Pain Management in Acute Fracture Care

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Abstract: The management of pediatric and adolescent pain continues to evolve. Similar to the adult population, pain in children is a complex process modulated by both physiologic and psychological factors. It is essential for the orthopaedic clinician who manages pain in the acute setting to understand the medical aspects of pain control in the larger context of the opioid crisis which has changed the manner in which pain management is delivered. An understanding of options for delivering analgesia is particularly important in the setting of acute fracture management. Utilization of anti-inflammatory medications, diversion techniques, and regional anesthesia are integral to management in the emergency room, preoperatively, intraoperatively, and postoperatively. A multi-faceted approach is essential to achieve successful pain management.

Key Concepts:

- Recent operational delays in fracture care delivery (in order to test for COVID-19) have necessitated increased attention to pediatric pain management.
- The opioid crisis is a complex problem that affects both the parents and the child.
- A comprehensive analgesic strategy should be used for this population in the emergency room, intraoperatively and postoperatively.
- Compartment syndrome manifests differently in pediatric patients, and analgesic modalities should be chosen which do not mask its development.

Introduction

A significant amount of orthopaedic literature has concentrated on indications for treatment and surgical techniques, and patient satisfaction (both short- and long-term) is largely tied to management of pain. At the same time, providers must be judicious in their utilization of pain medications in the context of the opioid crisis. Most recently, the management of pain in pediatric and adolescent patients who suffer acute fractures continues to evolve; for instance, COVID-19 has shifted the type of trauma which is seen and speed with which it is treated.

The purpose of this paper is to review pain management strategies for acute fracture care in the pediatric population in the setting of a national opioid crisis. An understanding of pediatric pain presentation can guide the clinician in regard to pain management in the emergency room, pre-operatively, intraoperatively, and post-operatively. Multiple analgesic modalities will be reviewed, with a particular concentration on regional anesthesia and non-opioid options.

Recent Challenges

Raitio et al. examined pediatric orthopaedic trauma volume in Finland during the COVID-19 pandemic and noted a 32% drop in lower limb trauma.[1] In Italy, Baxter et al. reported a 33% drop in overall pediatric trauma admissions, yet saw a concurrent increase in supracondylar humerus injuries due to fall from play

structures.[2] Similarly, Memeo et al. saw a 22% increase in pediatric fractures (particularly the upper limb), even with a 78% overall decrease in pediatric emergency room visits.[3] In the United States, Bram et al. found a 2.5-fold decrease in pediatric fracture volume with a shift toward home-based and/or bicycle trauma as opposed to sports injuries.[4] This lack of physical activity, particularly sports,[2] is most pronounced amongst adolescents.[5] There has also been an increased incidence of fractures occurring due to non-accidental trauma.[6.] Orthopaedic clinicians must be vigilant in identifying presentations/fracture patterns that raise suspicion of non-accidental injuries.

In addition, the speed with which care is delivered has slowed as a negative COVID test is required in many institutions prior to intervention and magnifies established delays in analgesic administration to pediatric patients with long bone fractures that existed before the pandemic.[7] Beyond immobilization, the following can provide prolonged pain relief in the setting of treatment delay: intravenous pain medications, distraction modalities, and regional anesthetic techniques. Pain management strategies in the context of COVID-19 treatment delays have nicely expanded beyond ketamine and fentanyl.[12] A multi-modal/multi-team approach that integrates safe clinical practices with prolonged analgesia is critical in the current healthcare climate. Turner et al. examined 81 pediatric patients who received ultrasound guided femoral nerve blocks and found they had longer duration and improved quality of analgesia compared to those receiving systemic medication alone.[8] Other studies have used regional anesthesia (hematoma blocks,[9] forearm nerve blocks,[10] infraclavicular blocks for forearm fractures[11]) and found excellent pain relief with less utilization of ED time and resources.

