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Approaches to Pediatric Musculoskeletal Pain

Opioids and So Much More

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Treatment of musculoskeletal pain in children poses unique challenges, particularly in the context of the ongoing opioid epidemic. In addition to the developmental level of the child, the type of pain he or she is experiencing should influence the team's approach when collaborating with the patient and the family to develop and refine pain management strategies. Understanding the categories of pain that may result from specific types of musculoskeletal injuries or orthopaedic surgeries influences the selection of medication or other most appropriate treatment. Although opioids are an important part of managing acute pain in the pediatric population, many other pharmacological and nonpharmacological therapies can be used in combination with or in place of opioids to optimize pain management. This article will review strategies for collaborating with families and the multidisciplinary team, provide an overview of pediatric pain assessment including assessment of acute musculoskeletal pain in children, and discuss pharmacological and nonpharmacological options for managing pain after acute injury or surgery.

Background

Management of acute musculoskeletal pain in the pediatric population poses difficult and unique challenges, particularly in the context of the current opioid epidemic. Managing the pain that children experience either after musculoskeletal injury or following orthopaedic procedures requires intention and care. The clinician must consider the child's developmental level, disposition, baseline fears, and previous experiences with pain. The child's family and their perception of the patient's pain also play a large role in pain assessment and treatment. Inadequate treatment of pain may result in patient and family dissatisfaction, emotional stress, delayed healing, and longer hospital stays (Ali, Drendel, Kircher, & Beno, 2010). Pediatric patients may misinterpret anxiety as pain that can obscure the character and location of their physical pain. For these reasons, it is imperative that the clinician learn not only how to adequately assess pain in pediatric patients but also treat the pain or discomfort appropriately with an understanding of when opioid use is warranted and when alternatives may be preferable.

Education and Expectations

Family and Patient Education

Setting clear expectations by educating the patient and his or her family prior to the surgical procedure is key to managing postoperative pain and ensuring patient satisfaction. Pediatric patients often mistakenly perceive anxiety as pain; consequently, if parents convey their fears to their child, the child's perception of pain and discomfort may be amplified. To minimize patient and family anxiety, the clinician should clearly explain the expected quality and duration of pain and likely outcome of interventions planned for its management. For example, telling the patient and the family preoperatively that they should expect pain at a level of 4–5 out of 10 even after pain medication, rather than telling them more broadly that their pain will be well controlled, gives them a more concrete understanding of what to expect. This preparation is important not only for planned procedures but also for emergent surgeries whenever possible. Even a brief discussion with a family prior to surgery for an unexpected extremity fracture can allow both patient and family to cope with postoperative pain more constructively and realistically.

Multidisciplinary Education

Pain management requires a multidisciplinary approach that involves child life specialists, nurses, and physicians. In the preoperative setting, child life specialists can explain procedures, provide distraction techniques, and utilize medical play to prepare patients for their upcoming procedures. These activities equip both the child and the family with the information and understanding they

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The authors have disclosed no conflicts of interest.

DOI: 10.1097/NOR.0000000000000523

need to cope with their experience. For example, children prepared for surgery by a child life specialist have been shown to exhibit lower levels of anxiety postoperatively (Brewer, Gleditsch, Syblik, Tietjens, & Vacik, 2006). Intraoperatively, collaboration with pediatric anesthesia to select the appropriate pain medication is essential (Frizzell, Cavanaugh, & Herman, 2017). Postoperatively, nurses provide critical input to nurse practitioners, physician assistants, and physicians who manage postoperative pain. To be effective, nurses in the emergency department, postanesthesia care unit, and pediatric floors should be familiar with the types and expected levels of musculoskeletal pain associated with various injuries and surgeries, in order to propose appropriate interventions. Finally, for larger procedures with prolonged and painful recovery, or those that require epidural or nerve block pain control, it may be beneficial to involve the pediatric pain team (Frizzell et al., 2017).

Pediatric Pain Assessment

Assessment Scales

A patient's self-reported pain level is considered the most accurate measurement of pain (Joestlein, 2015). However, pain assessment in pediatrics can be especially challenging if the patient is unable to report his or her pain intensity because of age or developmental level. In addition, pediatric patients often mistakenly perceive anxiety as pain, and both their own and their parent's fears may amplify the child's perception of discomfort. Research has shown that children will often not report their pain without being asked (Drendel, Kelly, & Ali, 2011). Therefore, the assessing clinician must always ask the child about his or her level of pain. Clinicians caring for pediatric orthopaedic patients must also be aware of the pain scales appropriate for various developmental levels (Drendel et al., 2011). For infants, the Neonatal Infant Pain Scale is a validated tool used to differentiate expression of pain from general infant distress. Neonatal Infant Pain Scale includes assessment of facial expression, cry, breathing, movements of arms and legs, and alertness (see Table 1). Another tool validated for use in infants and children younger than 7 years is the Faces, Legs, Activity, Cry, and Consolability (FLACC), which considers five behaviors indicative of pain in pediatric patients (see Table 2; Drendel et al., 2011). The FLACC scale is especially useful in nonverbal children regardless of chronological age.

