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Multimodal Analgesia Reduces Opioid Requirements in Trauma Patients with Rib Fractures

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Abstract

Background: Rib fractures are common in trauma patients and are associated with significant morbidity and mortality. Adequate analgesia is essential to avoid the complications associated with rib fractures. Opioids are frequently used for analgesia in these patients. This study compared

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Conflicts of Interest

Michael Bosse reports stock ownership in an orthopaedic implant company and a grand from the DOD. Christopher Griggs reports American College of Emergency Physicians board membership and payment from Boston University for preparation of pain management and opioid prescribing. Daniel Leas reports consultancy for Restor3d and ownership in Pressio. Joseph R. Hsu reports consultancy for Globus Medical and personal fees from Smith & Nephew speakers' bureau. Michael Runyon reports research funding from Abbott Laboratories and Bristol-Myers Squibb. All other authors have nothing to declare.

the effect of a multimodal pain regimen (MMPR) on inpatient opioid use and outpatient opioid prescribing practices in adult trauma patients with rib fractures.

Study Design: A pre-post cohort study of adult trauma patients with rib fractures was conducted at a Level 1 trauma center before (PRE) and after (POST) implementation of an MMPR. Control charts were utilized to assess changes over time. Patients on long-acting opioids before admission and those on continuous opioid infusions were excluded. Primary outcomes were oral opioid administration during the first 5 days of hospitalization and opioids prescribed at discharge. Opioid data were converted to morphine milligram equivalents (MME).

Results: 653 patients met inclusion criteria (323 PRE, 330 POST). There was a significant reduction in the daily MME during the second through fifth days of hospitalization; and the average inpatient MME over the first 5 inpatient days (23 MME PRE vs. 17 MME POST, p=0.0087). There was a significant reduction in the total outpatient MME prescribed upon discharge (322 MME PRE vs. 225 MME POST, p=0.006). There was evidence for special cause variation in percent of gabapentanoid prescribed (higher POST), average MME while in the hospital (lower POST), and the percent of patients prescribed an opioid at discharge (higher POST). There was no special cause variation related to percent of patients receiving opioids in the hospital.

Conclusion: The implementation of an MMPR in patients with rib fractures resulted in significant reduction in inpatient opioid consumption and was associated with a reduction in the quantity of opiates prescribed at discharge.

Level of Evidence—Level IV Retrospective comparison

Brief Description:

Implementation of a multimodal pain regimen among patients with rib fractures (n=653) resulted in significant reduction in inpatient opioid consumption and a reduction in quantity of opioids prescribed at discharge.

Keywords

Opioid; Prescribing; Multimodal Pain Regimen

Background

Rib fractures are present in up to 10% of injured patients, frequently occurring in the setting of multi-system trauma. They are a major cause of acute and chronic pain, which can lead to decreased quality of life and delay in return to routine activities. Current management strategies rely on aggressive pain control, pulmonary hygiene, and early mobilization. Rib fractures are associated with a mortality rate of up to 10% and a complication rate of 13%, with pain contributing to the subsequent morbidity (1). Almost half of complications are pulmonary, including atelectasis or lobar collapse, pneumonia, aspiration, pulmonary embolism, pleural effusions and acute respiratory distress syndrome (ARDS) (2). In addition, in a retrospective review, patients sustaining blunt trauma with moderate to severe rib cage injuries were associated with higher rates of reevaluation and readmission (3). Pain control in these patients is an often complex and challenging endeavor, and yet is essential

to enhance recovery, optimize pulmonary hygiene and mitigate the worsening sequelae of disease.

Opioid analgesics remain the mainstay for pain management in patients with rib fractures despite multiple alternative analgesic options. In the United States, opioid prescriptions have nearly quadrupled from 1999 to 2014, without any measured difference in reported pain (4). Prescribing of opioids to opioid naïve patients has been shown to increase chronic opioid use five-fold compared with patients who did not receive opioids (5). The increase in opioid prescriptions has also been associated with a rapid rise in the number of drug overdoses. Opioid overdose is now the leading cause of injury-related death in over 30 states with more than 100 deaths per day in the United States (6).

In an effort to address this epidemic, many institutions have implemented the use of a multimodal approach to pain control relying on non-opioid analgesics including non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, skeletal muscle relaxants, alpha-2 agonists, mood stabilizers, neuropathic pain medications including gabapentinoids, N-methyl-D-aspartate (NMDA) receptor antagonists, topical analgesics as well as interventional therapies. Multimodal analgesia relies on synergistic combinations of medications to decrease dosing requirements and minimize adverse drug reactions for any single medication (7). In the setting of rib fractures, a multimodal approach has been suggested to address both pain control and respiratory performance(8). Numerous studies have addressed multimodal analgesia in the elective surgical patient population. Multimodal protocols have been less studied in the trauma population. The purpose of this study was to compare the effect of a multimodal pain regimen (MMPR) on inpatient opioid use and outpatient opioid prescribing practices in adult trauma patients with rib fractures.

