38
\$0–\$39,999	73 (24)	15 (21)	58 (79)	
\$40,000–\$99,999	114 (38)	16 (14)	98 (86)	
≥\$100,000	87 (29)	19 (22)	68 (78)	
Refused	19 (6)	5 (26)	14 (74)	
Unknown	6 (2)	0 (0)	6 (100)	
Study group, n (%)				0.92
Intervention	145 (48)	27 (19)	118 (81)	
Control	154 (52)	28 (18)	126 (82)	
Transferred to study hospital, n (%)				0.46
Transferred	155 (52)	31 (20)	124 (80)	
Not transferred	144 (48)	24 (17)	120 (83)	
Operative procedure, n (%)				<0.001
Procedure	151 (51)	7 (5)	144 (95)	
No procedure	148 (49)	48 (32)	100 (68)	
ICU, n (%)				0.88
Any ICU days	73 (24)	13 (18)	60 (82)	
No ICU days	226 (76)	42 (19)	184 (81)	
MV, n (%)				0.48
Received MV	16 (5)	4 (25)	12 (75)	
No MV	283 (95)	51 (18)	232 (82)	
Sedative medication, n (%)				<0.001
Received sedative	79 (26)	3 (4)	76 (96)	
No sedative	220 (74)	52 (24)	168 (76)	
Anxiolytic medication, n (%)				<0.001
Received anxiolytic	103 (34)	2 (2)	101 (98)	
No anxiolytic	196 (66)	53 (27)	143 (73)	
Injury Severity Score, median (IQR)	5 (4, 9)	4 (1, 9)	5 (4, 9)	0.003
Hospital days, median (IQR)	2 (1, 3)	1 (1, 2)	2 (1, 3)	<0.001

IQR, interquartile range; MV, mechanical ventilation.
*Column percentage.
†Row percentage.
‡Column percentage totals for all patients do not sum to 100% due to rounding.

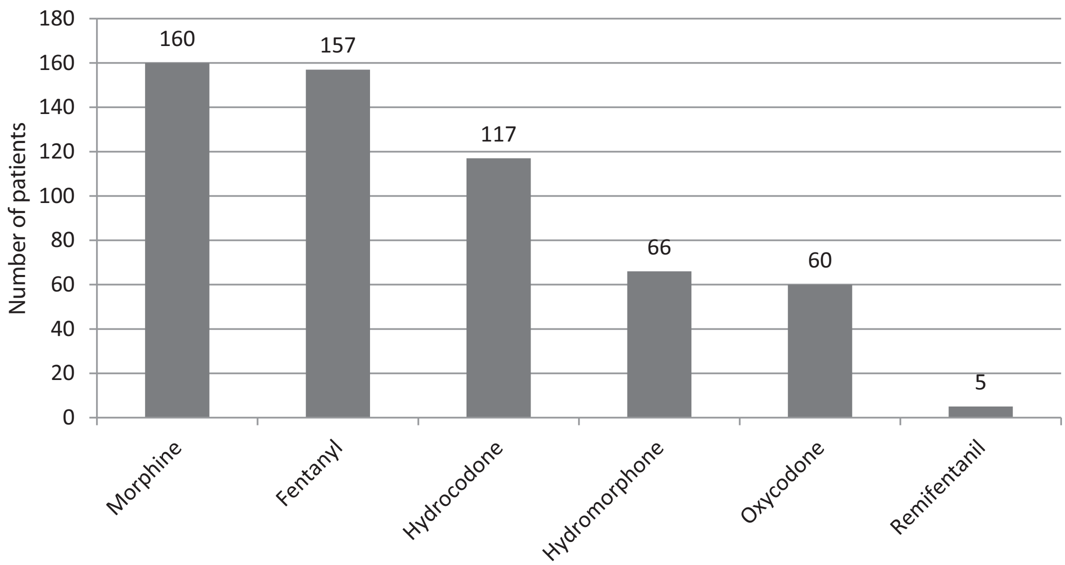

Figure 2. Opioids administered to study patients (n = 224).

controlling for other covariates in the model. Those with superficial injuries and chest injuries were also administered fewer opioids when compared with children without these injuries. As ISS increased, MME also increased; for example, going from ISS = 2 to ISS = 8 resulted in an 81% (95% CI 43% to 129%) increase in MME administered while

Table 2. Injuries and Mechanisms of Injury by Opioid Use (n = 299)