Once children are old enough to grasp the concept of seriation, self-report pain scales can be used. Examples of these scales include the Wong-Baker Faces Scale and the Faces Pain Scale-Revised (see Figures 1 and 2). In appropriate circumstances, these scales can be used on children as young as 4 years of age; however, even children as old as 12 years may have difficulty with self-report pain scales. One study found that up to 40% of 5- and 6-year-olds had trouble understanding pain scales due to inability to grasp the concept of "greater than versus less than" (Stanford, Chambers, & Craig, 2006). When choosing which pain scale to utilize, the clinician must take into account the patient's developmental level based not only on age but also on clinical assessment and input from the patient's family. Children older than 8 years can use a numeric pain scale to rate pain from 0 to 10, although the clinician must be careful to use anchor words such as "zero representing no pain and ten representing the worst pain ever." Proper assessment of pain using the appropriate tool will lead to better treatment of pain.

Table 1. Neonatal Infant Pain Scale

Parameter	Finding	Points
Facial expression	Relaxed	0
	Grimace	1
Cry	No cry	0
	Whimper/mumbling	1
	Vigorous cry	2
Breathing	Relaxed	0
	Change in breathing patter	1
Arms	Relaxed	0
	Flexed, extended, or tense	1
Legs	Relaxed	0
	Flexed, extended, or tense	1
Alertness/Arousal	Sleeping or calmly awake	0
	Uncomfortable or fussy	1

Understanding and Assessing Pediatric Pain and Discomfort

The assessment of acute musculoskeletal pain in pediatric patients requires an understanding of the emotional as well as the physical aspects of pain. Fear and anxiety can worsen a child's perception of pain. Anxiety may stem from a variety of sources, including unfamiliar environment, staff, equipment, loss of control, hospital alarms, and parental attitudes (Joestlein, 2015). Moreover, due to communication barriers in pediatrics, the clinician must perform a thorough and detailed assessment, including accurate evaluation of the location of pain, to distinguish musculoskeletal pain due to injury or surgery from other physical causes of discomfort. The latter may include pain at the intravenous site, abdominal pain from constipation or hunger, muscle pain from prolonged bed rest, and even discomfort from the blood pressure cuff (Joestlein, 2015). Thus, a comprehensive assessment should always include asking the child to point to where it hurts. This approach avoids unnecessary use of narcotics and enables the selection of appropriate medication to address the specific pain or discomfort.

Types of Pain and Corresponding Treatments

Pain is experienced when injured or damaged tissues release prostaglandins and cytokines, which leads to stimulation of peripheral nerve fiber pain receptors or nociceptors (McCann & Stanitski, 2004). Understanding the types of injuries or surgeries that activate specific categories of nociceptors allows the selection of

TABLE 2. FACES, LEGS, ACTIVITY, CRY, AND CONSOLABILITY (FLACC) PAIN SCALE

	Scoring		
Category	0	1	2
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, disinterested	Frequent to constant quivering chin, clenched jaw
Legs	Normal position, relaxed	Uneasy, restless, tense	Kicking or legs drawn up
Activity	Lying quietly, normal position, moves easily	Squirming, shifting back and forth, tense	Arched, rigid, or jerking
Cry	No cry (awake or asleep)	Moans or whimpers, occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging, being talked to; distractible	Difficult to console or comfort

medication appropriate for the treatment of the particular pain.

BONE

Older children often describe bone pain as a deep, achy, consistent pain that does not fluctuate minute to minute. Bone pain is likely to occur with any acute injury to the bone or with surgery involving large or small bones, as well as with inflammation of the bone, as in osteomyelitis. Patients with acute fractures are likely to experience some level of bone pain, with displaced fractures more painful than nondisplaced fractures. High-energy mechanisms with bony injuries often require opioids in combination with nonopioid analgesics and muscle relaxants. Fractures of the femur, tibia, and both bone forearm usually necessitate this combination of treatment. Compartment syndrome awareness and education are critical when designing combination therapies and when treating high-energy injuries.

MUSCLE

Muscle discomfort from injury or surgical procedures may be due either to pain or to muscle spasm. Understanding the difference between the two is important for proper pain management, as they are experienced and treated differently. Familiarity with surgical approaches enhances the assessment of tissue insult and injury with resultant discomfort.

A patient may experience significant muscle pain, even without bone injury. Examples of this include severe sprains, tears such as anterior cruciate ligament tear, and muscular inflammation such as tendinitis. Muscle pain can also result postsurgery for the treatment of a bony injury or problem, due to surgical incision through and/or manipulation of muscle to attain access to the bone. Prolonged muscle retraction, as in spinal surgery, can also contribute to muscle discomfort.

Another, highly uncomfortable source of muscle pain results from muscle spasm, which can occur following bone fracture or postoperatively. With fracture, muscle spasm can occur when the bone from a displaced fracture interjects into the muscle and the muscles surrounding the injury spasm as they try to hold the fractured bone in place. This is commonly seen in femur fractures and displaced hip fractures. Muscle spasm discomfort should improve once the fracture is reduced and thus the patient should not require antispasmodic agents longer that 1–2 days after surgical correction or fracture reduction.