Methods

Patient Population

A retrospective cohort study was performed to detect differences before and after the implementation of a multimodal pain regimen in accordance with STROBE guidelines. The Institutional Review Board approved the study. Adult (>/=18) patients admitted to Atrium Health Carolinas Medical Center with the diagnosis of rib fractures were eligible for inclusion in the analysis. Carolinas Medical Center is an American College of Surgeons-verified Level 1 trauma center located in Charlotte, North Carolina. Our trauma registry was queried to identify adult patients with rib fractures between July 2016-December 2016 (“PRE,” i.e.: before protocol implementation); and July 2017-December 2017 (“POST,” i.e. after protocol implementation). Patients with current pre-admission long-acting opioid medication use were excluded to minimize the impact of any preexisting opioid dependency. Patients on continuous opioid infusions were also excluded.

Multimodal Pain Regimen

A multidisciplinary committee of trauma surgeons and pharmacists designed and implemented an MMPR, including a pain control guideline and multimodal pain medication order set within the electronic health record (EHR) in May 2017. Prior to the initiation

of the MMPR, short and long-acting opioids were first line therapies in the adult pain management order set used to provide initial care. Long-acting opioids have been associated with increased risk of injury, addiction and overdose and are no longer being used routinely. The MMPR implemented includes scheduled acetaminophen, ibuprofen, gabapentin, methocarbamol, and/or topical lidocaine as first line agents (Figure 1). A combination of short acting opioids in both IV and PO form are used as second line options. These medications were ordered unless there were individual contraindications.

Data Collection and Outcomes

Patient demographics, including age, gender, Injury Severity Score (ISS), and Chest Abbreviated Injury Score (Chest AIS) were compared pre- and post-MMPR implementation. The primary outcome was inpatient opioid administration in morphine milligram equivalents (MME) during the first 5 days of hospitalization. Secondary outcomes included use of NSAIDs and gabapentinoids, frequency of receiving an opioid prescription at discharge, MME prescribed at discharge, hospital length of stay (LOS), need for intensive care unit (ICU) admission and ICU LOS, need for mechanical ventilation and duration of mechanical ventilation, incidence of acute kidney injury (AKI) and incidence of upper gastrointestinal bleeding (UGIB). Inpatient opioid use was manually extracted from the EHR and converted to morphine milligram equivalents (MME). The opioids prescribed on discharge were also recorded and converted to MME. To identify any increase in non-steroidal anti-inflammatory complications, the incidence of AKI and UGIB were identified using existing fields in the trauma registry. In addition, a subset analysis was done on patients with isolated rib fractures, defined as greater than one rib fracture and an Abbreviated Injury Scale (AIS) score of <=2 for areas outside the chest.

Data Analysis

Continuous variables were checked for normality graphically using histograms. Descriptive statistics were reported (counts and percentages for categorical variables, means and standard deviations for normally distributed continuous variables, medians and interquartile range for non-normal continuous variables).

We used control charts to assess changes in ISS, GCS, percent of patients that received a gabapentanoid, percent of patients that received an opioid in the hospital, the average MME, and the percent of patients that were prescribed an opioid at discharge over time(9,10). The pre-MMPR implementation period was used to calculate the center line and determine special cause variation in the post-implementation period. The July-December time periods were originally chosen for the pre and post periods to account for seasonality differences that could have affected the intervention. Points that qualify for special cause variation (as specified per the Institute for Healthcare Improvement) have been highlighted in red.

Differences between patients pre- and post-MMPR were also assessed using chi-square tests (Fisher’s exact test in the case of small cell counts) for categorical variables. T-tests or Wilcoxon rank-sum tests were used for continuous normally or non-normally distributed data, respectively. For MME prescribed at discharge, a logarithmic transformation was applied prior to statistical analysis to achieve normality (descriptive statistics presented in

tables and results are in original scale). SAS software version 9.4 was used for all analyses (SAS Institute Inc., Cary, NC, USA). All statistical tests were two-tailed and p-values less than 0.05 were considered statistically significant.

Results

During the study period, a total of 820 patients were assessed for eligibility based on presentation during either the PRE or POST study period with the presence of rib fractures. Mechanisms of injury were broad with the majority secondary to blunt trauma. 167 patients were excluded; 158 for continuous opioid infusions and 9 for chronic opioid use prior to admission.A total of 653 patients (323 PRE, 330 POST) met inclusion criteria for review. Of note, 4 patients in the PRE group and 5 patients in the POST group were excluded from data collection for pre-admission chronic opioid use. The majority of patients were male with approximately half of patients between 18–55 years old (Table 1). The most common injury mechanisms were motor vehicle crash and falls, and the injury mechanisms did not change significantly over the two time periods. Although the specific concomitant injuries and number of rib fractures were not tracked in this study, the ISS and Chest AIS were not significantly different over the two time periods. The admission lactate was also similar between the two time periods. The hospital LOS, ICU admission rate, ICU LOS, rate of mechanical ventilation and number of ventilator days were unchanged after implementation of MMPR.

