Abstract:
The acutely injured child poses unique clinical challenges in many respects. Our understanding of these unique characteristic differences and ability to care for pediatric trauma patients has greatly improved over recent decades; however, one area in pediatric trauma care continues to suffer from relative neglect in research and shows few signs of improvement in clinical practice: analgesia. Studies of analgesia practices continue to describe pervasive undertreatment of pain in the pediatric trauma patient. A growing body of evidence suggests that poorly controlled acute pain (oligoanalgesia) not only causes suffering but may lead to both immediate complications that worsen outcomes as well as debilitating chronic pain syndromes that are often refractory to available treatments. This article will provide a review of pain in injured children with respect to its pathophysiology, clinical ramifications, and patterns of analgesia practices. Impediments to analgesia are examined regarding multiple providers of care for the acutely injured child including prehospital personnel, nurses, and physicians. Finally, the article will provide analgesia recommendations with an approach to pain relief and sedation for the injured pediatric patient.

Keywords: oligoanalgesia; pain; pediatric; trauma

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Analgesia for the Pediatric Trauma Patient: Primum Non Nocere?

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Evaluating pain in the trauma patient poses unique challenges as it may simultaneously involve both somatic and visceral pain from a variety of origins. The pain response is a complicated process that may evolve from acute (normal) to chronic (maladaptive) pain with persistent or repetitive exposure to injury-provoked pain. This is true for patients of any age; however, children appear especially vulnerable to the harmful effects of oligoanalgesia. Understanding how both acute and chronic pain occurs may help us better control and prevent the pain responses that can cause harmful changes after injury. A comprehensive description of pain physiology in the pediatric trauma patients is beyond the scope of this article. Instead, we will focus on select concepts of the pain response, how the pediatric patient’s response to injury and pain are unique, and how chronic pain syndromes are thought to occur. These pain-related issues include visceral vs somatic pain, the stress response, hypersensitivity vs habituation, central nervous system (CNS) plasticity, hyperalgesia, and central sensitization.

KEY CONCEPTS OF PAIN PATHOPHYSIOLOGY IN THE INJURED CHILD

Visceral vs Somatic Pain
Somatic and visceral pain systems have distinct physiologic and clinical features. Cutaneous somatic innervation is more dense and limited to a few spinal segments; therefore, cutaneous somatic pain is better localized and characterized by specific sensations. Deep somatic pain (muscles, joints) resembles visceral pain in its dull nature and poor localization. Visceral organs are innervated
by 2 sets of nerves: vagal and spinal nerves or pelvic and spinal nerves. Most internal organs are innervated by the vagus nerve; however, its role in transmitting pain signals is not yet clear. Most visceral afferent fibers are thinly myelinated or unmyelinated providing a dull and difficult to describe sensation. Visceral pain has poor localization as input is typically distributed over several spinal segments. This leads to similar pain sensations from nociceptive activity in unrelated organs (eg, urinary bladder and colon, gall bladder and heart). Visceral nerves receive convergent somatic input (skin, muscle) resulting in referred pain to unrelated sites (eg, retrosternal pain to the neck, cardiac ischemic pain to neck, shoulder, or jaw). The stronger emotional and autonomic reactions seen with visceral pain may reflect the involvement of the anterior cingulated gyrus, amygdala, and insular cortex. Last, visceral nociceptor activation can occur even in the absence of tissue damage (eg, functional abdominal pain).1,2

The Stress Response

Acute pain results in a stress response that manifests in physiologic, biochemical, and behavioral changes associated with hemodynamic instability and poor wound healing. Infants are particularly vulnerable to changes in intracranial pressures related to fluctuations in systemic vascular pressures because of an immature blood brain barrier. Autonomic responses to acute pain lead to fluctuations in heart rate and blood pressure. These responses may diminish with persistent pain and are often not a reliable marker for the presence of pain. Pain is also associated with hypoventilation that may lead to hypoxia. This may explain the seemingly paradoxical effect of improving respiratory function in critically ill patients when treating their pain with effective doses of opioids.3,4

Persistent or severe pain is associated with elevated levels of “stress hormones” such as catecholamines, glucagon, growth hormone, and lactate and ketones, whereas insulin levels are suppressed. Neonatal catecholamine and metabolic responses are 3 to 5 times greater than those in adults undergoing similar types of surgery. One of the most significant clinical studies on the harmful effects of poorly controlled acute pain was reported by Anand and Hickey5 in 1992. At the time the standard of care in anesthesia held that neonates would experience worse outcomes if provided a comparable level of anesthesia during surgery. Anand and Hickey5 conducted a trial with neonates requiring congenital heart disease repair. The investigators found that the control group demonstrated higher levels of stress hormones (eg, hyperglycemia, lactic acidemia), greater incidence of sepsis and disseminated intravascular coagulopathy, and had a 27% mortality rate. The intervention (medication) group had no increase in pulmonary or circulatory complications and no deaths. The results starkly contradicted prevailing wisdom at the time and were so remarkable the study was ended prematurely as it was considered too risky to continue practicing the standard of care.

Finally, behavioral changes seen in patients with poorly controlled pain include crying, agitation, and sleep disturbance. In one study, children in a burn unit were found to have posttraumatic stress disorder symptoms inversely related to the amount of morphine administered 6 months prior at their initial presentation.6 Thus, many physiologic, biochemical, and behavioral changes associated with poorly controlled pain are the very consequences of injury we hope to prevent and control to facilitate healing and prevent harmful outcomes.