Postoperatively, muscle spasm may result from the prolonged period of muscle retraction that occurs during surgery. For example, patients commonly experience muscle spasm pain because of manipulation occurring during closed or open reduction with spica casing for hip dysplasia, or following spine surgery, such as after posterior spinal fusion and instrumentation

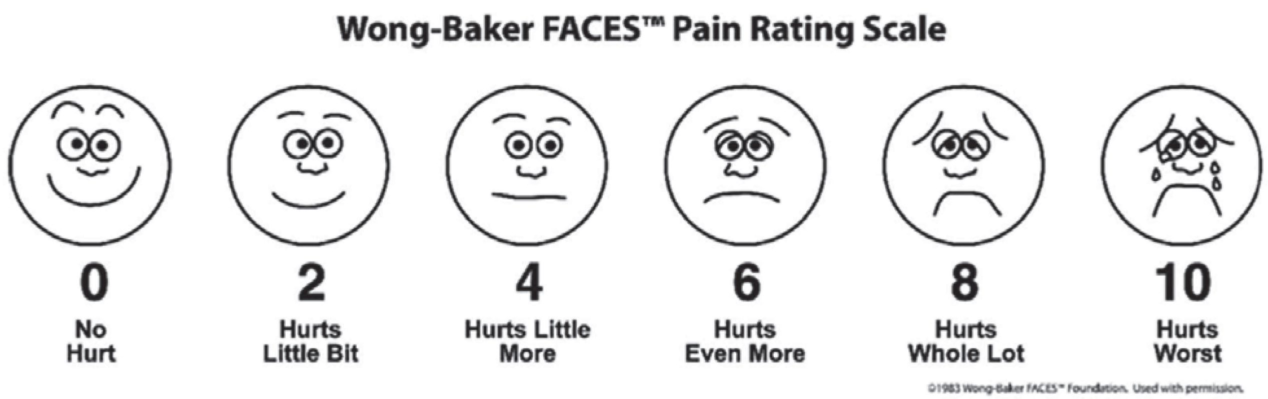

FIGURE 1. Wong-Baker FACES Scale. Reprinted from Wong-Baker FACES Foundation (2019). Wong-Baker FACES® Pain Rating Scale. Retrieved February 1, 2019 with permission from http://www.WongBakerFACES.org.

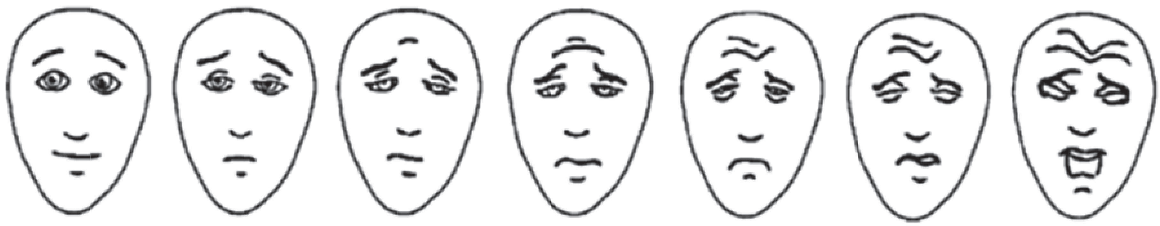

Figure 2. Faces Pain Scale–Revised. This Faces Pain Scale–Revised has been reproduced with permission of the International Association for the Study of Pain® (IASP). This figure may not be reproduced for any other purpose without permission.

for scoliosis or discectomies. Adolescents undergoing repair of idiopathic scoliosis often report postoperatively that they experience muscle spasms and tightness; this may lead to worse and/or longer lasting pain.

Being aware of signs of spasm is helpful in identifying this type of discomfort. Young children sleeping comfortably who suddenly jerk out of sleep may be experiencing muscle spasm pain. Often, the muscle spasm then causes bone movement and pain now with two types of discomfort that need to be addressed. Older children may describe the pain as shooting or cramping, or compare it to a "Charlie Horse" that they get when playing sports. In all cases, prevention or treatment of spasm should reduce pain and thereby facilitate pain control.

Neuropathic

Neuropathic pain can occur with injury or surgery involving the spine. Patients with herniated discs often describe pain radiating down their legs or out to their arms, or describe a tingling pain. During spinal surgery, injury occurs to both central and peripheral nociceptors. This injury leads to inflammation and release of chemical mediators, which changes the responsiveness of nociceptors that would normally have a very high threshold to fire. This sensitization of central and peripheral nociceptors and increase in excitability of spinal neurons are thought to be the causes of neuropathic pain (Rusy et al., 2010). Patients may describe neuropathic pain as sharp shooting pain or uncomfortable numbing or tingling pain radiating down their extremities. In children, treatment of neuropathic pain is most common after spine surgery or neuropathic phantom limb pain after amputation.