The Opioid Crisis

According to the CDC,[13] from 1999–2018, nearly 750,000 individuals died from a drug overdose, with 70,000 deaths in 2018 alone. **Drug overdose represents the leading cause of injury-related death in the United States, and nearly 66% percent of deaths involve opioid-related drugs.** The impact on the pediatric population is multidimensional; in a household with addicted family members, children may ingest the medications (accidentally or intentionally) leading to morbidity and mortality, misuse can occur in pregnancy (which can affect development after birth), parenting may be impaired leading to lack of supervision and/or attachment, financial resources may be strained, and/or risk of foster care placement may be increased.[14.] The over-prescription of opioids to children after their own procedures may play a role in fueling the crisis by increasing the circulation of opioids outside of the hospital setting. Delamerced et al. found that the majority of injured patients were overprescribed opioids which were subsequently stored in unsecure locations with no plan to dispose of unused doses.[15] Patient and provider education (with utilization of prescription databases) can avoid overprescription and decrease utilization. Examples of combined pediatric/adult strategies include provision of drug disposal strategies at the time of discharge for unused medications.[16]

Many believe the seeds of this crisis were planted in 2001 when the Joint Commission's Pain Management Standards helped to popularize pain as the "5th vital sign."[17] For many providers, this represented a turning point in the management of pain with increasing utilization of opioid medications. In response, the Joint Commission in 2011 recommended that other nonprescription-based strategies should play a role in pain management, including physical therapy, relaxation therapy, and cognitive behavioral therapy.[17] As a follow-up in 2016, the Joint Commission identified three areas to concentrate on in order to allow for judicious pain management practices: acute pain in the hospital, chronic pain, and recognition, management, and/or referral for patients with addiction.

Multiple strategies have been utilized to decrease opioid usage in the adult population. Ballreich et al. modeled mitigation strategies and found that projected mortality decreases were 0.3% with prescribing reductions, 15.4% with naloxone distribution, and 25.3% with addiction

treatment expansion.[18] Yet, a continual reflection on implemented strategies is critical as per Chen et al. who found that the current broad range of interventions (such as prescription monitoring programs) would only lead to a 2.3% decrease in overdose mortality.[19] If there is a concern for either drug-seeking behavior by the parent (i.e., asking for refills of pain medication when the patient is not in pain) and/or signs of physical/emotional abuse, child protective services as well as social work should be involved.[20]

Pain in Pediatric Patients

In patients less than 6 years of age, pain is largely expressed in a non-verbal manner.[21.] For many children, pain can manifest in the form of fear, anxiety, and behavioral changes. Furthermore, as with adults, pediatric patients can experience varying types of pain, including acute, prolonged, and chronic pain.[21] This is critically important for the orthopaedic surgeon caring for this population in order to aid in pain management. Acute pain (either from an acute injury/surgery) must be differentiated from prolonged pain (uncontrolled/inadequately controlled pain from an acute intervention/injury) and chronic pain (pain which lasts longer than would be typically expected for an acute injury).

In the acute setting, bone pain will typically be "sharp" when it originates from the periosteum and dull when it originates from the medullary cavity/marrow.[22.] In addition, pain from the surrounding soft tissues can serve as a contributing factor as well. This can occur due to an acute injury to the muscle and/or overuse of the muscle from repetitive injury.[23.] Neuropathic pain may also be present in injuries associated with neuropraxia or concomitant nerve injury. Concurrent diagnoses such as compartment syndrome and nerve damage must be explored as well as contributing factors to pain, particularly in the acute setting. Quantification of pain can be performed through various different scales, including the Visual Analog Scale, Faces Pain Scale, and Color Analog Scale.[24.]

Children with concurrent developmental conditions and/or neuromuscular conditions (autism/anxiety/developmental delay/neurological disorders) are at risk for pain-related complications as a result of difficulties in assessing the presence and severity of pain. For example, patients with neuromuscular conditions such as cerebral palsy may experience acute pain after trauma and/or surgical intervention due to muscle spasms as opposed to bone pain. As result, anti-spasmodic medications are integral in the management of acute pain in patients with these diagnoses. Limited research in this area further complicates this problem.[25.]

Although beyond the scope of this paper on acute fracture management, the incidence of complex regional pain syndrome as well as chronic pain is increasing in the pediatric population.[26-28] Management of these patients both in the preoperative and postoperative setting is optimized using a multi-disciplinary team approach of physical therapists, psychologists, anesthesiologists, pediatric rehabilitation, and primary care physicians who must work together to create a comprehensive treatment plan.