Hypersensitivity vs Habituation

One of the clinical hallmarks of a healthy adult’s response to pain is the ability to habituate. That is, with repeated or prolonged exposure to a similar stimulus, the autonomic responses tend to lessen. In contrast, younger patients tend to demonstrate just the opposite. This is classically found with the heel prick of a neonate. With repeated exposures, the infant exhibits a lower pain threshold (ie, more brisk flexor response) and autonomic lability.7 Similarly, older children report increased perception of pain if preceded by repeated painful experiences.8

On a conceptual level, the reason why infants may differ in a pain experience lies in the difference in understanding and processing the meaning of a painful experience. This is one of the most challenging areas to explore; it is unlikely we will ever know how infants perceive a painful experience. Pain experiences have both physical and emotional components that affect the reaction. Our cognitive maturity allows us to attenuate the emotional and neurophysiologic response of a non-life-threatening injury. One example is the pain from a percutaneous needle insertion. The pain experienced from trauma associated with a needle insertion is likely similar on an anatomical level in different aged individuals. The pain stimulates the same nociceptors, results in the release of similar neurotransmitters, and travels on the same neural pathways to similar areas of the brain. A healthy, mature individual should recognize the source of the pain as something that has a
positive purpose (to improve health) and a limited duration and intensity. Even the adult with needle phobia will recognize that the pain experienced will dissipate and not recur without warning. Infants and to a lesser extent children lack this perspective. This may also help explain why the stress response to the same pain stimulus is more brisk and intense in less mature or adaptive individuals.\(^7\)

There are several possible physiologic explanations for this phenomenon. One of the important components of pain physiology is modulation. Pain responses are either amplified or attenuated at the level of the dorsal horn of the spinal cord through the release of excitatory and inhibitory neurotransmitters. Less mature patients have a relative deficiency of inhibitory neurotransmitters and some inhibitory neurotransmitters, such as γ-Aminobutyric acid (GABA), have an excitatory effect in the premature infant.\(^7\)

Another explanation lies at higher levels in a process known as integration. When pain signals ascend to the brain, they are distributed to multiple supraspinal centers including the reticular activating system, olivary, paraventricular, and thalamic nuclei; limbic system; cingulate and postcentral gyrus; frontal and parieto-occipital areas. At these levels, the pain signal is integrated and processed. Pain is identified by its localization and characteristics. The information is matched with memories of past experiences that in turn mediate levels of arousal, attention, and sympathetic responses. In laboratory studies, less mature subjects demonstrate less inhibitory pathway activation compared to more mature subjects. It is hypothesized that recognition of nonharmful painful stimuli can aid in blunting the pain signal. This ability logically relates to experiences and age and is inherently deficient in younger patients.\(^9\)

**Central Nervous System Plasticity**

One of the greatest concerns regarding oligoanalgesia in young patients is the potential for altering the developing CNS. The plasticity of the nervous system is now recognized in all age groups but is thought to have a particularly profound impact on young children because they have rapidly developing nervous systems. Pain researchers have demonstrated that poorly controlled and repetitive exposure to pain has a unique and lasting negative impact on the CNS of young patients and that this effect is potentially more profound with less maturity.

In laboratory studies of rat pups, the repeated exposure to pain results in morphologic changes at the site of injury and the dorsal horn of the spinal column. These changes may be temporary or long lasting. They are seen at a variety of levels including changes in protein phosphorylation, altered gene expression, loss of neurons, formation of new synapses, and loss of inhibitory interneurons. Local tissue damage in the early postnatal period results in profound and lasting sprouting of sensory nerve terminals (A & C fibers) and sprouting of neighboring dorsal root ganglia cells in the spinal cord leading to inappropriate functional connections and hyperinnervation. Clinically, these changes result in allodynia and other features of neuropathic pain.\(^10\)

Repetitive pain also appears to accelerate apoptosis. This refers to the “pruning” of unused neural pathways. Although this is a normal phenomenon during infancy, it appears to be accelerated in laboratory animals subjected to repeated painful stimuli. Finally, pain is associated with activation of N-methyl D-aspartate (NMDA) receptors located on neurons. The receptor is activated by glutamate resulting in an influx of Ca\(^{++}\) and Na\(^{+}\) activating a Ca\(^{++}\)-calmodulin complex. This leads to production of heat shock proteins that causes lysosome degranulation and necrosis of the nerve cell. The activation of NMDA receptors is thought to contribute to the development of chronic pain syndromes. Interestingly, this process is inhibited with the administration of opioids as well as “NMDA receptor antagonists” such as ketamine, methadone, and nitrous oxide.\(^11,12\)

Clinical evidence of these changes is found in the association of chronic conditions with exposure to painful stimuli. Anand et al\(^13\) described how functional abdominal pain is seen in higher rates in former premature infants who experienced frequent gastric suctioning. Studies using PET scans have revealed that the anterior cingulate cortex is particularly affected by pain. This area is associated with control of emotion and attention and may help explain why premature infants who experience more medical complications exhibit a higher rate of psychosocial disorders such as attention deficit hyperactivity disorder (ADHD) and lower academic achievement compared to matched controls.\(^14\)

**Pathways to Chronic Pain: Hyperalgesia, Central Sensitization, and Sympathetically Mediated Pain**

Multiple pathways are described to explain the development of chronic pain after injury. These mechanisms include hyperalgesia from local inflammatory markers, sensitization of neurons proximal
to and surrounding damaged nerves, and sympathetically mediated pain.