Other Sources of Discomfort

Children may report high levels of pain that may be completely unrelated to the injury or surgery. Adequately addressing other sources of discomfort such as constipation, anxiety, positioning, skin discomfort, or itching may often improve or relieve the patient's pain. All pediatric patients should be placed on a bowel regimen postsurgery to manage constipation as a side effect of medications and prolonged immobilization. In addition, every effort should be made to utilize child life therapists and to engage the patient's parents or guardians to ease the patient's anxiety and discomfort related to the injury and any procedures, large or small. Engaging the parents and child life is useful for peripheral intravenous insertion. Children may also have pain at the level of the skin either after injury or after surgery. Older children may be able to describe their pain as deep verses on the surface, which can help distinguish what type of pain they are experiencing.

Some of the medications children receive after surgery as well as the dressings and adhesives used may cause pruritus. This can be very troubling to children and young children may not be able to adequately express their discomfort. Children receiving a continuous opioid infusion or frequent doses of intravenous opioids are more likely to experience itchiness. Often, treating the itching relieves the child's discomfort. Medications such as diphenhydramine, hydroxyzine, or nalbuphine may helpful for these children.

Pain Management

Distinguishing the type of pain the child is experiencing can be difficult and requires careful assessment of the patient as well as knowledge of the injury and procedure. Opioids should be used in combination with non-opioid medications to optimize pain control. Understanding the different types of discomfort that may lead the child to rate his or her pain at a higher level will help the practitioner better treat and manage pain in the pediatric patient. Table 3 lists types of discomfort and suggested pharmacological and nonpharmacological interventions that may be utilized. These are described in detail later.

Pharmacological Interventions

Opioids

Opioids act on both central and peripheral nerve receptors. They increase the pain threshold in peripheral nerves and the spinal cord and change the brain's perception of pain. They can be given orally, intravenously, intrathecally, epidurally, and topically (Nowicki et al., 2012). The three major groups of opioids include natural derivatives of opium poppy—morphine and codeine; synthetic opioids—fentanyl, sufentanil, and meperidine; and semisynthetic opioids—hydromorphone, hydrocodone, and oxycodone (McCann & Stanitski, 2004). Table 4 lists the dosing of commonly used opioid medications in pediatrics. In children, morphine and fentanyl are most often used for intravenous pain management, whereas oxycodone, hydromorphone, and codeine are most common for oral pain management (Frizzell et al., 2017). Fentanyl has a faster onset (30 seconds) and shorter duration than morphine (30–60 minutes), so it can be a good choice for brief procedures requiring conscious sedation, in the operating room,

Table 3. Types of Acute Pain and Discomfort and Suggested Interventions

Type of Discomfort	Oral Pharmacological Intervention	Intravenous Pharmacological Intervention	Nonpharmacological Alternatives
Bone pain	Oxycodone; Ibuprofen[a]	Morphine Ketorolac[a] Nerve block[b]	Ice Elevation
Muscle pain	Ibuprofen[a]	Ketorolac[a]	Heat Ice Elevation Physical therapy Massage therapy Acupuncture TENS
Muscle spasm	Diazepam	Diazepam Nerve block[b]	Massage therapy Acupuncture
Nerve pain	Gabapentin	Nerve block[b]	Acupuncture Massage therapy
Skin/incisional pain	Acetaminophen Ibuprofen	Acetaminophen Ketorolac[a]	Ice
Abdominal pain/constipation/ ileus/nausea	Acetaminophen Docusate[c] Senna[c] Polyethylene glycol[c] Ondansetron[d]	Ondansetron[d]	Heat Ambulation Positioning Acupuncture
Itching	Diphenhydramine Hydroxyzine	Diphenhydramine Nalbuphine	Cold application
Anxiety related	Lorazepam Diazepam	Lorazepam Diazepam	Relaxation Distraction Meditation Child life Pet therapy Music

Note. TENS = transcutaneous electrical nerve stimulation.
[a]Conflicting research regarding use in spine fusion and large bone fractures although many studies have demonstrated its efficacy and safety in children and adults.
[b]Local anesthetic such as bupivacaine.
[c]These medications will help with constipation but will not directly affect pain.
[d]Given for postoperative nausea.

and in the immediate postoperative period (McCann & Stanitski, 2004). Intravenous morphine also provides excellent analgesia with longer duration of action of up to 3–4 hours, so it is often used for severe breakthrough in pediatric acute musculoskeletal pain. Intravenous hydromorphone is about 10 times more potent than intravenous morphine, so it is often reserved for those patients who do not respond well or are not adequately treated with morphine.

Intravenous opioids are also used in patient-controlled analgesia (PCA). Use of PCA has been shown to be effective at treating a variety of types and levels of pain in the pediatric population in children older than 6 years. Its effectiveness is related to the ability to maintain opioid concentrations in the blood in a narrower range than possible with oral or bolus intravenous dosing by using a basal rate with or without demand dosing (Frizzell et al., 2017; Nowicki et al., 2012). Another benefit includes giving the child some sense of control over his or her pain and his or her treatment, as often the loss of control is one of the more difficult aspects of hospitalization. The clinician must be aware that even among children who undergo the same procedure, some may respond better to certain medications than others. Close collaboration with the pediatric pain team can assist in managing any patient with a PCA infusion.