There was no evidence for special cause variation in the for change in mean ISS or GCS in the post implementation period (Supplemental Figure 1a–b). Therefore, we did not adjust for ISS or GCS when analyzing the other outcomes of interest. There was evidence for special cause variation for percent gabapentanoid prescribed (higher in the implementation period) (Figure 2a). There was no evidence for special cause variation for the percent of patients receiving an opioid in the hospital. However, the 2 and 3 upper control limit lines cannot surpass 100%, which may have limited our ability for detection (Supplemental Figure 1c). Among patients prescribed inpatient opioids, there was evidence for special cause variation in the post-implementation period for average MME (decreased in post-implementation) (Figure 2b). Finally, there was evidence for special cause variation for percent of patients prescribed an opioid at discharge (higher in the post implementation period) (Figure 2c).

Implementation of the MMPR reduced daily inpatient opioid administration during the first five days of hospitalization (23 MME PRE vs. 17 MME post, p=.007) (Table 2). There was a statistically significant increase in percentage of patients receiving inpatient opioids during their first five inpatient days after the MMPR implementation (291 patients, 90.1% PRE vs 315, 95.5% POST, p=0.008). However, there was a statically significant reduction in MME during each of days two through five of hospitalization (Table 2). At the time of discharge, there was no significant difference in the number of patients prescribed opioids (196 patients, 60.7% PRE vs. 220 patients, 66.7% POST, p=0.11) (Table 2). However, in patients who received opioids on discharge, there was a statistically significant reduction in the daily encounter MME (the daily quantity of opioids if taken as prescribed) for each prescription (median: 45, IQR (30.0–54.9) PRE MME vs. median: 32.1, IQR (24–49) POST

MME, p=0.02) (Table 2). There was a corresponding decrease in total MME prescribed after the implementation of the MMPR.

A sub-group analysis was conducted on patients admitted with isolated rib fractures (an extra-thoracic AIS score of <=2). Within this subset, there were a total of 368 patients (167 PRE vs. 201 POST). These patients were also mostly men, with a similar age distribution, and with similar ISS and Chest AIS before and after the MMPR implementation (Table 3). Similar to the overall group, the hospital LOS, ICU admission rate, ICU LOS, rate of mechanical ventilation and number of ventilator days were unchanged after implementation of MMPR. When comparing isolated rib fracture patients, there was no statistically significant change in the overall median MME received during the first five days of admission (18 PRE vs. 16 POST, p=.11). However, when patients who received no inpatient opioids on days 1 through 5 were excluded, there was a statistically significant decrease in opioid consumption on inpatient days 2 and 3 (Table 4). At the time of discharge, there was no difference in the frequency of opioids prescriptions between the two groups (111 patients, 66.5% PRE vs. 137 patients, 68.2% POST, p=0.73). In this subgroup, there was a significant reduction in the total MME prescribed at discharge (median: 315.0, IQR (210–488) MME PRE vs median: 225, IQR(180–375) MME POST, p=0.03) (Table 4).

Although there was no effect on the use of NSAIDS, there was a statistically significant increase in use of gabapentinoids during the hospitalization after the initiation of the MMPR. In all rib fracture patients, there was a statistically significant increase in gabapentin after MMPR implementation (218, 67.5% PRE vs 282, 85.5% POST, p <.0001) (Table 1). In the subgroup-analysis of isolated rib fractures, there was also a statistically significant increase in gabapentinoid use (117, 70.1% PRE vs 172, 85.6% POST, p=0.0003) (Table 3). Of note, with the statistically significant increase in gabapentin use after the MMRP implementation, there were no changes in readmission or unplanned ICU admission rates.

Discussion

In trauma patients with rib fractures, implementation of an MMPR significantly reduced inpatient opioid consumption and outpatient opioid prescriptions. While the use of NSAIDS was unchanged by the MMPR implementation, the use of gabapentinoids was significantly increased. This is one of only two studies to examine the effects of a multimodal pain regimen on inpatient and outpatient opioid use in patients with rib fractures.

Management of pain in trauma patients with rib fractures requires a careful balance of providing relief of suffering and optimizing pulmonary performance to decrease complications while limiting the use of opioids and minimizing the side effects of non-opioid analgesics. The opioid epidemic has necessitated the development of alternative strategies to managing rib fracture pain. Multimodal pain regimens, regional and neuraxial analgesia, non-pharmacologic therapies and operative stabilization have all been investigated as possible therapeutic interventions.

In the current study, we saw a significant increase in the use of gabapentin after the implementation of our MMPR. Gabapentin is a structural analogue of γ-aminobutyric

acid (GABA), although it does not appreciably interact with GABA receptors(11). Gabapentin inhibits the $\alpha_2\delta$ subunit of voltage-gated calcium channels in the brain and reduces presynaptic release of excitatory neurotransmitters that are associated with pain perception(11). Gabapentin is labeled for postherpetic neuralgia and is used in an off-label fashion for neuropathic, post-operative, and chronic pain.