After an injury, inflammatory mediators are released that may cause the pain response to increase even in the absence of additional injury. This sensitization of nociceptors results in primary hyperalgesia at the site or injury. Primary hyperalgesia manifests clinically as a more intense pain response than expected from stimuli. Secondary hyperalgesia may develop in the area surrounding the area of injury as a result of sensitization of neurons in the CNS. This central sensitization occurs when receptors that normally conduct nonpain signals (eg, touch) now transmit pain signals. When nonpainful stimuli such as touch result in a pain response the condition is called allodynia. Clinical examples of this include the severe and diffuse pain associated with burns (light touch), pharyngitis (swallowing), arthritis (movement), and in more unusual conditions such as complex regional pain syndrome (formerly reflex sympathetic dystrophy).15

Hyperalgesia may also result from damaged or severed nerves. Instead of a diminished pain signal, Wallerian degeneration of the severed nerve may result in sensitization of nociceptors in adjacent nerves (primary hyperalgesia) and increase spontaneous activity of adjacent nociceptors resulting in central sensitization (secondary hyperalgesia). This paradoxical pain response manifests in the clinical syndrome of neuropathic pain. Symptoms include intense burning and electrical sensations that are often refractory to opioids in usual doses.15

As noted above, nociceptor stimulation is often associated with a resulting increase in sympathetic activity. In some circumstances, the reaction reverses: nociceptors may develop sensitivity to catecholamines. This is known as sympathetically maintained pain. In these conditions, trauma (even seemingly trivial trauma) provokes a pain response that features not only hyperalgesia but also allodynia. The classic example is complex regional pain syndrome that, in the pediatric patient, typically involves the lower extremity of school-age girls and is often associated with edema and dramatic changes in cutaneous perfusion.15

Summary of Neurophysiologic Reponses to Pain

Pain responses appear heightened in younger patients whose CNS is more vulnerable to physiologic stress. Repetitive and persistent pain is associated with morphologic changes of the nervous system at multiple levels. Analgesics have a neuroprotective effect by decreasing inhibitory neurotransmitter activity, increasing inhibitory neurotransmitters, and stabilizing neurons. The clinical result may include a lower incidence of sepsis, metabolic acidosis, disseminated intravascular coagulopathy, and death. Given this information, it appears that pain control is important for all patients and particularly the youngest. Ironically, studies of our clinical practice reflect just the opposite.

**ANALGESIC PRACTICE FOR PEDIATRIC TRAUMA PATIENTS**

Most of the information available regarding pain management for pediatric trauma patients focuses on isolated injuries and burns. There are more studies addressing pain management for adult trauma patients than for children. In general, studies on analgesia practice in medicine over the past several decades reveal pervasive patterns of apparent undertreatment. In this section, we will examine the following aspects of clinical practice. What are the patterns of analgesia for pediatric patients? What are the patterns of analgesia for trauma patients? What are some of the impediments to providing analgesia for pediatric trauma patients?

**Analgesia for Children**

This year marks a decade since the Joint Commission on the Accreditation of Healthcare Organizations cited inadequate analgesia as the first nondisease healthcare crisis in the United States. Its response to this problem included numerous guidelines, resources, and requirements to assess and treat pain. Despite this effort, it is unclear whether we have seen improvement in the clinical practice of pain management for children. Pain research since the 1970s describes how children are given analgesics less often than adults for similar conditions and prescribed approximately 50% of the weight-based equivalent of analgesics.16-18 Furthermore, the milligram per kilogram dosing of analgesics is generally directly related to age, that is, younger patients receive lower milligram per kilogram dosing regardless of clinical situation.19 In 1996, Broome et al20 reported that younger children received inconsistent pain assessment and management and that institutional standards regarding pain control were often ignored. That same year, Cummings et al21 reported on children admitted to a Canadian hospital, noting that 21% had uncontrolled pain and that children were offered analgesics less than prescribed (ie, prn medications available but not provided).

Interestingly, some studies have shown that those with pediatric subspecialty training may provide less...
analgesia than their generalist counterparts. In 2004, Cimpello et al\textsuperscript{22} described this in a review of more than 700 children with fractures seen in 3 emergency departments (EDs) for 2 years. In this study, general emergency physicians prescribed more analgesics and recommended pain treatment and advice on discharge more often than their pediatric emergency medicine-trained colleagues. Quinn\textsuperscript{23} described a comparison of the use of local anesthetic for lumbar puncture in children and found an even more striking contrast between those with and without pediatric subspecialty training. In this study of children presenting to different EDs in Baltimore, 93% of children treated by those without pediatric training received local lidocaine before lumbar puncture, whereas only 4.5% of children presenting to the children's hospital ED received lidocaine. At the pediatric institution, those receiving lidocaine included 0 of 168 infants, 1 of 18 toddlers, and only 8 of 12 children older than 4 years. The treating physicians were asked whether pain was experienced to the same degree regardless of age and 51% agreed with this statement.\textsuperscript{23}

In addition to the patterns found in pediatric patients, studies of other specific demographic groups have also demonstrated patterns of oligoanalgesia. Elderly patients (\textgreater 70 years old) also receive less analgesia in the ED.\textsuperscript{24} Analgesia research by Todd et al\textsuperscript{25} has described significant ethnic and racial disparities in the administration of analgesia. Hispanic patients in Los Angeles with isolated long bone fractures were twice as likely to receive no analgesia compared to non-Hispanic white patients, and black patients in Atlanta were less likely to receive adequate analgesia compared with white patients.\textsuperscript{26} Finally, patterns of sex discrimination are reported with women often receiving less analgesia than men.\textsuperscript{27} The reasons for these patterns of disparities are difficult to elucidate but important to examine; they are addressed later in this article.