Opioids can also be administered via epidural catheter. This generally will provide prolonged pain control without the level of sedation produced by intravenous administration (Nowicki et al., 2012). Caudal and lumbar epidural catheters are the most commonly used in children, with caudal blocks often in younger children and lumbar blocks in older children (McCann & Stanitski, 2004). With epidural administration, varying degrees of motor block can occur, which can make physical therapy, as well as postoperative neurovascular and motor assessment, more difficult (Nowicki et al., 2012). For this reason, they should be used very cautiously in patients who are at a high risk for compartment syndrome postoperatively.

If the patient is able to tolerate oral medications, an oral opioid should be used as first line for severe pain, as the effects are likely to last longer than intravenous formulation, and transitioning the patient off intravenous medications is an important step in preparing for discharge. Codeine is less commonly used now, likely

Table 4. Commonly Used Opioid Medications in Pediatrics

Drug	Bolus vs. Cont.	Intravenous Dosing		Oral Dosing	
		Weight <50 kg	Weight >50 kg	Weight <50 kg	Weight >50 kg
Morphine	Bolus dosing	0.05–0.1 mg/kg per dose every 2–4 hours p.r.n.	2–5 mg every 2-4 hours p.r.n.	0.2–0.5 mg/kg per dose every 3–4 hours p.r.n.	10–20 mg per dose every 3–4 hours p.r.n.
	Continuous infusion	0.01[a] mg/kg/hour Titrate to effect, maximum 0.03 mg/kg/hour	1.5[a] mg/hour		
Fentanyl	Bolus dosing	1–2 μg/kg per dose every 1–2 hours p.r.n.	25–50 μg every 1–2 hours p.r.n.	NA	
	Continuous infusion	0–0.5[a] μg/kg/hour	25–50[a] μg/hour		
Hydromorphone	Bolus dosing	0.005–0.015 mg/kg per dose every 3–6 hours p.r.n.	0.2–0.6 mg every 2–4 hours p.r.n.	0.03–0.06 mg/kg per dose every 3–4 hours p.r.n.	1–4 mg per dose every 3–4 hours p.r.n.
	Continuous infusion	0.003–0.005[a] mg/kg/hour, maximum 0.2 mg/hour	0.2–0.3[a] mg/hour		
Oxycodone	Bolus dosing	NA		0.05–0.2 mg/kg per dose Q4–6 hours p.r.n.	5–10 mg per dose every 4–6 hours p.r.n.

Note. NA = not applicable.
[a]Dosing appropriate for PCA infusion. Higher dosing may be used if patient has secured airway.

because of the FDA warning about life-threatening respiratory depression (Frizzell et al., 2017). With a bioavailability of up to 87% and a half-life of 3–5 hours, oxycodone is an excellent choice for acute pain management in the pediatric population. Hydrocodone can also be utilized but the oral form is about twice as strong as oxycodone and six to 10 times more potent than oral morphine, so it must be used in much smaller doses. Its use is often reserved for children with severe pain after surgery or those for which oxycodone is ineffective.

Side effects of opioids, including constipation, ileus, urinary retention, and respiratory depression, must be considered when electing to use them for pain control in children. Any pediatric patient receiving intravenous opioid pain medication should be monitored on pulse oximetry, especially if receiving a continuous infusion from an intravenous or epidural PCA. Respiratory depression can also occur with oral opioid use; the provider should therefore begin with low-dose use of opioid, as most children are opioid naive and may experience side effects more readily than an adult patient with chronic musculoskeletal pain. For patients with high-impact injuries such as supracondylar humerus fractures and tibial shaft fractures, where risk for compartment syndrome is high, opioids should be used judiciously to avoid oversedating the patient and masking the early warning signs such as severe pain and anxiety (Frizzell et al., 2017). Furthermore, any child prescribed opioids should be concurrently placed on a bowel regimen to prevent constipation.

Providers may be hesitant to prescribe opioids, given the large and undesirable side effect profile. Furthermore, with the current opioid epidemic across the United States, as well as the recent intravenous opioid shortage, there has been an increasing push for providers to minimize the reliance on opioids for pain control. However, there are some conditions for which opioids are not only useful but also necessary. The pain that results postoperatively from an open reduction of a fracture is moderate to severe and involves pain at the level of the bone. Opioids are excellent at targeting bone pain and thus pediatric patients who undergo open surgery for fractures should be prescribed opioids postoperatively and upon discharge from the hospital. Common pediatric fractures such as supracondylar humerus fractures vary in severity. Type 3 supracondylar fractures require surgical management. After surgery for supracondylar humerus fractures, pain is usually moderate to severe for 1–3 days, after which opioids are often no longer needed. Likewise, displaced long bone fractures that require surgical fixation are quite painful and opioids should be a part of the postoperative pain regimen. Oxycodone can be used in combination with other nonopioid analgesia for pain after fracture management. Nondisplaced fractures and those requiring only closed reduction are not usually painful enough to necessitate the use of opioids for longer than 1–2 days. Opioids are also useful after large surgical procedures such as spinal fusion, osteotomies, and slipped capital femoral epiphysis repair.