Gabapentin is associated with neurologic and respiratory adverse drug reactions and requires dose reduction in the setting of renal impairment. In December 2019, the FDA(12) warned of serious, life-threatening, and fatal respiratory depression in patients receiving gabapentinoids. This risk may be increased with concomitant use of opioids and other central nervous system depressants, conditions such as chronic obstructive pulmonary disease, and in elderly patients. Furthermore, gabapentin misuse and withdrawal have been described and must be considered as potential complications, especially in at-risk populations(13,14). As a result of these potential risks, the use of gabapentin in patients with multisystem trauma should be done with caution.

While there are more studies investigating the use of gabapentin in surgical patients, there remains limited data on its benefit in the trauma population. A meta-analysis of pre-operative gabapentin administration to patients in the setting of abdominal, orthopedic, gynecological, thyroid, breast, prostatectomy, caesarean section and thoracotomy surgery was associated with lower post-operative opioid use(15). However, in critically ill patients with rib fractures, there was no difference in numeric pain scores, oxygen requirement, or opioid consumption between gabapentin and placebo(16).

NSAIDs are another non-opioid analgesic option for managing trauma patients with rib fractures. Complications from NSAIDs are considerable and include gastrointestinal and renal adverse drug reactions. Gastrointestinal complications range from mild dyspepsia and heartburn to life threatening bleeding and perforation. Consistent use of NSAIDS for greater than 4 days is associated with increased risk of severe complications including bleeding, clinically significant ulceration and perforation(17). In our study, no cases of clinically significant upper gastrointestinal hemorrhage were identified either before or after implementation of the MMPR.

NSAIDs decrease prostaglandin synthesis and therefore affect intraglomerular hemodynamics by decreasing the ability of the afferent arteriole to vasodilate(18). As, such, renal blood flow is altered. NSAIDs are also associated with interstitial nephritis(18). Risk factors for drug-induced kidney disease include older age and chronic kidney disease, with a 3–4 fold increased risk of worsening renal function for patients with abnormal baseline renal function who use ibuprofen(19). Given the advanced age of many patients with rib fractures, the risk of high-dose NSAID use remains significant. Despite 30% of our patients being >65 year of age, the rate of acute kidney injuries was low and remained unchanged by the implementation of the MMPR. However, it is possible that some of the adverse effects of NSAIDS may have been delayed and unrecognized on initial admission.

There have been conflicting results for the use of non-opioid analgesics in patients with rib fractures. Lidocaine patches have been shown to have minimal impact on pain control

in a randomized controlled trial when compared with standard therapy (20). However, some studies examining the effect of non-opioid medications in patients with rib fractures have demonstrated success in minimizing opioid use. In one small retrospective cohort study, scheduled intravenous (IV) ibuprofen was associated with decreased opioid use and decreased hospital length of stay(21). Another retrospective cohort study showed IV ketorolac was associated with a decreased incidence of pneumonia in patients with rib fractures(22). These studies did not explore the impact of a multimodal pain protocol on the quantity of opioids prescribed at the time of discharge. In addition, the studies did not evaluate the effect of multimodal regimens on adverse drug reactions, including stress ulcer bleeding and acute kidney injury, or polypharmacy effects, such as unplanned ICU admission.

While the effects of multimodal pain regimens in elective surgical patients has been well documented, their impact in trauma patients is less clear. Several studies note decreased opioid usage after implementation of a multimodal regimen. In a recent retrospective study of more than 6000 trauma patients over an 8-year period, the authors found a significant reduction in inpatient opioid consumption as well as the quantity of outpatient opioid prescriptions in patients with at least one rib fracture(23). While this is the only study to date to examine the effect of a multimodal pain regimen on inpatient and outpatient opioid use in rib fracture patients, this study does have notable limiting factors. At the start of the study, the opioid epidemic came into national focus, substantially changing the culture regarding opioid use, resulting in both providers and patients having a better understanding of the dangers of opioid use. Thus, provider and patient awareness regarding the opioid epidemic were likely a significant confounding factor that may have obscured the true impact of a multimodal regimen on inpatient and outpatient opioid use in that study. In addition, scheduled tramadol, an opioid derivative, was used as part of the MMPR in this study, raising concerns for the significant opioid exposure in the MMPR itself, which may have increased the total inpatient MME requirement. Indeed, the outpatient prescription rate of tramadol increased significantly during the duration of the study. This would not only expose patients to the risk of tramadol addiction, abuse, and misuse, but also to other adverse effects specified in the US Boxed Warning for this agent(24). These include, but are not limited to, life-threatening respiratory depression, complex effects resulting from interactions with drugs affecting cytochrome P450 isoenzymes, and potential for profound sedation, coma, and death when used concomitantly with benzodiazepines or other CNS depressants.