Emergency Room/Preoperative Management

Emergency room management of pediatric and adolescent musculoskeletal pain is critical, particularly as patients may experience severe pain in this setting prior to immobilization.[29] Noble et al. examined 905 patients with long bone fractures in their pediatric emergency room and found that the median time for pain assessment from presentation was 6 minutes, with receipt of pain medication within 87 minutes.[7] Disparities were seen with decrease use of narcotics in African-American patients, publicly insured patients, patients who arrive by private vehicle, and patients with single bone fractures. In addition, emergency room crowding has also been shown to decrease the timeliness of analgesic administration.[30]

Multiple medications can be utilized initially to treat pain prior to intervention, including ibuprofen, diazepam, fentanyl, morphine, ketamine, oxycodone, and hydromorphone.[31.] In resource-limited settings,

orthopaedic surgeons may deliver analgesia, but emergency room practitioners should administer pain medications if available. Multiple studies have sought to determine the optimal pain control regime for patients in the emergency room with extremity fractures. Recommendations are summarized in Figure 1 (from American College of Surgeons, *Best Practices Guidelines for Acute Pain Management in Trauma Patients*, https://www.facs.org/-/media/files/quality-programs/trauma/tqip/acute_pain_guidelines.ashx).

In the PRIME trial comparing intranasal fentanyl to ketamine for the management of acute extremity injuries, the authors found that ketamine was just as effective in providing analgesia without the risk of opioid morbidity.[32] Koller et al. examined oxycodone, ibuprofen, or a combination in the initial management of orthopaedic injury pain and found that all provided effective analgesia.[33] This is consistent with a recent systematic review which found that ibuprofen may be the preferred initial drug of choice in treating orthopaedic pain due to its efficacy in reducing pain, combined with an improved safety profile as compared to opioid medications.[34] Comparisons between morphine and ibuprofen have also been performed, and have found no differences in efficacy between the two medications (with decreased side effects with ibuprofen).[35] Furthermore, randomized controlled studies (i.e., the NO OUCH trial) are currently being performed to compare the efficacy of nonsteroidal to opioid medications in the acute care setting.[36,37] It is also important to note that although codeine has been historically used in the management of acute musculoskeletal pain,[38] concerns about its side effects and efficacy have lessened its utilization.[39]

Beyond administration of pain medications, child life and diversion therapy are also an important adjunct in the management of acute pain in this population. This can include various distraction techniques such as music and the use of devices such as an iPad.[40-43] Although many institutions will have dedicated child life services, the absence of this resource does not preclude the use of diversion techniques. As electronic devices are readily available, utilization of "screens" can be used by the provider to provide pain relief, particularly when performing immobilization and/or casting for fractures that do not require manipulation. Utilization of the entire orthopaedic team is critical as medical students, residents, fellows, and advanced practice providers can assist in diversion techniques.

If interventions (such as closed reduction and casting) are necessary in the emergency room, multiple nonsystemic modalities can be utilized to provide pain relief. As mentioned earlier, hematoma blocks[9] and nerve blocks [8,10,11] can be used in lieu of traditional procedural sedation techniques. Although pediatric procedural sedation has been found to be safe even when performed by general community emergency physicians,[44] short-term behavioral changes are seen after sedation in children 1-2 weeks after discharge.[45] Thus, further research and prospective trials are needed that compare traditional strategies with regional methods more likely available at large institutions.

Utilization of Regional Anesthesia

The increasing utilization of regional anesthesia in the pediatric and adolescent population has allowed for improvements in pain control in patients undergoing intervention. The safety and efficacy of these techniques have been well established.[46] Regional anesthesia can block sensory input while at times preserving motor function. In addition, muscle relaxation can be achieved which not only aids the clinician during the procedure but also decreases the amount of systemic medication given. Options for regional anesthesia include caudal and lumbar epidural anesthesia as well as peripheral nerve blocks (intra-scalene, supra-clavicular, infra-clavicular, axillary, lumbar plexus, fascia iliaca, femoral nerve, adductor canal, saphenous, and sciatic). Pediatric regional anesthetic blocks are typically done after the patient is under sedation due to anxiety and difficulty lying still. This is in contrast to adults where blocks are given without sedation for fear of missing a peripheral nerve injury; despite this fear, this has not been shown to increase the risk of nerve injury.[47]