\section*{Analgesia in Trauma}

Research on analgesia practice for trauma patients reveals similar patterns of undertreatment, particularly for children. Friedland et al\textsuperscript{28} compared analgesia provided for 215 children presenting to Cincinnati Children's Hospital (Ohio). Children with vaso-occlusive crisis from sickle cell disease received analgesics at 100% of visits, within 52 minutes (mean), with 78% therapeutic dosing (average), and with analgesia guidance given on discharge at 100% of visits. In comparison, children with fractures received analgesics at 31% of visits, at 1.5 hours (mean) after presentation, with 69% therapeutic dosing, and with analgesia advice given at 74% of visits. Children with burns received analgesics even less often (26% of visits), with 70% therapeutic dosing, and with only 27% receiving analgesia instructions at discharge.\textsuperscript{28} O'Donnell\textsuperscript{29} found that 49% of 172 children with musculoskeletal injuries presenting to an ED were provided analgesics. Another 2002 study noted only 50% of burn victims received adequate analgesia in EDs.\textsuperscript{30} Neighbor et al\textsuperscript{31} described opioid use for severely injured patients in a level I trauma center over the course of 1 year. Of more than 500 cases, only 48% received intravenous opioids within the first 3 hours with the mean time to first dose of 95 minutes. Risk factors for receiving less opioid included younger age (<10 years old), intubation, lower revised trauma score, or not requiring fracture manipulation.\textsuperscript{31}

Studies of prehospital care demonstrate 2 patterns. In general, prehospital personnel tend to undertreat pain in trauma patients; however, when analgesia is provided by prehospital personnel, it makes a significant difference in the time to analgesia compared to patients who receive their first dose of analgesia by hospital personnel. A 2000 report on prehospital analgesia in more than 1000 patients showed that only 1.5% of patients received analgesia after an extremity injury.\textsuperscript{32} A 2002 study on transports of patients with isolated lower extremity injuries showed analgesic use in just 18.3% of transports.\textsuperscript{33} Several studies on the use of prehospital analgesia protocols for injured patients have demonstrated safety, effectiveness, and increased use of prehospital opioid analgesia.\textsuperscript{34-38} In a 2005 review of emergency medical services (EMS) transports by 20 different EMS agencies in Michigan, analgesia was provided by EMS for 22% of children having fractures or burns; however, these children received their medications 1 hour sooner than those who had to wait for a dose provided by the ED.\textsuperscript{39}

\section*{Impediments to Analgesia}

Efforts to understand the causes of oligoanalgesia have revealed a wide array of possible explanations. Influences may come from the patient, family, and society as well as the medical profession. For health care professionals, these explanations include (1) fear of masking signs of serious injury or illness, (2) fear of causing or exacerbating hemodynamic or respiratory insufficiency, (3) inadequate pain assessment skills or efforts, (4) lack of understanding about pain and analgesics, and (5) concerns about creating addictive behavior by providing analgesia. One of the purported reasons for withholding analgesics in the trauma patient is the belief that...
pain relief achieved by analgesics could mask symptoms of an underlying pathologic condition. The implication is that outcomes will worsen due to a delay in diagnosis and progression of symptoms. A study of 215 physicians and nurses in 9 Israeli trauma units reported that analgesics were frequently withheld to assist diagnosis. Most providers in this study believed that analgesics should be withheld in cases of abdominal or multisystem injury; however, 75% reported that they had inadequate knowledge about pain management.

Although seemingly logical, the paradigm that analgesia worsens outcomes is not substantiated in the literature. The basis for this belief may lie in part with a classic surgical text originally authored by Cope, *Early Diagnosis of the Acute Abdomen*. The text states that in the setting of acute abdominal pain of unclear etiology analgesia will (1) mask signs and symptoms of a surgical condition causing a (2) delay in diagnosis with resulting (3) increase morbidity and mortality. Although these assertions were replicated in subsequent editions, they do not offer supporting evidence. In recent years, researchers have attempted to test this assumption with respect to the patient with possible acute appendicitis. More than a half dozen studies have examined the use of morphine (typically 5-mg doses) in patients with signs of peritonitis. None of the studies revealed adequate analgesia provided for patients who simultaneously rated pain moderate or severe 74% of the time. It is logical that improved pain assessment would lead to improved analgesia. In a 2004 prospective study of 150 adult trauma patients, 60% of those with pain scores received analgesics compared to 33% without pain scores. The mean time to analgesia was 68 minutes in this study. However, a recent pediatric study on pain assessment failed to show a change in analgesia administration rates and time to analgesia with improved documentation of pain scores. Barriers to analgesia likely occur at multiple steps beginning with pain assessment and then the response to that information.