Several factors should be considered when determining how large a supply of opioids to prescribe. First, the provider must understand the patient's expected pain duration. If severe pain is expected for 2–3 days, a supply lasting this long is appropriate. When prescribing opioid analgesics, a paper prescription may be required and monitored per each state's regulatory guidelines. Discharge instructions should always include directions to call if the pain is not relieved by prescription pain medication, as this is a sign of complications such as compartment syndrome. Second, the provider must consider the individual patient's risk of developing side effects that may outweigh the benefits of the medication (Frizzell et al., 2017). For example, if the patient is a child with severe spastic cerebral palsy and respiratory issues, the amount and dosage of opioids must be weighed against this patient's increased risk of developing respiratory compromise and constipation. Furthermore, as with any patient, the provider must assess the risk for abuse of the medication. This risk is usually lower in the pediatric population, but if there is concern for potential for abuse, it should be discussed openly with the patient and the parent or guardian to develop a safe plan for the patient once he or she returns home.

Acetaminophen

Acetaminophen works by inhibiting prostaglandin H synthase (McCann & Stanitski, 2004). It is a weak inhibitor of cyclooxygenase 1 and 2 so it has minimal anti-inflammatory effects but has substantial analgesic effects (Nowicki et al., 2012). Acetaminophen can be given intravenously, orally, or rectally. It is safe for all ages, including neonates, and has been shown to improve early pain scores postoperatively (Frizzell et al., 2017). See Table 5 for pediatric dosing of acetaminophen and other nonopioid pain medications. Acetaminophen is often effective when combined with narcotic agents to target different levels of pain (McCann & Stanitski, 2004). Acetaminophen may be very helpful at addressing the pain at the level of the skin. Children with injuries or surgeries may complain of pain at the location of their cuts or incisions. For this superficial level of pain, acetaminophen is often quite useful. Although side effects are minimal, overdose can lead to liver failure; families must therefore be counseled on appropriate dosing. Intravenous acetaminophen is an excellent choice for control of postoperative pain before the patient can take oral medications, and initial studies have found it to be both safe and effective for the management of postoperative moderate to severe pain following orthopaedic surgery (Sinatra et al., 2005; Sinatra et al., 2012). In infants and children younger than 3 years, rectal acetaminophen is often a good choice, as oral administration can be difficult if the child spits out or refuses oral medications.

Nonsteroidal Anti-inflammatory Drugs

Nonsteroidal anti-inflammatory drugs have antipyretic, anti-inflammatory, and analgesic properties. They work by inhibiting cyclooxygenase in the peripheral tissues, which decreases production of prostaglandins. Prostaglandins play a major role in the inflammatory response and desensitize nociceptors leading to pain (McCann & Stanitski, 2004).

Nonsteroidal anti-inflammatory drugs can be given intravenously or orally and are generally well tolerated. They provide analgesia for longer duration than opioids, with fewer potential for side effects, and are approved for use in children older than 6 months. Use before this age is controversial due to concerns for kidney damage and prolonged bleeding (Aldrink et al., 2010). In addition, there is risk of allergic reaction and sensitivity (Berkes, 2003). Although rare, Reye's syndrome can occur with aspirin and other salicylates and therefore it is used cautiously (Bhutta, Van Savell, & Schexnayder, 2003). Nonsteroidal anti-inflammatory drugs are excellent at targeting muscle pain and should be considered for any injury or procedure where muscle damage is expected. Side effects include bleeding around the surgery site and gastrointestinal (GI) bleeding due to associating with reversible platelet dysfunction. Controversy exists about the possibility that NSAIDs may inhibit bone healing and lead to fracture nonunion. Animal studies have demonstrated this as a potential side effect; however, numerous studies in children and adolescents have shown NSAIDs to be effective and safe for use postoperatively with low risk of complications (Kay, Directo, Leathers, Myung, & Skaggs, 2010; McCann & Stanitski, 2004; Sucato et al., 2008).

Ketorolac is a nonselective NSAID that is effective in postoperative pediatric orthopaedic patients. Use for longer than 72 hours carries the risk of GI and renal damage, so its use should be limited to the immediate postoperative period (Nowicki et al., 2012). Ketorolac provides excellent analgesic effect with minimal side effects and has been shown to lead to shorter hospital stays, less GI discomfort, and decreased narcotics requirement postoperatively (Eberson, Pacicca, & Ehrlich, 1999; Watcha, Jones, Lagueruela, Schweiger, & White, 1992). The concern for nonunion and bleeding may appear especially worrisome in patients undergoing