In a smaller retrospective cohort study of critically ill trauma patients, the authors found a significant decrease in inpatient opioid use following MMPR implementation (25). Additionally, they found a corresponding decrease in inpatient opioid consumption with each successive number of pharmaceutical adjuncts used. Interestingly, Hamrick, et al.(25) also found that a majority of patients were prescribed a higher daily opioid dose on discharge than they had used during the preceding 24 hours of hospitalization, suggesting opportunities for customizing prescriptions to more closely match inpatient opioid requirements. However, this study was a small heterogenous group of polytrauma patients, which represents quite a variable spectrum. There was a significant difference in injury mechanisms pre and post multimodal regimen implementation. The researchers also

compared time periods two years apart, which again raises the possibility that changes in patient and provider awareness of the growing opioid epidemic during the study, distorted the actual impact of the multimodal regimen.

In the current retrospective study, we evaluated a brief time period before and after the implementation of an MMPR to minimize the impact of changes in provider and patient perspective over the course of the study. Like the previous retrospective studies, we did see a statistically significant reduction in the quantity of opioids administered during the inpatient setting for polytrauma patients with rib fractures. However, we did not observe the same reduction in inpatient opioid consumption in patients with isolated rib fractures. We did see a reduction of inpatient MME for days 2 and 3 in isolated rib fracture patients who required inpatient opioids. It is unclear whether the lack of a statistical difference in the inpatient MME of this subgroup was related to an overall lower injury burden, as suggested by the lower ISS, and thus decreased opioid requirements, or the lower power of this subset analysis. Notably, after the implementation of the MMPR, there was no change in NSAID use, suggesting that some individual elements of MMPR were already being used prior to the protocol. There was a statistically significant increase in gabapentin use after the implementation of the protocol, which may have contributed to the reduction in the opioid consumption during the study period. However, we cannot conclude that this alone was responsible for the reduction in MME. Consideration must also be given to the risk-benefit profile of this agent and its place in pain management closely scrutinized given its potential for adverse drug reactions. There was a significant decrease in the MME prescribed at discharge to patients after implementation of the MMPR, although no difference was seen in percentile of patients prescribed opioids on discharge. This was also true for the subset of isolated rib fracture patients.

Limitations of this study include its retrospective design. While exposure to NSAIDs and gabapentin were assessed, dosing strategies and adherence to the MMPR were not. We also do not have data regarding the use of neuraxial or regional anesthesia techniques or surgical stabilization of the rib fractures in our patient population, which may impact the inpatient and outpatient opioid requirement. However, given the stability of our performance of regional anesthesia and surgical stabilization over time as well as their use in the minority of our total rib fracture patients, the effect on our outcomes is likely to be relatively small. Given the variable reasons for opioid infusions for mechanically ventilated patients other than pain control, patients requiring opioid infusions were excluded. In addition, this exclusion likely eliminated some of the moderate traumatic brain injury (TBI) patients and all severe TBI patients as these patients were intubated and supported with opioid infusions as part of their TBI therapy. This occurrence can be seen in the median admission GCS of 15 in both PRE and POST groups. This exclusion eliminated the falsely low estimate of oral opioid consumption in these patients, but also excluded many of the more severely injured patients. This exclusion did minimize the effect of TBI on the perception and management of rib fracture pain. Another limitation of our study is the lack of information on number of ribs fractured and characteristics of the rib fractures. While this information was beyond the scope of our review, we do know that the chest AIS was similar PRE and POST MMPR, suggesting no significant change in the severity of the chest injuries over the study period. Lastly, the development of the MMPR at our institution was largely in

response to the growing opioid epidemic. It is possible that providers' attitudes regarding opioid prescriptions changed during the study period and that this contributed to the observed decrease in outpatient opioid prescriptions. The majority of inpatient orders and discharge prescriptions were written by rotating residents and trauma advanced practice providers. Although the use of the MMPR order set was advised and encouraged, rotating personnel could have contributed to variability in compliance with the use of the order set. While the Hawthorne effect could be responsible for some participant bias and enhanced compliance with MMPR order set usage, this effect on provider behavior was likely modest given the frequent order set modifications and guideline development within our trauma program. Since the MMPR order set was imbedded within our trauma admission order sets, its use was likely robust as it became the least labor-intensive method to enter orders, including pain medication. It is also unclear if the North Carolina Strengthen Opioid Misuse Prevention (STOP) Act legislation, passed in 2017, had any impact on our results (26). This legislation limits opioid prescriptions to a 5-day supply after injury or trauma and 7-day supply after surgical procedures. One might postulate that the decrease in inpatient opioid use and outpatient prescriptions were due to this legislation, the implementation of this MMPR, or a combination of both.

The impact of the opioid epidemic cannot be overstated. While we search to find solutions to minimize opioid consumption, we must also refrain from overly optimistic, simplistic solutions without evidence of their effectiveness. MMPRs have become a common solution to minimize opioid consumption in most trauma centers, despite minimal evidence of the effectiveness in doing so. When establishing guidelines and protocols, as important as the implementation phase is the subsequent review of the effectiveness. Adherence to and assessment of outcomes after a new guideline has been implemented is crucial to a strong performance improvement program. Our intent was to review an institutional performance improvement initiative in the form of an MMPR. In our review, we have concluded that our MMPR did result in a statistically significant reduction in both inpatient opioid consumption and outpatient prescription quantity. In addition to continued use of the MMPR, we will continue to search for which combinations of which medications are the most effective and to find mechanisms to mirror an outpatient prescription with a patient's inpatient opioid requirement. It is unknown whether these results are generalizable beyond level 1 trauma centers or at other hospitals or regions with different ongoing interventions or legislation surrounding opioid prescribing. Next steps should include dissemination of this intervention to other settings to determine generalizability.