A study of 355 ED nurses revealed deficits in understanding pharmacologic analgesic principles and concepts such as addiction, tolerance, and dependence. Scores correlated with education level and improved after a 1-day seminar. Fifty-three percent of nurses cited the potential for analgesics to mask signs of injury or illness as a barrier to providing treatment. Forty-eight percent reported inadequate pain assessment skills.

In a 2004 study of prehospital personnel, Hennes et al found significant differences in the comfort level of EMS providers in administering analgesics depending on a patient's condition. Of the subjects, 93% to 95% reported feeling comfortable providing analgesics to patients with pain from fractures, burns, or nonspecific chest pain if the patient was older than 17 years. Much fewer respondents felt comfortable if similar patients were 7 to 17 years old (chest pain, 36%; extremity injury, 70%; burn, 77%) and even less if younger than 7 years (chest pain, 24%; extremity injury, 38%; burn, 44%). In this study, respondents cited the following as barriers to providing analgesia to pediatric patients: inability to assess pain (57%), difficult vascular access (80%), delay of transport (66%), fear of complication (68%), record keeping (50%), and possible drug seeking (65%).

Although attention to pain in the adult medical literature has increased exponentially in recent years, a focus on analgesia for children and trauma patients remains sparse. Much of the research in pediatric pain centers on animal models. Major pediatrics and pediatric emergency medicine texts still provide relatively little attention to pain. The advanced trauma life support course practically ignores the subject. In previous editions of the advanced trauma life support provider manual, pain...
was briefly addressed in a paragraph that followed the section on the secondary survey. The most recent edition has omitted even this brief mention. The index cites just 2 pages where pain is addressed in the current manual: as part of C-spine evaluation and under musculoskeletal trauma. In the latter section, the authors’ guidance states “Whenever analgesics, muscle relaxants, or sedatives are administered to an injured patient, the potential exists for respiratory arrest.” In comparison, the Emergency Nurses Association course, Advanced Trauma Nursing: A Conceptual Approach, has an entire chapter on pain in the trauma patient. This contrast highlights the differing emphasis on pain management seen in the nursing and medical professions.

RECOMMENDATIONS FOR ANALGESIA IN THE PEDIATRIC TRAUMA PATIENT

The dictum “First do no harm” seems to conflict with efforts to effectively control pain; but as explained in the preceding pages, there is considerable harm inflicted by allowing pain to continue unchecked. This final section will cover select modalities for both pain and anxiety. Although there is no panacea for traumatic pain, the treating clinician will find success with anticipation of analgesia needs, an understanding of both the patient and available treatments, and an approach of titrating to effect.

Pain Management Approach for the Injured Child

When treating pain, physicians often tend to think only of medications (“when you have a hammer, all the world's a nail”), however, effective pain management relies first on the skilled use of nonpharmacologic approaches. The first key intervention is pain assessment and reassessment. Just as shock is overlooked if capillary refill, heart rate, and blood pressure measurements are neglected, untreated pain usually occurs because it is not recognized. The challenge lies not only in finding effective tools to measure pain but simply paying attention to pain in the clinical setting.

Using our most validated instruments (eg, Wong-Baker Faces scale), pain assessment is generally considered to be unreliable in children younger than 3 years and the visual analog scale is generally not useful in children younger than 6 years (Table 1). Furthermore, acutely injured patients may require intubation and therefore lose the ability to vocalize discomfort. When a patient is unable to perform a pain score, the clinician is left with secondary assessment measures. Vocalizations such as crying, grunting, or moaning may reflect pain; however, children with painful injuries may make no sound simply because they fear that vocalizations will prompt an injection. Heart rate and blood pressure are often elevated in acute pain; however, hemodynamic changes are not always reliable markers in painful settings. Vagal responses to pain may decrease heart rate, whereas some patients demonstrate a more attenuated sympathetic response, particularly when pain is prolonged. When uncertain one should ask a simple rhetorical question: Is this a painful condition/situation? If so, examine the effect of a small dose of analgesia on vital signs, muscle tone, respiratory effort, and overall affect.

Just as important as “doing the right thing” is caution not to do the “wrong thing.” Anxiety and pain are magnified in children when they feel a loss of control and lack psychosocial support. This, of course, is also true for adults; the difference lies in the ability to recognize and express these feelings. How we speak with vulnerable children can make a tremendous positive or negative impact on their experience and reaction to the care we provide. Children may be scared by either a poor choice of words (“we'll give this a shot”) or language they either do not understand or misunderstand. Making unrealistic promises (“this won't hurt”) or invalidating feelings (“that doesn't really hurt”) only serves to undermine your relationship with the patient. Painful treatments should never be used as threats or punishments. Take care to keep needles or needle/syringe images out of view when possible. When possible, keep the patient close to eye level and let them sit up whenever feasible. Last, children are usually very concerned about losing blood. When they see their own blood, they may benefit from reassurance that the amount of blood loss is not harmful to them.