TABLE 5. COMMONLY USED NONOPIOID MEDICATION DOSING

	Dosing	
Drug	Weight $<$50 kg	Weight $>$50 kg
Acetaminophen	10–15 mg/kg per dose every 4–6 hours[a,b]	650 mg every 6 hours[a-c]
Ibuprofen	10 mg/kg every 6 hours	400–600 mg every 6 hours
Ketorolac	0.5 mg/kg every 6–8 hours	15–30 mg every 6–8 hours
Diazepam	0.05–0.2 mg/kg per dose every 6–8 hours	2–10 mg every 6–8 hours
Gabapentin	Limited data available	300–1200 mg given night before or morning of surgery and then 300 mg 1–3 times per day postoperatively while in the hospital

[a]Dosing same for IV, oral, and rectal.
[b]Maximum daily dose: 75 mg/kg/day.
[c]Maximum daily dose: 4 g/day (650 q4-6h or 1 g q6h).

spine surgery, such as adolescents with spine fusion and instrumentation for scoliosis. However, a prospective, randomized, double-blind placebo-controlled trial by Munro et al. (2002) showed that ketorolac is effective at decreasing pain scores and the need for narcotics after spine fusion without any untoward side effects such as bleeding, hardware failure, or nonunion. Retrospective studies have shown similar results with no difference in the incidence of bleeding or nonunion between those who did and did not receive ketorolac postoperatively (Pradhan et al., 2008; Vitale et al., 2003). For providers looking to minimize narcotic use, ketorolac provides an excellent alternative that can be considered in most orthopaedic surgical procedures.

Once the patient can tolerate oral medications or is ready for discharge, ibuprofen or naproxen can be utilized for continued pain control. Use of one of these agents in combination with an oral opioid will provide improved pain control versus the use of either medication alone. Ibuprofen is safe and effective and can be given for several days around the clock to provide a baseline level of musculoskeletal pain relief. It should be avoided in patients with a known diagnosis of peptic ulcers or those with known kidney problems or solitary kidney.

Instructing families to alternately administer ibuprofen and acetaminophen every 6 hours around the clock, so that the patient is receiving a medication at least every 3 hours, will often help minimize the use and need for supplemental opioids. This method maintains a continuous blood-level concentration of analgesic medication with use of opioids only for breakthrough pain. Parents should be instructed to wake their children overnight to administer pain medication so that the child does not fall behind and wake up in severe pain.

Benzodiazepines

Benzodiazepines can be useful in helping control muscle spasm after surgery or injury. Benzodiazepines act in skeletal muscle as well as the central nervous system. Diazepam is the most commonly used antispasmodic in the pediatric orthopaedic population (Nowicki et al., 2012). Diazepam can be utilized for spasm pain that occurs as the result of long bone fractures. It has also been increasingly used for muscle spasm after spine surgery, most commonly scoliosis repair in adolescents. Recent studies evaluating rapid recovery pathways after spinal fusion for adolescent idiopathic scoliosis have used diazepam for muscle spasm as part of the protocol with positive results (Fletcher et al., 2014; Gornitzky, Flynn, Muhly, & Sankar, 2016; Muhly et al., 2016). Side effects of diazepam include respiratory depression, drug tolerance, and effects on motor function. When used in combination with opioids, the risk for respiratory depression is greater and the patient should be closely monitored when initially receiving this medication. If ordered as a standing regimen, the order should instruct the nurse to hold for respiratory rate less than 10 breaths per minute for adolescents and for rate less than 15 breaths per minute for younger children. Furthermore, diazepam does not exhibit analgesic properties, so it should always be used as part of a multimodal pain regimen in combination with analgesics and anti-inflammatories (Nowicki et al., 2012). Pediatric and adolescent patients who can differentiate types of pain often describe the muscle spasm as the worst, as it leads to cramping and worsening pain. Thus, administering diazepam every 6 hours for the first 24–48 hours after major orthopaedic surgery such as spine surgery may in fact prevent the spasm pain from intensifying, making for a quicker and less painful recovery.

Gabapentin

Gabapentin is an oral GABA analog, the mechanism of which is not completely understood (Frizzell et al., 2017). It is thought that gabapentin exhibits analgesic effects by decreasing spontaneous neural firing (Rusy et al., 2010). This may be especially helpful in spine surgery or injury along the spine such as disc herniation. It is also effective for children with amputation who experience phantom limb pain (Rusy, Troshynski, & Weisman, 2001). By decreasing spontaneous neural firing, gabapentin may reduce neuropathic pain. Its use should be considered in patients with descriptors of neuropathic pain, such as stabbing or sharp radiating pain that travels down the legs or out to the fingers.

Use of gabapentin for pain control after spinal fusion surgery has also been researched. A study by Rusy et al. (2010) found that use of a single preoperative dose of gabapentin as well as postoperative gabapentin three times per day significantly reduced morphine requirement and decreased pain scores on the day of surgery and postoperative Day 1 in pediatric and adolescent patients undergoing spinal fusion. Common side effects of gabapentin include lethargy and emotional lability, so the child should be monitored closely, especially if gabapentin is used in combination with other sedating agents. Whenever possible, it should be administered at bedtime to help decrease the sleepiness that may be associated with the medication. It may be helpful to involve the pediatric pain team if prescribing gabapentin, especially for longer term use, as the medication should be tapered slowly, so as not to induce seizures. Short-term use in the immediate postoperative period may not require a taper, but the clinician should consult the pharmacist and pediatric pain colleagues to determine appropriate dosing and duration.