In trauma patients with rib fractures, implementation of an MMPR significantly reduced inpatient opioid consumption and outpatient opioid prescriptions. We are witnessing an advance in the use of various non-opioid analgesics as well as procedural techniques to aid in the treatment of pain. Future efforts will likely be directed at expanding regional and neuraxial analgesia techniques, non-pharmaceutical adjunct usage, and developing a tool to determine the appropriate quantity of opioids for discharge, using the patient's inpatient requirement as a guide. With a growing number of options now available for pain control, it is crucial to determine which methods, and in which combinations, are most effective at reducing pain, with the least complications and in the most cost effective way, as we continue to treat rib fractures in trauma patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Conflicts of Interest and Source of Funding:

Michael Bosse reports stock ownership in an orthopaedic implant company and a grand from the DOD. Christopher Griggs reports American College of Emergency Physicians board membership and payment from Boston University for preparation of pain management and opioid prescribing. Daniel Leas reports consultancy for Restor3d and ownership in Pressio. Joseph R. Hsu reports consultancy for Globus Medical and personal fees from Smith & Nephew speakers' bureau. Michael Runyon reports research funding from Abbott Laboratories and Bristol-Myers Squibb. This work was supported in part by a cooperative agreement (CE14-004 Award Number CE002520) from the Centers for Disease Control and Prevention and by an internal grant from the Carolinas Trauma Network Research Center of Excellence. Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention

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ADULT TRAUMA ADMISSION NON-CRITICAL CARE

Analgesics: Opioids

- ☐ Oxycodone
  - ☐ 2.5 mg oral q4h PRN **mild pain (1-3)**
  - ☐ 5 to 10 mg oral q4h PRN **moderate pain (4-7)**, see Order Comments (start at 5mg and if after 30 minutes pain score does not decrease by 1, may give additional 5mg. For subsequent doses, may provide 10mg if pain score 5 or greater. May provide for pain score greater than 7 if requested by patient in place of severe pain medication. Document request as a MAR comment. MAX 10mg q4hr.)
- ☐ ADULT PHARM PCA HYDROmorphone (SUB)*
- ☐ Hydromorphone
  - ☐ 0.25mg IV q2h PRN **moderate pain (4-7)**, see order comments (UNABLE TO TOLERATE ORAL MEDICATION: 2nd option if patient unable to tolerate oral medication. May provide for pain score greater than 7 if requested by patient in place of a severe pain medication. Document request as a MAR comment.)
  - ☐ 0.25 to 0.5 mg IV q2h PRN **severe pain (8-10)**, see order comments (start at 0.25mg and if after 30 minutes pain score does not decrease by 1, may give additional 0.25mg. For subsequent doses, may provide 0.5mg if pain score 8 or greater. MAX 0.5mg q2hr.)

Analgesics: Non-Opioids

NOTE TO PROVIDER: Select ONLY one nonsteroidal anti-inflammatory drug (NSAID)

- ☐ ibuprofen (USE WITH CAUTION IN PATIENTS ON NEPHROTOXIC MEDICATIONS)
  600 mg oral q6h, with food
  800 mg oral q6h, with food
- ☐ ketorolac
  30mg IV q6h x 5 days (weight 50kg or greater AND age less than 65 years)
  15mg IV q6h x 5 days (weight less than 50kg OR age 65 years or greater)
- ☐ acetaminophen (DO NOT COMBINE WITH OTHER ACETAMINOPHEN CONTAINING PRODUCTS)
  650mg oral q6h
  650mg rectal q6h
- ☐ gabapentin
  300mg oral q8h
- ☐ methocarbamol
  500mg oral q8h