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<tr>
<th>Patient Description</th>
<th>Recommended Scale</th>
<th>Scoring Range</th>
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<tr>
<td>Infants</td>
<td>NIPS: Neonatal Infant Pain Scale</td>
<td>0-21</td>
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<tr>
<td>Preschool</td>
<td>Wong-Baker Faces Scale</td>
<td>0-5</td>
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<td>School age--adolescent</td>
<td>Visual Analog Scale</td>
<td>0-10</td>
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<tr>
<td>Intubated/ noncommunicative</td>
<td>Comfort Scale</td>
<td>8-40</td>
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Keys to an optimal rapport with your patient include honesty, clarity, and empowerment. Give them choices wherever possible. The key is recognizing which patient may benefit from detailed information and which patient copes better with distraction. While many children are extremely frightened of needles, some have worse anxiety when they cannot see what is happening to them. Distraction is a potentially powerful intervention and generally easier to implement at younger ages. Hypnosis, an advanced form of distraction, has a long track record of effective pain control in many acute and chronic pain situations.

There is considerable evidence in the literature that supports family presence in the medical setting. Researchers have found that with clear guidelines and support, patients and family members report greater preference for family presence even in critical situations. Clinicians in these studies report no increase in adverse outcomes when family members are present and experts in the field report a lower medicolegal risk when family members are present at end of life settings. The key to family presence is providing skilled personnel such as clergy, nurses, or child life services to guide the family members about where they should be in a trauma room and under what circumstances they may be asked to leave. If your institution does not already have a policy describing how to provide safe and effective family presence, there are multiple resources available to develop such a policy.58-63

The concepts listed above do not require a medical license or sophisticated understanding of pharmacology. Rather, they require a basic understanding of child development and a willingness and ability to pay attention to verbal and nonverbal cues of distress. When practiced and performed well they can make the difference between an optimal situation and one that is unmanageable.

Pharmacologic Interventions

In a sense, all analgesics are “nerve blocks.” Whether a pain signal is interrupted by a local or generalized anesthetic, systemic opioid, or effective distraction, each intervention works by attenuating the pain signal at some level. The keys to safe and effective use of medications include an understanding of the characteristics of the medications and a willingness to carefully titrate to effect. This section is not intended to provide an exhaustive list of available treatments. Attention will focus on general concepts with added detail about select and commonly available medications. A more complete review of both pharmacologic and complementary approaches to analgesia is found in the references cited.64-66

Acute Pain

The immediate goal of acute pain management is to get pain under control and then maintain that control. Even when the former is achieved, we often end up “chasing” the pain when we neglect to reassess and treat until the patient is again in severe distress. This results in both ineffective analgesia and more medication administered. A secondary goal in acute pain management is the prevention of chronic pain. Through the careful titration of medication and attention to nonpainful stressors that worsen painful experiences, clinicians can provide safe and effective pain control in most patients.

Opioids are usually the central therapy for managing severe acute pain. There is considerable variability of opioid responsiveness in some patients, and they may require significantly higher dosing. Such patients may either have differences in opioid receptors (often a familial pattern) or a higher tolerance due to chronic exposure to opioids. Of the numerous potential side effects of opioids, the most common are gastrointestinal dysmotility (nausea, pain, and constipation), sedation, and tolerance/dependence. Proactive treatment of constipation is strongly recommended for patients receiving regular doses of opioids.

Morphine, the “gold standard” analgesic, has a relatively slow onset of action and a half-life of 2 to 3 hours. It is typically dosed as 0.05 to 0.1 mg/kg for the opioid-naïve patient in severe pain. Subsequent dosing of 0.02 to 0.05 mg/kg should take place every 10 minutes to desired level of analgesia. Although morphine is perhaps the most familiar opioid, it is sometimes not the ideal medication for trauma patients. Disadvantages include a slower onset, higher incidence of allergic reactions due to histamine release, more venodilation and risk of hypotension, and greater effects on gastrointestinal motility than other commonly used opioids.

For the acutely injured patient whose initial evaluation is still in progress, fentanyl offers a number of advantages. Fentanyl is metabolized in the liver to inactive compounds; however, this is not significantly altered in liver disease. Onset is within 5 minutes and therapeutic levels are achieved for 20 to 60 minutes. Typically, the opioid-naïve patient in severe pain is safely and effectively treated with an initial dose of 2 to 3 μg/kg of fentanyl. A continuous infusion can sustain therapeutic levels and allow
careful titration. In addition, the literature shows growing interest in intranasal administration of fentanyl. This offers the obvious advantage of analgesia without intravenous access. Some studies suggest that a dose of 1.7 \( \mu g/kg \) of intranasal fentanyl is equivalent to 0.1 \( mg/kg \) of morphine.\(^6\) In this author's experience, a higher dose of fentanyl (2-3 \( \mu g/kg \)) is required for mild-moderate pain. Oral transmucosal fentanyl is another option; however, effective doses by this route are associated with high rates (25%-50%) of nausea and vomiting.\(^6\) Finally, hydromorphone offers several potential advantages to morphine and fentanyl including fewer allergic reactions, longer duration of action, and somewhat less tolerance when used for prolonged periods.

Opioids are ideally dosed to maintain a steady state serum concentration and avoid peaks and troughs. Once pain control is achieved, it is important to anticipate the need for boluses of analgesia. Even small movements, turning the patient or inadvertently bumping a chest tube or endotracheal tube can cause significant exacerbations of pain. The patient with a femur fracture may appear to have good pain control when lying motionless but quickly loses that control when moved. Before moving the patient for x-rays or other reasons, consider a small (1-2 \( \mu g/kg \)) bolus administered several minutes in advance of anticipated movement. If the patient seems excessively sedated fentanyl also has the advantage of a relatively short half-life. If opioid reversal is necessary in a stable but excessively sedated patient physicians should begin cautiously with small doses of naloxone (0.001 \( mg/kg \) per dose) to avoid excessive blockade of opioid and resulting severe pain.