Peripheral Nerve Blocks

Peripheral nerve blocks are an excellent way to minimize and control postoperative and postprocedural pain. This approach entails injection of local anesthetic near a peripheral nerve to stop the transmission of the pain signal from the peripheral to the central nervous system. The nerve block can be either a single injection or a continuous infusion of anesthetic, such as bupivacaine, with a catheter close to the nerve (Nowicki et al., 2012). Nerve blocks have the advantage over many other medications in that they are less likely to provoke systemic side effects. They also promote earlier return of bowel function and may decrease postoperative opioid requirements and reduce anxiety related to pain (Frizzell et al., 2017). Nerve block catheters are generally well tolerated and pose very little risk of complications in pediatrics even with prolonged use (Anghelescu et al., 2012; DeVera, Furukawa, Matson, Scavone, & James, 2006). For these reasons, they should be considered in patients with potential for several days of severe postoperative pain. In pediatrics, nerve block catheters are often used for pain control after major hip surgeries such as osteotomy for Perthes disease or developmental dysplasia of the hip or avascular necrosis of the femoral head. Peripheral nerve blocks should be used with extreme caution in any patient for which compartment syndrome is an expected complication; they may hinder assessment of this syndrome, whose first early warning sign is severe pain, out of proportion to the injury or procedure. Nerve blocks can also make mobility difficult, so in patients for whom early mobilization is critical, they may not be appropriate or may need to be adjusted such that the patient can participate in therapies.

Nonpharmacological Interventions

As previously mentioned, anxiety can often greatly contribute to pediatric patients' perception of pain. Careful explanation of procedures and giving the child some sense of control are often helpful in easing fears. For example, allowing patients to remove or help change their own dressing may be less frightening than having the practitioner take it off. Distraction and medical play therapy with the child life team are also very helpful. A study by Davidson, Snow, Hayden, and Chorney (2016) found that psychological interventions such as music, movies, distraction, and imagery reduced self-reported pain scores in children, at least in the immediate postoperative period. Utilization of mind–body approach is supported by the American Academy of Pediatrics. Various modalities exist to accomplish the mind–body connection including breathing techniques, meditation, and consultation with chaplain or other spiritual leader. The interventions should be modified on the basis of the patient's development age (Brown, Rojas, & Gouda, 2017). These methods are relatively easy to implement and thus should be used in combination with pharmacological interventions to optimize pain management.

Topical therapy with ice or cold may also be beneficial after orthopaedic and muscular injury. The mechanism of analgesia mediated by ice is still not well understood; it may be related to reducing incidence of muscle spasm or causing vasoconstriction that decreases inflammation in the area of injury (Ali et al., 2010). Ice application after musculoskeletal injury such as sprain or tear, or after surgery such as anterior cruciate ligament repair, is often helpful in controlling pain for the first few days. Patients and families should be instructed to check the skin frequently to avoid the risk of cold-induced tissue damage (Ali et al., 2010). Similarly, definitive evidence for effectiveness of heat application as an analgesic modality is uncertain. However, heat application may be useful after muscle strain, especially in the neck, shoulders, or back. Application of warm packs can also be used for abdominal pain and cramping related to constipation or ileus postsurgery.

Transcutaneous electrical nerve stimulation has not been studied specifically in pediatrics for musculoskeletal pain. Transcutaneous electrical nerve stimulation has been shown to be safe for use in pediatric patients with constipation. It works by transmitting electric current from a small device through the surface of the skin. Although some studies in the adult population show promise for its use for pain related to trauma, further research is needed regarding use in the pediatric population.

Likewise, well-designed studies supporting the use of acupuncture for acute musculoskeletal pain are lacking in the pediatric population. There is weak evidence that acupuncture may improve pain scores, but most studies have been conducted in adults. Nonetheless, acupuncture has been shown to be relatively safe in pediatrics and thus provides another adjunctive therapy that could be used in conjunction with intravenous and oral analgesics to manage pain. Evidence that acupuncture reduces the incidence of nausea and vomiting in postoperative pediatric patients is more robust. Multiple placebo-controlled studies in pediatrics have shown it to be as effective as pharmacological management; it thus could be considered in children with postoperative nausea and vomiting (Jindal, Ge, & Mansky, 2010).

Conclusion

Musculoskeletal pain is an individualized experience for each child and family. It is essential to intently listen to the child and to have realistic expectations for orthopaedic procedure related pain management. Although the healthcare team is of course more knowledgeable about pain and treatment modalities than children and families, shared decision making is important. The clinician's experience with musculoskeletal pain, the ability to achieve patient trust, and clear communication of the treatment will facilitate the process of recovery. Employing multimodal and multipharmacological treatment strategies based on a comprehensive understanding of various types of pediatric musculoskeletal pain will both reduce anxiety and help ensure expedient recovery for the pediatric patient.

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