Figure 1. Pediatric Pain Medications

Medication	Dosing		Precautions (P), Contraindications (C), and Considerations[B]
	Maintenance Dose[A]	Maximum Suggested Dose/Duration[B]	
Acetaminophen	PO: 10-15 mg **per kg** q4-6h PR: 20-25 mg **per kg** q6h IV: 7.5-15 mg **per kg** q6h	PO: 75 mg **per kg** per day (4,000 mg per day) PR: 100 mg **per kg** per day (maximum 5 days) IV: 60 mg **per kg** per day (3,750 mg per day)	Liver dysfunction (P) Cardiac dysfunction (P) Avoid suspension and injectable products with ketogenic diet (C)
NSAIDs			
Ibuprofen	PO: 10 mg **per kg** q6-8h	40 mg **per kg** per day (400 mg per dose)	Renal dysfunction (C) Cardiac history (C) GI bleeding (C) Avoid suspension with ketogenic diet (C) Fracture (P)
Ketorolac	PO: 1 mg **per kg** q4-6h IV/IM: 0.5 mg **per kg** q6h	PO: 10 mg per dose; 40 mg per day IV/IM: 15 mg per dose Maximum 5 days of therapy regardless of route	
Skeletal Muscle Relaxants			
Methocarbamol	PO/IV: 15 mg **per kg** q8h	1,000 mg per dose; 4,000 mg per day	Sedating, especially with other CNS depressants Limit IV use to less than 3 days
Diazepam	PO: 0.1 mg **per kg** q6h IV: 0.05 mg **per kg** q4-6h	10 mg per dose; 40 mg per day	
N-methyl-D-aspartate (NMDA) Antagonists			
Ketamine	IN: 1.5 mg **per kg** IV/IM: 0.3 mg **per kg**	IN: 1 mL per nostril	Acute psychosis, CVA, cardiac decompensation (C) Dose based on ideal body weight if obese Dependence potential Monitor for emergence reactions

Medication	Dosing		Precautions (P), Contraindications (C), and Considerations[B]
	Maintenance Dose[A]	Maximum Suggested Dose/Duration[B]	
Opioids			
Fentanyl	IN: 1.5 mcg **per kg** IV: 1-2 mcg **per kg** q1h CI: 1-3 mcg **per kg** per hour	IN: 100 mcg per dose IV: 2 mcg **per kg** per dose (25-50 mcg) CI: 5 mcg **per kg** per hour	All opioids confer risk of addiction and life-threatening respiratory depression Extended-release preparations are not intended for acute pain Fentanyl may accumulate in lipid stores with prolonged use
Hydromorphone	PO: 0.03 mg **per kg** q4h IV: 0.015 mg **per kg** q3-6h CI: 0.003-0.005 mg **per kg** per hour	PO: 0.06 mg **per kg** per dose IV: 0.015 mg **per kg** per dose (1-2 mg) CI: 0.005 mg **per kg** per hour (0.2 mg per hour)	
Morphine	PO: 0.2 mg **per kg** q3-4h IV: 0.1 mg **per kg** q2-4h CI: 0.01 mg **per kg** per hour	PO: 0.5 mg **per kg** per dose (15-20 mg) IV: 2-10 mg per dose based on age CI: 0.04 mg **per kg** per hour	
Oxycodone	PO: 0.1 mg **per kg** q4-6h	5-10 mg per dose	

[A]Assumes opioid-naïve, age at least 6 months, and normal renal/hepatic function.
[B]The information listed in this table is intended to represent general dosing recommendations and adverse effect concerns and is not intended to be an extensive listing of all possible precautions, contraindications, and considerations.
Key: PO – oral; IM – intramuscular; IV – intravenous; IN – intranasal; CI – continuous infusion.

Contraindications for regional anesthesia include lack of parental consent, infection at the site of blockade, need for postoperative neurologic exam, coagulation disorders, or altered anatomy.

Of concern for patients who receive regional anesthesia is the potential for missing a compartment syndrome. Unlike adult patients who will complain of pain, pallor, paresthesias, paralysis, and pulselessness, pediatric patients will manifest signs of compartment syndrome with anxiety, agitation, and increasing analgesic requirement.[48] Although studies have shown that utilization of regional anesthesia has not alone led to delays in the diagnosis of compartment syndrome,[49] procedures at high risk for development of this condition (i.e., tibia fractures, polytrauma) should involve regional anesthesia carefully. **Dangerous scenario: A multi-injured child or child at risk for compartment syndrome has worsening anxiety and need for further analgesia despite regional anesthesia. Usually, these calls go to the pain team who will work to get the pain under control without understanding this may mask compartment syndrome. In this scenario the floor team needs to be trained to also contact the**

orthopaedists who are more cognizant in diagnosing compartment syndrome.

