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Pain management for the pediatric trauma patient

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Trauma is a leading cause of Pediatric Morbidity and Mortality in the United States accounting for over 500,000 hospitalizations and 15,000-20,000 deaths each year[1]. Pain frequently accompanies injury. Strategies to comfort pediatric trauma patients are essential components of their management and may help not only to reduce pain but also improve cardiorespiratory stability. Effective pain management can also allay fear and anxiety; prevent the development of procedure-phobia which frequently develops in these patients who often require multiple daily painful dressing changes and other diagnostic and therapeutic procedures; and reduce the incidence and severity of post-traumatic stress disorder and other psychological disturbances.

The International Association for the Study of Pain defines pain as "An unpleasant sensory and emotional experience connected with actual or potential tissue damage, or described in terms of such damage". They go on to state that pain is always subjective. Pain assessment can be very difficult in pediatric trauma patients since many of these patients are not able to communicate that they are in pain. Also, many aspects of pain are influenced by the child's developmental stage, including perception, expression, understanding, and causal attributions of the pain as well as the suitability of various treatments[2]. Fundamental to the management of any clinical problem is assessment. Just as it is inconceivable that one would know when to begin antihypertensive therapy or whether the therapy was effective without measuring the patient's blood pressure, so it is with pain. Yet as I have just stated, pain is always subjective and difficult to measure but it can be measured in everyone even though the measurement may be very crude. For example it may only be possible to say that pain is present or absent. Pain assessment is the first step in managing pain and is always tied to planning future analgesic therapy. Pain assessment tools exist which can be used for children at different ages and stages of development and under a variety of circumstances[2]. In assessing pain, many physiological and behavioral factors are taken into account: Also consider the etiology of pain. Reassessment is essential since it is important to determine if analgesic interventions are adequate.

In discussing pain management for the pediatric trauma patient I think it is useful to look at three distinct phases trauma patients experience to varying degrees. There are unique challenges associated with pain management during each phase. These phases are the emergency, healing, and rehabilitation phases. During each phase, there is background pain which is present all the time. Background pain may be diffuse as with extensive injuries or localized involving a single extremity or body cavity. There is also incident or breakthrough pain which is pain that occurs as a result of nursing care, dressing changes, debridements, manipulations, or other diagnostic and therapeutic procedures. Successful pain management of the trauma patient requires a plan to manage both background and incident pain.

In addition to background and incident pain it is useful to consider the three basic mechanisms underlying pain: nociceptive, neuropathic, and psychogenic. Effective management for each of these types of pain involves different treatment modalities. Most commonly the trauma patient experiences nociceptive pain during the emergency and healing phases. This is the classic pain mechanism were substances released by damaged tissue (bradykinin, K+, H+, histamine, bradylinin, prostaglandins, serotonin, substance P, etc) activate the free nerve terminals of A-delta and C fibers located in virtually every tissue. The signal is transmitted to the dorsal horn of the spinal cord where the nociceptive afferents synapse with neurons comprising several ascending pain pathways such as the spinothalamic tract, spinoreticular tract, and the spinomesencephalic tract. Neuropathic pain is less common and it is less well understood[3]. It is thought to occur weeks after peripheral nerve injury which may not have been appreciated at the time of injury. We most commonly see patients with neuropathic pain in the healing or rehabilitation phases. However, neuropathic pain can be seen immediately after an injury. Sometimes the injuries appear to be quite minor. It is very important to distinguish neuropathic from nociceptive pain since this pain

usually persists as a chronic pain syndrome and it is unresponsive to the usual analgesics, NSAIDs and opioids. Most commonly, children with neuropathic pain developed severe, constant, spontaneous, burning pain 2-3 months after injury. The pain is in the distribution of a stocking or glove and not in the distribution of any single peripheral nerve. Allodynia - severe exacerbations of pain with stimuli that does not normally result in pain such as wearing a sock or stroking with cotton or even a draft - is often present. Hyperesthesia or severe pain in response to stimuli which normally produces less pain, may also be present. The affected body part, is often protected and splinted by the patient. If the foot is involved, the patient may be unable to bear weight and may require crutches to ambulate or a wheel chair. Other classic features are that the extremity is initially red and hot but later becomes cool and clammy with a striking bluish-mottled discoloration. Late trophic changes occur including hair loss, brittle nails, muscle wasting, and joint contractures from disuse. Numerous terms have been applied to this condition. Complex regional pain syndrome type I is the old RSD and is used when there is no documented nerve injury. CRSP II is the old Causalgia and implies that there is a documented peripheral nerve injury. The most important aspect of treatment is Physical Therapy with emphasis on desensitization, range of motion, and strengthening exercises. TENS units may be useful in a few patients. Psychologic evaluation should occur early and cognitive and behavioral techniques of pain control (behavioral modification, biofeedback, relaxation, distraction, coping strategies) should begin early too. For children who are not able to initiate PT due to pain, a trial of a variety of medications is begun including anticonvulsants (gabapentin, carbamazepine), antidepressants (amitriptyline), mexilitine, and sympathetic blocks may be required. Improvement can take months but most children recover completely. Lastly, psychogenic pain can occur in pediatric trauma patients. Normally, children who have suffered traumatic injuries do experience psychologic stress. Reduction in physical activity, depression, anxiety, and irritability may be normal and adaptive after injury but occasionally these psychologic responses are disproportionate to the degree of injury and result in magnified pain and impaired functioning. Psychologic evaluation and intervention may be required in these patients but this is beyond the scope of my talk and I will not discuss this further.