Injury	All patients (n = 299)*	No opioid (n = 55)†	Opioid (n = 244)†	p Value
Primary mechanism of injury, n(%)				
Pedestrian, cyclist, other transportation	84 (28)	12 (14)	72 (86)	0.34
Fall	80 (27)	15 (19)	65 (81)	0.76
Motor vehicle collision	62 (21)	15 (24)	47 (76)	0.13
Struck by/against	31 (10)	9 (29)	22 (71)	0.08
Burn	12 (4)	0 (0)	12 (100)	0.13
Cut/pierce	5 (2)	1 (20)	4 (80)	0.99
Other/unspecified/unknown	25 (7)	3 (12)	22 (88)	0.59
Injury type (not mutually exclusive), n (%)				
Fracture	194 (65)	23 (12)	171 (88)	<0.001
Internal	108 (36)	32 (30)	76 (70)	<0.001
Traumatic brain injury	83 (28)	31 (37)	52 (63)	<0.001
Superficial	63 (21)	15 (24)	48 (76)	0.21
Open wound	56 (19)	6 (11)	50 (89)	0.10
Dislocation	18 (6)	3 (17)	15 (83)	0.99
Unspecified	11 (4)	1 (9)	10 (91)	0.70
Injured body region (not mutually exclusive), n (%)				
Extremity	137 (46)	6 (4)	131 (96)	<0.001
Head	67 (22)	22 (33)	45 (67)	<0.001
Chest	46 (15)	8 (17)	38 (83)	0.85
Abdomen	38 (13)	3 (8)	35 (92)	0.08
No injured body region	61 (20)	19 (31)	42 (69)	0.004
Minor injury (ISS $\leq$ 3), n (%)	49 (16)	19 (39)	30 (61)	<0.001
Multiple injured body regions, n (%)	48 (16)	4 (8)	44 (92)	0.11

ISS, Injury Severity Score.
*Column percentage.
†Row percentage.

Table 3. Odds Ratios for Opioid Use (n = 283)

Variable	Odds ratio	95% CI
Female vs male	2.60	(1.09, 6.17)
Age 13–15 y vs 10–12 y	4.47	(1.78, 11.11)
Age 16–17 y vs 10–12 y	3.07	(1.17, 8.05)
Log Injury Severity Score	4.25	(2.16, 8.35)
Fracture	2.91	(1.25, 6.77)
Open wound	3.46	(1.22, 9.79)
Chest injury	0.12	(0.03, 0.41)
Traumatic brain injury	0.08	(0.03, 0.19)

controlling for the other variables in the model. The oldest age group (16 to 17 years) received the greatest amount of opioid. There was a statistical difference in log MME between the 4 study sites (ANOVA F-statistic = 6.54, $p < 0.001$).

When log MME/kg was modeled instead of MME, similar results were found for all covariates, with the exception of age. The effect of age was attenuated as part of the overall administration of opioids due to children having greater body weight at older ages. Children aged 13 to 15 years had a 36% increase ($\beta = 0.31$) in MME/kg compared with children aged 10 to 12 years. An increase in opioid MME/kg was also apparent for children aged 16 to 17 years (82%, $\beta = 0.60$) compared with children aged 10 to 12 years.

Child sex was not included in the final model based on the selection procedure, but was forced into the final model as part of a sensitivity analysis. The predicted amount of opioids from the model were not different between males and females (log MME more for females, $\beta < 0.01$, $p = 0.96$). In addition, fracture had a significant effect on opioid administration, but was not included in the model predicting opioid amount based on selection procedures; instead, extremity injuries were selected into the model. These 2 types of injuries were correlated ($r = 0.53$, $p < 0.001$), and a similar effect was found when fracture was substituted for extremity injury in the second model.

DISCUSSION

When a child suffers a traumatic injury, health care providers face the challenge of managing pain appropriately. Failure to provide adequate relief from pain can result in prolonged recovery, post-traumatic stress, and delayed return to functionality.[18-22] At the same time, exposure to opioids has been associated with future opioid misuse.[4,23] This poses a great challenge for providers in managing both short- and long-term welfare of patients. We