Data in regard to the utilization of regional anesthesia for pain management have been positive, although utilization should be judicious if postoperative neurologic exams are needed. Li et al. examined brachial plexus blocks in patients undergoing elbow surgery and found improved postoperative pain control without significant complications.[50] Glover et al. similarly examined 230 supracondylar humerus fractures that underwent closed reduction and percutaneous pinning and found decreased intraoperative opioid consumption as well as PACU pain scores without compartment syndrome development.[51] Further study is needed to determine the impact of lower extremity blocks on postoperative pain control in this population.

Not to be forgotten, infiltration of local anesthetic is still a useful adjuvant for decreasing opioid usage. Herrera et al. examined the use of hematoma blocks after femoral elastic nailing and found the time to first narcotic dose postoperatively was delayed 5 hours.[52] Similarly, Georgopolous found that the intra-articular injection of 0.25% bupivacaine significantly improved postoperative pain control after closed reduction and pinning of supracondylar humerus fractures.[53]

Postoperative Management

The management of postoperative pain after intervention is critical as well. After large procedures, patient- and/or parent-controlled IV analgesia can be utilized but with attempts to limit the utilization of opioid medications. Anti-inflammatory medications are the cornerstone of such practices, but unnecessary concern for fracture healing persists despite accumulating evidence to the contrary. Nuelle et al. examined 102 patients who had fractures and found effective pain control along with no impairment in radiographic and clinical healing.[54] Similarly, DePeter et al. retrospectively examined 808 patients with fractures and did not find any association with ibuprofen use and any clinically important bone healing complications.[55] Even administration of ketorolac has not been shown to impair fracture healing, albeit in a juvenile rat model.[56] **Unfortunately, the utilization of anti-inflammatory medications in fracture management continues to be low despite the evidence that proves its effectiveness without significant morbidity.[57]**

Clinicians continue to over-prescribe narcotics; Stillwagon et al. examined 126 patients who underwent surgical treatment for supracondylar humerus fracture. Patients only used a mean of four doses of oxycodone postoperatively, although a mean of 47 doses were prescribed.[58] Similarly, Nelson et al. examined 81 patients who underwent treatment for supracondylar humerus fractures and found that patients used less than 25% of the opioid medication prescribed.[59] As a result, the authors now recommend seven doses of postoperative medication for these patients. Strategies that educate families, patients, and providers on proper narcotic prescription practices have been shown to be effective in reducing these trends.[60] With appropriate education and minimal narcotic dispensing by physicians, patients who request additional medication should be examined for ischemia, compartment syndrome, infection, and/or drug-seeking activity by caregivers.

Other medications can also be used as adjuvants beyond anti-inflammatories and small doses of opioids. Acetaminophen can be given pre- and postoperatively as part of a multimodal regime. Gabapentin can be utilized for chronic neuropathic pain that results after intervention. Tramadol, as with codeine, should be used sparingly in the pediatric population due to concerns about side effects after a warning was issued by the FDA.[61] Methadone has also been shown to provide effective analgesia and has decreased morphine consumption after large surgeries such as posterior spinal fusion.[62]

Future Directions

Further randomized controlled trials that examine various oral, intravenous, and regional pain modalities must be performed in the pediatric and adolescent population.

The limitation of narcotic prescriptions while at the same time ensuring adequacy of pain relief is critical. Multimodal, team-based approaches to pain control in this population can lead to improved clinical outcomes.

Summary

The effective management of pediatric pain is a historical problem that continues to be affected by contemporary issues such as the COVID-19 crisis and the opioid crisis. Safe and judicious opioid usage is important for pediatric and adolescent physicians. An understanding of the unique aspects of pediatric pain presentation allows for various techniques to be implemented in pain control. In addition to traditional opioids, anti-inflammatory medications, regional anesthesia, and diversion techniques can be utilized. Decreasing the prescription of opioids in the acute trauma setting is key.

Additional Links

1. https://www.facs.org/-/media/files/quality-programs/trauma/tqip/acute_pain_guidelines.ashx
2. https://posna.org/Physician-Education/QSVI/PostOp-Pain-Management-Prescription-Guidelines

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