During the emergency phase, the greatest challenge is providing analgesia for extensive injuries in patients who may be compromised from a neurologic or cardiorespiratory standpoint. The first priority is patient stabilization and preservation of life. This phase is variable in duration, usually < 72 hours and often less than a day. Although patient stabilization is the first priority, analgesia is not contra-indicated, particularly after surgical and neurological evaluations are complete. Analgesia may improve cardiorespiratory stability (an example is improved oxygenation and ventilation in a child with rib fractures) and also may improve patient cooperation with diagnostic and therapeutic procedures. The type of analgesics administered and the way in which they are administered depend upon the patient, personnel, and institution. Patient controlled analgesia (PCA) is not an option in children less than 6 years old, cognitively impaired, or physically unable to press the demand button on the PCA device. If a pain service is not available to round on patients twice a day, continuous epidural analgesia and Patient Controlled Epidural Analgesia (PCEA) are not advised. Nevertheless, whenever possible, analgesic techniques should be patient directed since 1) there is a wide variation in pain even with similar injuries, 2) there is a wide variation in response to analgesics and 3) these techniques have less reliance on physicians, nursing staff, and pharmacy resulting in fewer delays in receiving analgesics. During the emergency phase diffuse background pain is best managed with systemic opioids by continuous infusion (children < 6 years old, unable to use button, or cognitively impaired), intermittent boluses - patient controlled (children > 6 years old) or provider controlled, or a combination of the above. Incident pain can be managed with additional systemic opioids, ketamine, nitrous oxide, or general anesthesia. Regionalized trauma during the emergency phase may be amenable to regional anesthetic management with epidural or peripheral nerve block. Epidural analgesia is provided with a variety of medications alone or in combination. Incident pain can be treated the same as with diffuse trauma except that the regional technique may be adequate by itself. The most common PCA medications and settings we employ are illustrated in this table I. Morphine is the primary drug used but we have found a number of patients who either have inadequate analgesia with morphine or don't tolerate morphine due to annoying side effects, and have excellent analgesia and fewer side or no effects when switched to hydromorphone[8].

Systemic opioids we use for breakthrough/incident pain are morphine 50 (range, 25-100) μg/kg IV every 2-3 hours as needed, hydromorphone 10 (range, 5-20) μg/kg IV every 2-3 hours as needed, and nalbuphine 50 (range 50-100) μg/kg IV as needed every 3-4 hours. Nalbuphine is a mixed

Table I. Pediatric patient controlled analgesia regimens.

Opioid	Demand (μg/kg)	Lockout (minutes)	Basal (μg/kg/h)	1 h Limit (μg/kg)
Morphine	20	8	20	100
Hydromorphone	4	8	4	20
Fentanyl	0.2	5	0.2	1

agonist/antagonist opioid (kappa agonist, mu antagonist) which has analgesic properties similar to morphine up to a dose of 200 μg/kg[5]. But there is a ceiling to analgesia above which increasing the dose of nalbuphine does not result in more analgesia. Nalhuphine is useful in treating mu related side effects such as nausea, vomiting, pruritis, and urinary retention. Morphine and hydromorphone should not be administered to children receiving epidural opioids because of the markedly increased risk of respiratory depression when combining systemic and epidural opioids.

Epidural analgesia at CHOP usually involves the local anesthetic bupivacaine 0.75-1.25 mg/ml in combination with an opioid (thoracic epidurals: fentanyl 2-5 μg/ml; or lumbar epidurals: morphine 25-50 μg/ml). The usual infusion rates are 0.2 - 0.4 ml/kg/hour (maximum 20 ml/h). Due to bupivacaine toxicity, infusion rates are kept below 0.4 mg/kg/h bupivacaine. If the tip of the epidural catheter is as it should be, placed near the center of the dermatomes were analgesia is desired, the epidural infusion rate rarely needs to exceed 0.3 ml/kg/h. PCEA is similar to PCA only it involves epidural analgesia with local anesthetic in combination with an opioid. These are the typical settings we use at the Childrens Hospital of Philadelphia (Table II).

Finally, for continuous peripheral nerve block infusions we commonly employ bupivacaine 1.25 mg/ml at a rate of 0.2 - 0.32 ml/kg/h (maximum rate 10 ml/h) but others have recommended using bupivacaine 2.5 mg/ml at initial rates of 0.15 ml/kg/h or 0.375 mg/kg/h[6]. Whichever method is chosen, it is important to adhere to the dosing guideline not to exceed bupivacaine 0.4 mg/kg/h in order to avoid bupivacaine toxicity[7].