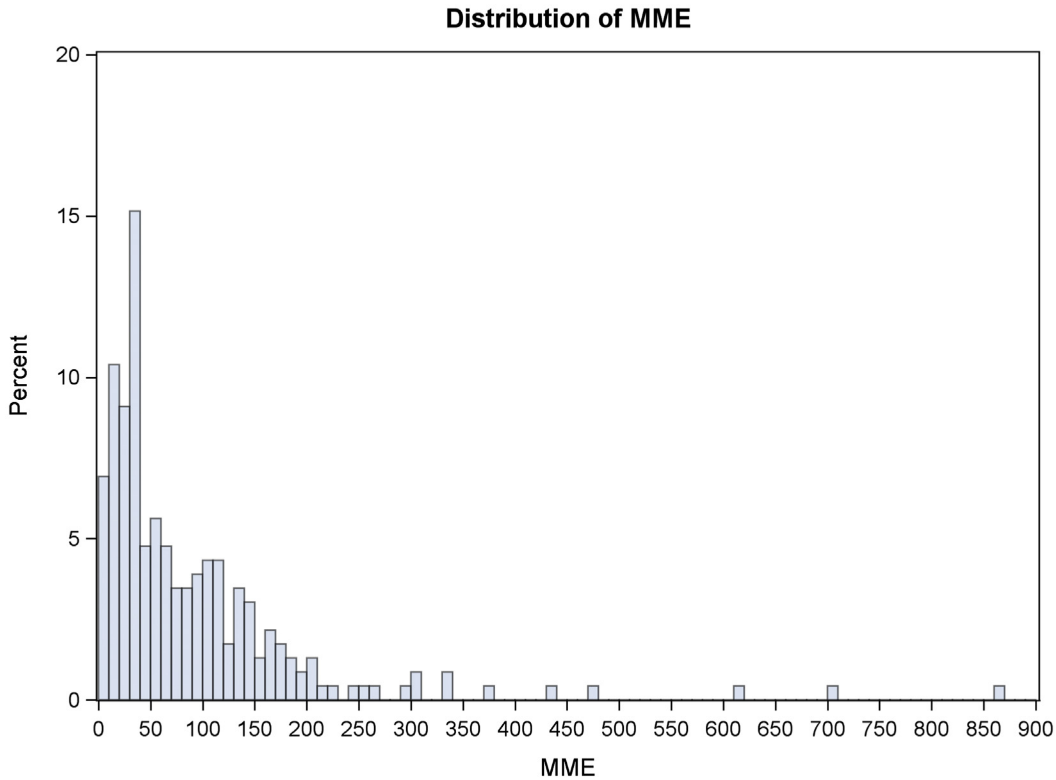

Figure 3. Amount of opioid received in the first 48 hours of hospitalization expressed in milligram morphine equivalents (MME), excluding children receiving mechanical ventilation (n = 232).

Table 4. Log Morphine Milligram Equivalent for Opioid Administration (n = 232)

Variable	β	SE	Difference, %	95% CI	p Value
Age 13–15 y vs 10–12 y	0.62	0.14	86	(41, 145)	<0.001
Age 16–17 y vs 10–12 y	1.02	0.18	177	(95, 295)	<0.001
Log ISS	0.54	0.11	81*	(43, 129)	<0.001
Extremity injury	0.33	0.14	39	(6, 83)	0.02
Superficial injury	−0.37	0.17	−31	(−51, −4)	0.04
Chest injury	−0.51	0.21	−40	(−60, −9)	0.02
Traumatic brain injury	−0.61	0.18	−46	(−62, −23)	0.001

SE, standard error; ISS, Injury Severity Score.
*Change in percent difference for Log ISS uses the expected change going from ISS of 2 to 8, roughly 1 natural log increase in ISS.

therefore find it imperative to describe and understand current opioid administration practices during hospitalization so opportunities for improvement in patient care can be identified.

Study findings demonstrate that more than 80% of pediatric trauma patients received at least 1 opioid administration in the first 48 hours of hospitalization. Patterns of opioid use and magnitude of opioid exposure varied significantly by child age, injury, and acuity. The majority of children who received an operative procedure were given an opioid, and median ISS was higher for patients who received an opioid compared with those who did not receive an opioid. In addition, having a fracture was associated with nearly 3 times higher odds of being administered an opioid. Children experience significant pain with fractures, especially if the fracture required operative fixation, and opioids are commonly administered for pain management.[34,35]

Other study findings were unexpected and illuminate 3 areas for future work and intervention. First, child sex was an important predictor of whether or not a child was administered an opioid (Table 3), but was not an important predictor of the amount of opioids being administered (Table 4). In other words, females were more likely than males to be given an opioid, but did not receive more opioids (MME) than males. Injury Severity Score or other clinical factors were controlled for in our models of opioid administration, so this finding suggests possible differences in how boys and girls perceive and express pain, as well as possible bias in how providers and parents respond to pain with boys and girls. Given the association between pain and post-traumatic stress in children,[36] these sex differences in opioid administration may reflect underlying processes that affect the psychological response to traumatic injury. There is a need for increased awareness of communication and behaviors expressed by parents and providers toward each other and the child during the evaluation and management of pain in the pediatric trauma population, as these communications may be influenced by level of distress[37] and preconception about pain.[38-40] Providers should also look for opportunities to have discussions with patients and their families about communicating levels of pain and appropriate expectations of pain management during hospitalization.[27,41]

Second, older teenagers had 3 to 4 times higher odds of receiving an opioid than younger children (ages 10 to 12) and received more opioids than younger children during the first 48 hours of hospitalization. This may be attributable to physical size differences, as weight increases as children age, but weight only partially explained differences in opioid administration. Findings may also suggest that older children may be treated too aggressively or younger children may not be treated aggressively enough, and such variability may have an impact on patient distress after hospitalization.[42-44] Data from the larger dataset include post-hospitalization measures assessing child distress and quality of life in the months after the injury. Future analyses will explore the association between age and opioid administration patterns on quality of life and post-traumatic stress after hospitalization.