Figure 1.
Revised MMPR Orderset

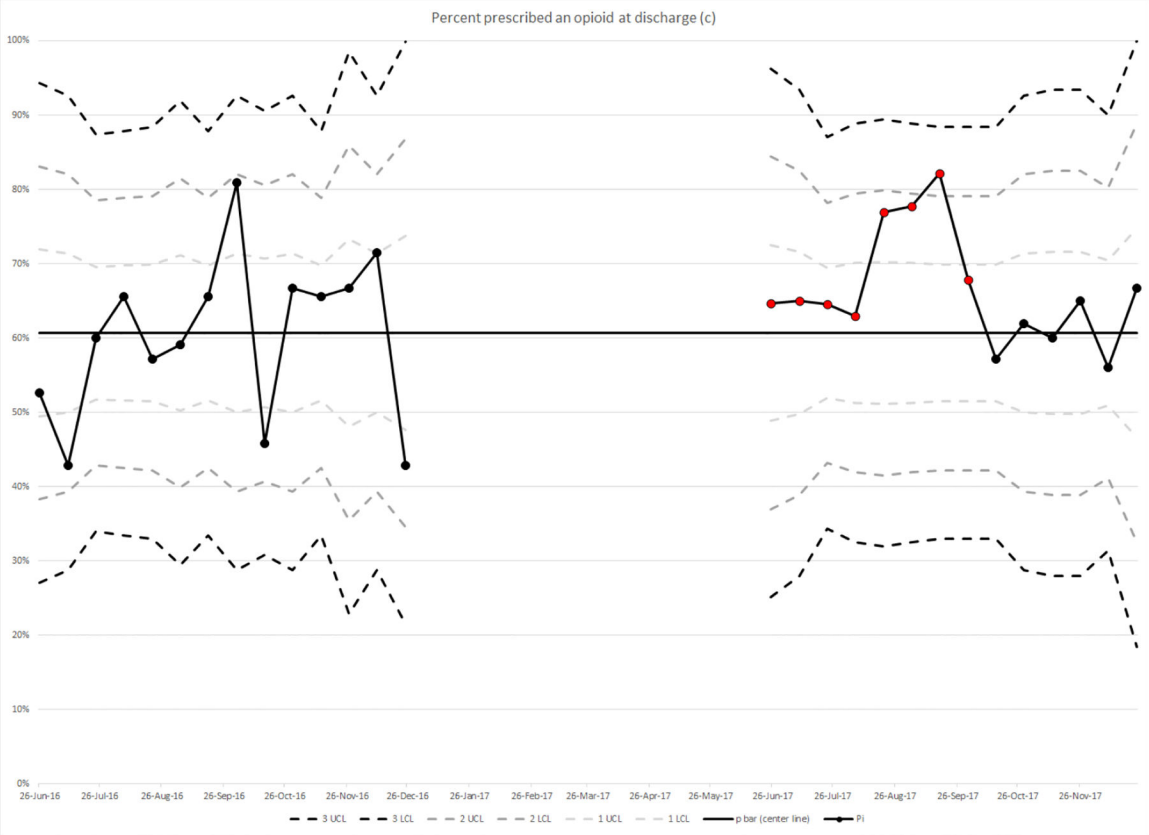

Figure 2.

Control Charts for percent of patients receiving a gabapentinoid (a), average MME (b), and percent of patients prescribed an opioid at discharge (c)

Rules for special cause variation include: 1) 1 point outside 3 sigma limit; 2) 6 consecutive points increasing or decreasing; 3) 8 or more consecutive points above or below centerline; 4) 2 out of 3 points in outer third; 5) Hugging – 15 points in inner third. Special cause variation is shown in red.

Table 1.

Patient Demographics and Clinical Outcomes Before and After MMPR Implementation

	Pre MMP N=323	Post MMP N=330	P-value
Male, n (%)	233 (72.1)	221 (67.0)	0.15
Age (years), n (%)			
18–55	180 (55.7)	159 (48.2)	0.11
56–65	57 (17.6)	60 (18.2)	
66+	86 (26.6)	111 (33.6)	
Mechanism of injury			0.56
Fall	84 (26.01)	104 (31.52)	
Motorcycle crash	38 (11.76)	33 (10.00)	
Motor vehicle crash	143 (44.27)	143 (43.33)	
Other	44 (13.62)	38 (11.52)	
Pedestrian struck	14 (4.33)	12 (3.64)	
Injury Severity Score (median, IQR)	14 (9–19)	13 (9–17)	0.08
Chest Abbreviated Injury Scale (median, IQR)	3 (2–3)	3 (2–3)	0.83
ED GCS (Median, IQR)	15 (15–15)	15 (15–15)	0.08
ED lactate (Median, IQR)	1.99 (1.26–2.93)	1.89 (1.22–2.81)	0.50
Inpatient NSAID use, n (%)	240 (74.3)	225 (68.2)	0.08
Inpatient Gabapentinoid use, n (%)	218 (67.5)	282 (85.5)	<.0001
Hospital Length of Stay (days), median (IQR)	3 (2–6)	4 (2–7)	0.41
Admitted to ICU, n (%)	138 (42.7)	140 (42.4)	0.94
ICU Length of Stay (median, IQR)	3 (2–4)	2 (2–4)	0.99
Mechanical Ventilation, n (%)	32 (9.9)	22 (6.7)	0.13
Ventilator Days (median, IQR)	2 (1–9)	2 (1–5)	0.48
Incidence of AKI, n (%)	3 (0.9)	1 (0.3)	0.63
Incidence of Upper GI Bleed, n (%)	0 (0)	0(0)	NA
Readmission, n (%)	4 (1.2)	4 (1.2)	1
Unplanned admission to ICU, n (%)	5 (1.6)	4 (1.2)	0.75
SBP (6 missing), mean (STD)	133 (26)	134 (25)	0.57
Shock Index (6 missing), median (IQR)	0.68 (0.56–0.79)	0.65 (0.55–0.78)	0.39

Table 2.