Although not commonly used in the ED setting, some pediatric EDs are using patient-controlled analgesia (PCA) for select patients (eg, sickle cell pain crisis) with good results. In general, PCA requires a patient with at least a 5-year-old developmental level. Although not all patients prefer this approach, many patients achieve greater control with lower doses of opioid when they have immediate control of their analgesia with a PCA. Typically, a basal infusion of opioid is provided with a limited number of PCA doses programmed into the PCA pump.

Nonsteroidal antiinflammatory medications such as ibuprofen and ketorolac are potentially useful treatments either alone for mild pain or as adjuncts for moderate pain. Efficacy studies comparing ketorolac to morphine and acetaminophen have yielded mixed results.\(^6\) Given the risk of decreased platelet function and gastritis, the role for regular use of nonsteroidal antiinflammatory medications in the acutely injured patient is therefore limited to situations where the risk for surgery is low and pain levels are not severe.

Finally, nerve blockade at the spinal cord can provide effective analgesia with a fraction of the dose required for systemic treatment. Long-term use of epidural analgesia is possible and can offer appropriate candidates unique benefits. Although commonly used for labor pain, cesarean delivery, and thoracic and abdominal surgery in adults, many pediatric institutions do not yet routinely use this approach as it requires close observation from those trained in this procedure.

### Sedation of the Trauma Patient

Sedation of the pediatric trauma patient poses unique challenges due to the risk of shock from blood loss and CNS injury due to altered cerebral perfusion pressures secondary to intracranial swelling. In addition, these patients often require analgesia for pain. Although multiple studies have shown that preprocedural fasting times do not correlate with aspiration, the clinician should consider the risks of nausea and vomiting in each situation.\(^7\) The ideal sedatives for the necessary procedure in an acutely injured pediatric patient include the following properties: analgesia, minimal alteration in systemic and intracranial perfusion pressures, and short acting or reversible. No single agent offers the ideal combination of benefits for all situations; therefore, clinicians must rely on different options often with a combination of agents. Expertise in a handful of modalities is a better investment than marginal familiarity with a broad array of treatments.

Before starting sedation, one should verify that equipment, medications, and personnel are in place to respond effectively to a sudden decrease in ventilation or oxygenation, emesis, hypotension, or seizure. Have an airway technician immediately available if your intention is to provide moderate to deep sedation. Recall that in light sedation (previously conscious sedation), the patient responds appropriately to physical and verbal stimuli. In deep sedation, the patient is not easily aroused, may have partial or complete loss of protective reflexes, and loses the ability to respond purposefully to physical or verbal stimuli. Last, anticipate when you might stop a procedure. Take for example a child who appears deeply sedated when untouched but screams during a painful orthopedic procedure. The orthopedist is focused on completing the procedure. The physician in charge of sedation should decide
whether it is reasonable to attempt or complete the procedure or defer to another setting such as the operating room with general anesthesia.

The following strategy may be helpful in choosing optimal sedation medications for a given scenario or procedure. These are general recommendations, and each case requires an individual assessment by a physician trained and experienced in sedating children. First, determine if the analgesia requirement will be low (e.g., laceration repair) or high (e.g., reducing a fracture). Next, determine if the procedure is likely to be less than or greater than 5 minutes. The key is to provide effective sedation and analgesia with the least amount of medication. In all cases, local or regional anesthetic is recommended where possible to limit the dose and duration of systemic medications. Last, strongly consider an amnestic agent (e.g., benzodiazepine) as an adjunct for frightening situations/procedures. Do not proceed with a painful procedure until assured that the patient's sedation and analgesia is adequate.

For lower analgesia requirements, fentanyl or nitrous oxide is recommended. Advantages of nitrous oxide include its rapid onset and recovery time and excellent anxiolysis;72 fentanyl offers superior analgesia. Nitrous oxide requires specific apparatus including a scavenging system and familiarity with administration. Contraindications against sedation with nitrous oxide include first trimester pregnancy, pneumothorax, chronic respiratory disease, bowel obstruction, CNS injury or depression, and shock.73

For more painful procedures, it is sometimes challenging to find a safe therapeutic window with fentanyl. In these cases, ketamine is often a good alternative as it can provide effective analgesia and sedation without loss of spontaneous respirations.74 Ketamine tends to increase secretions and has a positive chronotropic and inotropic effect that can result in an increase in systemic pressures. Ketamine administration is associated with increased intracranial pressure; however, this effect is attenuated with benzodiazepine administration or hyperventilation. Interestingly, one study of patients with traumatic brain injury found a decrease in intracranial pressure in patients given ketamine and propofol.75 In addition, ketamine often causes emesis and dysphoria upon waking (“emergence reaction”). The former is associated with higher dosing and the latter with older children and adults.11 Therefore, it is prudent to premedicate with atropine if increased secretions pose a problem, consider an anxiolytic such as ondansetron and warn the family of the possibility of an emergence reaction (estimated to occur in 50% of older children and adults). When a procedure requires more than 5 minutes, propofol is a useful agent.76 Propofol can provide deep sedation without loss of spontaneous respirations and wears off within minutes of discontinuation. Side effects include negative inotropy, so special attention should be paid to the blood pressure in patients receiving fentanyl and propofol. Propofol is typically bolused with a starting dose of 1 to 3 mg/kg and then maintained with an infusion at 5 mg/kg per hour titrated to effect. Contraindications to propofol include soy or egg allergy. Alternatives to propofol include midazolam, etomidate, or methohexital (Table 2).