Third, 33% of patients who got an opioid received 100 MME or more in the first 48 hours of hospitalization, and 12% received an excessive amount of opioid (≥180 MME). This proportion was surprisingly high given the relatively low injury severity and short length of stay of the sample. To put this into context, it is helpful to consider an example patient receiving 100 MME: this is the equivalent of a 40 kg child receiving 7.5 mg of hydrocodone every 4 hours for 48 hours, plus an additional 4 mg intravenous (IV) morphine. In addition to high or excessive amounts of opioid, recall that nearly two-thirds of patients with minor injury received an opioid medication, and more than three-quarters of children who received an opioid received more than 1 type of opioid. These numbers deserve further investigation. We are not aware of any guidelines that specify the cumulative total amount of opioid that is appropriate for a pediatric or adult trauma patient, as the thresholds of high and excessive exposure in this study were chosen somewhat arbitrarily based on the current recommended amount for adults with chronic pain.[27] Nevertheless, these findings suggest areas of future research and development of interventions for reducing opioid exposure, magnitude of opioid exposure, and co-administration of multiple opioids during hospitalization.

It is important to underscore the collaborative nature of this multisite research project. Not only does it describe practice patterns across institutions in the Midwestern region of the US, it also highlights instances in which hospitals can pool experience and practice to improve patient care at the other sites. For example, overall opioid exposure did not vary by study site, but 1 site had significantly lower log MME when compared with the other study hospitals. Patients at this hospital were younger than patients at the other study hospitals, but this particular hospital also had a multi-year, hospital-wide approach to reducing opioid use for all patient populations. Among other measures, their approach included scheduled administration of non-narcotic medication (acetaminophen, ibuprofen), an inpatient pain team consulting service that rounded on every patient, and the use of other nonpharmacologic methods to reduce pain. Other hospitals in the study had similar and innovative approaches to pain management. We recognize, however, that this research study was completed at high level trauma centers in major metropolitan areas, and many smaller or rural hospitals will not have the resources or personnel to implement these approaches. There are interventions that can be implemented in hospitals of all sizes, including, among other things, the use of non-narcotic adjuncts,[45,46] child life services,[47] and procedural distraction using electronic tablets or video games.[48,49] We hope that these study findings will encourage health care providers and hospital leaders to examine opioid administration patterns at their own institutions and to identify new methods of managing pain with fewer opioids.

Limitations

There are several limitations in this study. First, there were a number of patients who were ineligible for the study, refused to participate, or withdrew from the study. Findings may not be generalizable to all pediatric trauma patients, specifically those with intentional injury, moderate to severe traumatic brain injury, or significant previous mental health disorders. Similarly, all 4 study hospitals were located in the Midwest, and findings may not generalize to patients in other parts of the country or hospitals in rural areas. Second, data collection did not capture medication administered before arrival at the study hospital, nor did we collect information on non-narcotic medication or medication prescribed at discharge. Third, pain assessment is a critical component of pain management, but it is not included in the analyses. Initial pain assessment was documented inconsistently across the study sites and was available for only 55% of children in the study. Children who received opioids were more likely to have reported severe pain, but this result was not statistically significant. Fourth, the youngest children in the study were 10 years old due to study inclusion criteria, so we cannot generalize these findings to children under 10 years of age.

CONCLUSIONS

As rates of opioid use and misuse continue to climb, our nation faces a public health emergency to control exposure to opioids. Although many opioids are obtained illegally through diversion or other methods, a significant amount of opioid misuse begins with licit opioid use. Study findings indicate that most pre-adolescent and adolescent children were exposed to opioids when hospitalized for traumatic injury, and some children were exposed to excessive amounts of opioid during their hospital stay. No clear prescribing patterns were apparent, as prevalence and exposure varied by age, injury, acuity, and even study site. It is therefore critical for health care providers to develop a clear, long-term plan to address this crisis, and this effort begins with a better understanding of current prescribing patterns during hospitalization for pediatric trauma patients.

Author Contributions

Study conception and design: Pelaez, Davis, Spilman, Guzzo, Wetjen, Randell, Ortega, Pitcher, Kenardy, Ramirez

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Acknowledgement: The authors would like to thank the patients, families, and hospital staff who were involved in the research study. They would also like to specifically recognize the following individuals for their contributions to the study: Cassidy Branch (project management and manuscript review), Joseph Cavanaugh (data analysis), Vidya Chande (manuscript review), Darla Eastman (data interpretation and manuscript review), Javier Flores (data analysis), and Lisa Roth (project management).

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