The Healing phase begins after patient stabilization and lasts until all wounds are healed which can be weeks or months. Providing adequate analgesia during the healing phase may become more difficult as background pain sometimes increases when the patient becomes more mobile. One may also see a decreased tolerance for painful procedures which may be frequent, an increase in fear and anxiety associated with these procedures, depression, sleep disturbances, and post-traumatic stress disorder. Pain and injury can result in all of these phenomena and these phenomena can in turn result in increased pain. It is a vicious cycle. Therefore the goals during this phase are to continue to provide aggressive background analgesia as well as analgesia for painful procedures and incident pain; anxiolytic therapy may be required prior to painful procedures; and medications to facilitate sleep may also be required. Psychological consultation can also help develop non-pharmacologic techniques to reduce pain and anxiety as well as help the patient cope with the stress of trauma especially if there has been a loss of body function or part. Post Traumatic Stress Disorder is common in children and their families after major trauma and Psychologic evaluation is necessary to identify and treat effected individuals. All severely injured children should undergo psychological evaluation early in this phase to help identify and treat psychologic disturbances that may contribute to pain magnification.

Table II. PCEA infusate and settings.

- PCEA Infusate.
  - Bupivacaine 0.75 mg/ml with
  - PF MSO4 25-50 μg/ml or
  - Fentanyl 2-5 μg/ml
- Demand: 0.05-0.1 ml/kg
- Lockout: 20 minutes
- Continuous: 0.1 - 0.2 ml/kg/h
- 1 hour limit: 0.3 - 0.4 ml/kg/h

The pharmacologic interventions used to manage background and incident pain during the healing phase may be the same as those used during the emergency phase - at least initially. Patients are often transitioned from, aggressive techniques such as continuous morphine infusions, PCA, CEA, and PCEA to longer acting oral opioids such as MS contin, methadone, or oxycontin when it is anticipated that they will have nociceptive pain for a long time or shorter acting oral opioids if recovery is expected to be quick. Other agents such as NSAIDs may be used. Ketorolac 0.5 mg/kg IV every 6 hours can be used for brief periods in children who are not able to take oral medications. Alternatively ibuprofen 10 mg/kg every 6 hours can be administered orally. Novel techniques like transdermal fentanyl have also been employed. Incident/procedure pain is managed similarly to the emergency phase. Anxiolysis can be provided with clonidine, benzodiazepines, and/or antidepressants. Sleep can be facilitated by the judicious use of antidepressants, benzodiazepines, and in small children antihistamines like diphenhydramine or hydroxyzine. One of the biggest challenges during the healing phase is as indicated earlier, providing intense analgesia for brief procedures in a child who may be relatively comfortable between procedures. This intense analgesia should not be associated with prolonged post-procedure sedation and should ideally be administered safely by nursing personnel or the parents at home. Another challenge is managing complications of analgesia during this phase - the most common complications are nausea, vomiting, constipation, pruritis, and sedation.

Although the Rehabilitation phase for many pediatric trauma patients may be brief or non-existent, some children have an extensive rehabilitation which begins after the last wound heals. The patients are usually fully mobilized and receiving outpatient care only. Pain may continue to be nociceptive but tends to be a deeper, aching pain or a chronic pain syn-

drome such as CRPS, type I or II as previously discussed. Physical therapy, occupational therapy, and ongoing psychological support are the primary interventions. Opioids are rarely required for background pain and many patients can be treated successfully with weak oral opioids, NSAIDs, and/or acetaminophen. Incident or procedure pain is managed in ways discussed earlier for the healing phase. One oral analgesic we like to use during this phase is tramadol 1-2 mg/kg (maximunt dose 100 mg) every 6 hours (maximum daily dose 400 mg). Tramadol is an atypical opioid structurally related to codeine which has dual mechanisms of action, central serotonin and norepinephrine reuptake inhibition and weak affinity for the mu opioid receptor.

One of the challenges of the rehabilitation phase is weaning the opioid and benzodiazepine dependent child from these medications. This is done by transitioning the child to a long acting oral opioid, a long acting oral benzodiazepine, and starting clonidine which can reduce withdrawal symptoms during the wean. Weaning is time contingent with a 10-20% reduction in dose weakly. Note that after weaned from opioids and benzodiazepines, clonidine needs to be weaned also due to the potential for rebound hypertension. Intravenous Fentanyl to Methadone conversion is 1:1 in mg/24 h (i.e., 2.4 mg fentanyl per day = 2.4 mg Methadone per day divided in q 12 hour doses). Intravenous Midazolam to po lorazepam is 1:12 in mg/24 h (i.e., 72 mg midazolam/day = 6 mg lorazepam/day divided in q 6 h doses). Clonidine is administered as 8 - 10 μg/kg/day transdermal patch. During the transitioning of patients to methadone and lorazepam, careful monitoring for withdrawal symptoms as well as symptoms of central nervous system and respiratory depression is required and dose adjustments may be necessary.

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