### Prolonged Acute Pain

Managing prolonged or chronic pain is quite different than acute pain and generally not the

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**TABLE 2. Treatment options for procedural sedation of the trauma patient.**

<table>
<thead>
<tr>
<th>Analgesia Need</th>
<th>Duration</th>
<th>Recommendation</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild-moderate</td>
<td>Short (&lt;5 min)</td>
<td>Fentanyl (IV, IN)</td>
<td>Nitrous oxide (when anxiety &gt; pain)</td>
</tr>
<tr>
<td>Mild-moderate</td>
<td>Long (&gt;5 min)</td>
<td>Fentanyl (IV, IN) + propofol</td>
<td>Fentanyl infusion; Fentanyl + midazolam, etomidate, OR methohexital</td>
</tr>
<tr>
<td>(eg, long laceration repair)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate-severe</td>
<td>Short (&lt;5 min)</td>
<td>Ketamine</td>
<td></td>
</tr>
<tr>
<td>Moderate-severe</td>
<td>Long (&gt;5 min)</td>
<td>Ketamine + propofol</td>
<td>Ketamine infusion; ketamine + midazolam, etomidate, OR methohexital</td>
</tr>
</tbody>
</table>

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*a Local or regional blocks with anesthetics are recommended where possible to decrease the requirement for systemic medications. IV indicates intravenous; IN, intranasal.
Ketamine is a potent NMDA receptor antagonist and a source of poorly controlled pain.77 Anxiety may be a significant factor in the setting. Sleep deprivation is often an overlooked cause of increased opioid use in this context. When patients have difficulty weaning from opioids, one should consider the possible causes and alternative treatments. Opioid tolerance typically develops within a week of continuous use of the same opioid. Patients will exhibit a decreasing effect of similar doses of the medication. Although increased dosing can address this temporarily, it is usually more effective (ie, better analgesia with less medication) to switch to another opioid. Patients with increasing needs for boluses of analgesics (breakthrough pain) should be reassessed for both the causes of the pain and effectiveness of the pain plan. Although attention to the possibility of evolving organ damage is the priority, there are other common causes of increased opioid use in this setting. Sleep deprivation is often an overlooked source of poorly controlled pain.77 Anxiety may build with repetitive painful procedures, greater awareness of injuries, and a sense of lack of control over the situation.

Assuming more aggressive analgesia is not contraindicated one may consider changing the opioid. Frequent need for a short-acting opioid should prompt a consideration to add a long-acting opioid such as methadone or long-acting formulations of morphine, oxycodone, or hydromorphone. The objective is to find an effective dose and dosing schedule that minimizes the peaks and troughs of medication level and pain control. Any changes in treatment strategy for patients with chronic pain must involve the advice and ongoing care of a knowledgeable physician.

Nonopioid adjuncts may have an opioid-sparing effect and control the development of chronic pain. Unfortunately, pediatric trials for most of these adjuncs are lacking, particularly for pediatric trauma patients. A wide array of anticonvulsant medications have demonstrated effectiveness for various chronic pain syndromes. Gabapentin’s possible effectiveness for phantom limb pain and spinal cord injury pain in addition to its relatively benign side effect profile make it a reasonable consideration for some trauma patients.78 Cannabinoid therapy may offer some analgesia in addition to effectiveness as an anxiolytic and antiemetic.79 Ketamine is a potent NMDA receptor antagonist that has demonstrated effectiveness in suppressing postsurgical central sensitization and secondary hyperalgesia after burns. It has also been used effectively in the treatment of postamputation stump pain and complex regional pain syndrome.80 Tricyclic antidepressants such as amitriptyline have a long track record of effectiveness in a variety of chronic pain syndromes. Amitriptyline’s sedative effects may also help treat insomnia. More recent serotonin selective reuptake inhibitors have also shown some effectiveness.81

SUMMARY

Analgesia for the pediatric trauma patient remains a challenging and important area of research and clinical care. The relative infrequency of cases and the multidimensional nature of injuries makes clinical research daunting. Undertreatment of these patients continues due to a variety of influences including excessive fears about adverse effects of analgesics, a lack of attention to pain, and underappreciation of the harmful effects of poorly controlled pain. Medical education and training still underserves the issue of pain in the context of patient care. Numerous national and institutional guidelines and requirements have modest impact as the standards of care for analgesia are usually locally based.

Fortunately, the tools to improve care are within our grasp. Common pharmacologic and nonpharmacologic interventions are safe and effective if used in a judicious manner. Analgesia protocols for prehospital and hospital-based care can improve the percentages of patients treated; ultimately, the attitudes and understanding of providers regarding analgesia must evolve to achieve significant improvements in pain control. The emergency physician’s responsibility in caring for a patient includes effective pain relief during their care and until the patient is transferred to a subsequent physician. Once we recognize that the potential harm in “primum non nocere” lies as much in undertreatment as in overtreatment of pain, children having injury will receive more effective analgesia. +

REFERENCES