Patient opioid exposure before and after MMPR Implementation

	Pre MMP	Post MMP	P-value
Patients who received inpatient opioids, n (%)	291 (90.1)	315 (95.5)	0.008
Inpatient MME, all patients			
Day 1 (N=653), median (IQR)	12 (2–27)	10 (4–20)	0.91
Day 2 (N=619), median (IQR)	30 (8–53)	21 (8–45)	0.004
Day 3 (N=506), median (IQR)	30 (8–64)	19 (5–45)	0.0006
Day 4 (N=415), median (IQR)	30 (8–62)	19 (4–38)	0.0001
Day 5 (N=318), median (IQR)	30 (8–60)	15 (0–45)	0.004
Daily MME Administration over First 5 Hospital Days	23 (9–47)	17 (7–35)	0.007
Inpatient MME, patients who received any opioids during first 5 inpatient days			
Day 1 MME (N=606), median (IQR)	14 (4–29)	11.50 (5–22)	0.28
Day 2 MME (N=586), median (IQR)	32.5 (15–57)	22.50 (8–45)	0.0003
Day 3 MME (N=484), median (IQR)	36 (9–68)	20.5 (7–45)	<0.0001
Day 4 MME (N=402), median (IQR)	30 (14–64)	22.5 (5–38)	<0.0001
Day 5 MME (N=145), median (IQR)	30 (8–60)	15 (0–45)	0.002
Patients Prescribed Opioids at Discharge, n (%)	196 (60.7)	220 (66.7)	0.11
Total MME Prescribed at Discharge (N=416), Median (IQR)	322 (210–450)	225 (180–375)	0.007
Daily encounter MME prescribed at discharge (N=416), Median (Q1-Q3)	45 (30–55)	32.1 (24–49)	0.02

Table 3.

Patient Demographics and Clinical Outcomes Before and After MMPR Implementation in patients with isolated rib fractures (extra-thoracic AIS <=2)

	Pre MMP N=167	Post MMP N=201	P-value
Male, n (%)	116 (69.4)	135 (67.2)	0.64
Age (years), n (%)			
18–55	79 (47.3)	82 (40.8)	0.44
56–65	31 (18.6)	44 (21.9)	
66+	57 (34.1)	75 (37.3)	
Injury Severity Score (median, IQR)	10 (9–14)	10 (9–14)	0.61
Chest Abbreviated Injury Scale (median, IQR)	3 (3–3)	3 (3–3)	0.36
Inpatient NSAID use, n (%)	136 (81.4)	149 (74.1)	0.09
Inpatient Gabapentinoid use, n (%)	117 (70.1)	172 (85.6)	0.0003
Hospital Length of Stay (days), median (IQR)	3 (2–4)	3 (2–5)	0.45
Admitted to ICU, n (%)	62 (37.1)	70 (34.8)	0.65
ICU Length of Stay (median, IQR)	2 (2–4)	2 (2–3)	0.50
Mechanical Ventilation, n (%)	8 (4.8)	5 (2.5)	0.23
Ventilator Days (median, IQR)	2 (1–8)	3 (2–4)	0.51
Readmission, n (%)	2 (1.2)	3 (1.5)	1
Unplanned admission to ICU, n (%)	1 (0.6)	1 (0.5)	1

Table 4.

Patient opioid exposure before and after MMPR Implementation in isolated rib fractures

Isolated rib fractures (extra-thoracic AIS <=2)			
	Pre MMP	**Post MMP**	**P-value**
Patients who received inpatient opioids, n (%)	154 (92.2)	191 (95.0)	0.27
Inpatient MME, all patients			
Day 1 (N=368), median (IQR)	10 (2–23)	10 (4–20)	0.61
Day 2 (N=353), median (IQR)	23 (8–53)	23 (8–45)	0.19
Day 3 (N=279), median (IQR)	30 (4–70)	15 (4–40)	0.013
Day 4 (N=221), median (IQR)	25 (5–62)	18 (0–33)	0.013
Day 5 (N=159), median (IQR)	23 (1–60)	15 (0–45)	0.08
Daily MME Administration over First 5 Hospital Days	18 (8–46)	16 (7–33)	0.11
Inpatient MME, patients who received inpatient opioids			
Day 1 MME (N=345), median (IQR)	12.5 (4–27)	11.5 (5–20)	0.97
Day 2 MME (N=334), median (IQR)	26.5 (11–53)	22.5 (8–45)	0.09
Day 3 MME (N=267), median (IQR)	30 (8–75)	18.1 (4–45)	0.005
Day 4 MME (N=215), median (IQR)	28.8 (8–64)	20 (0–30)	0.008
Day 5 MME (N=155), median (IQR)	22.5 (4–60)	15 (0–45)	0.07
Patients Prescribed Opioids at Discharge, n (%)	111 (66.5)	137 (68.2)	0.73
Total MME prescribed at discharge (N=248), Median (Q1-Q3)	315.0 (210–488)	225.0 (180–375)	0.03
Daily encounter MME prescribed at discharge (N=248), Median (Q1-Q3)	45.0 (30–56)	32.1 (23–48)	0.13