

Postoperative Patient-Controlled Analgesia in the Pediatric Population: A Literature Review

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An exciting revolution in pediatric pain control has evolved in anesthesia during the past 2 decades. The creative use of systemic analgesic techniques has dramatically improved the quality of postoperative pain management. The postsurgical pediatric population is reaping the benefits of such advancements in acute pain management, as there is an increasing use of patient-controlled analgesia (PCA). The goal of PCA is to provide safe and effective postoperative pain control by achieving a continuous level of analgesia in the body, along with the opportunity for bolus doses as requested by the patient. The aim of this analgesic technique is optimal pain relief and a

high level of patient and parent satisfaction.

This review of the literature addresses safety issues, indications, contraindications, complications, and dosing regimens related to pediatric PCA. Recommendations for continuous pulse oximetry and sedation monitoring, along with individualized dosage requirements, are presented to decrease the incidence of complications. Overall, the literature shows that PCA provides adequate pain control and high levels of satisfaction for the pediatric postsurgical population and their families.

Keywords: Epidural PCA, patient-controlled anesthesia (PCA), PCA-by-proxy, pediatric pain management.

Nurse anesthetists play a crucial role in the profession of anesthesia as specialists in postoperative pain management. This requires an intricate understanding of both the neurophysiologic mechanism of pain and various treatment modalities. Postoperative pain is caused by tissue injury and the subsequent release of histamine and inflammatory mediators, which activate peripheral pain receptors (or nociceptors).¹ These nociceptors transmit the pain stimulus to the central nervous system (CNS) where pain perception and the release of pain neurotransmitters occurs. At the dorsal horn of the spinal cord there is an integration of the pain stimulus from the peripheral nociceptors and descending input from the central nervous system. As pain is a complex and multifactorial mechanism, it is important to understand that pain management involves decreasing nociceptive input into the CNS via various treatment modalities including systemic analgesics (opioid and nonopioid) and regional analgesic techniques.²

As efforts are made to improve modalities of pain control, focus must center on the often misunderstood subject of pediatric postoperative pain management. The historical beliefs that children require primarily behavioral treatment for pain and that neonates are physiologically unable to perceive pain have proved to be erroneous.³ This misconception, combined with inexperience, may lead to the limited use of analgesia and consequent harmful outcomes in the postoperative period.

It is of utmost importance that anesthesia providers are knowledgeable and proficient in assessing pain and using safe and effective pain management techniques in

the pediatric population. The use of patient-controlled analgesia (PCA) for postoperative pain control in the pediatric population is well supported in the literature and has demonstrated safe and effective outcomes for postoperative pain management.

The purpose of this article was to review the literature regarding pediatric PCA and its safety issues, indications and contraindications, complications, and dosing regimens.

Review of Literature

Anesthesia providers use evidence-based practice to guide their clinical decisions and facilitate high-quality care. Therefore, before adapting a treatment modality, the safety and efficacy must be proved.

- *Cancer and Palliative Pain Relief.* Ruggiero et al⁴ demonstrated the safety and efficacy of PCA use, over a 48-hour observation period, in 18 children with cancer pain, aged 6 to 15 years old. Patients with moderate to severe cancer pain were treated with a fentanyl background infusion (1 µg/kg per hour) plus fentanyl boluses by PCA (1 µg/kg), with a lockout time of 7 minutes. Monitoring by the participating physician included respiratory rate, pulse oximetry, heart rate, and blood pressure. Pain was assessed using the affective facial scale (AFS) or visual analog scale (VAS) based on the patient's condition and age. The PCA-specific patient assessments took place before the initiation of treatment and during treatment at 4-hour intervals. After the treatment period, the physician who initially instructed the child on the use of the PCA pump evaluated PCA efficacy and patient compliance via a questionnaire. The child answered "yes" or "no" to 7 questions and stated his or her overall feel-

ings about the PCA treatment. The questionnaires showed high levels of patient satisfaction, and 15 of the 18 children answered positively to all 7 questions.

The pain intensity scores after initiation of PCA indicated substantial pain relief when compared with the starting point; both pain scores and vital signs improved within 4 hours of treatment and appeared to remain constant over the observation period.⁴ The average dose of fentanyl delivered during the observation period to children was 16.3 $\mu\text{g}/\text{kg}$. Side effects occurred in 7 patients (39%), including itchiness (17%), vomiting (11%), and rashes (11%), which were treated with single doses of antiemetics or antihistamines. Major adverse effects such as apnea and bradycardia were not observed in the study. No mention of available reversal agents, recommended treatment for major adverse events, suggested monitoring techniques, or cautionary notes was made in the study.

The positive outcomes of this study support the safe and effective use of fentanyl PCA continuous infusions (1 $\mu\text{g}/\text{kg}$ per hour) plus fentanyl boluses by PCA (1 $\mu\text{g}/\text{kg}$) in the pediatric population.⁴ The proposed advantages include better analgesia during sleep-wake cycles and patient movement, no need for intramuscular injections, low rate of complications, overall satisfaction with pain control, and increased autonomy.⁴

Schiessl et al⁵ examined the safety and efficacy of PCA use in pediatric palliative care. According to the authors, previous studies in pediatric palliative care had revealed that pain during the last 4 weeks of life was effectively treated in only 30% of patients, morphine was the preferred opioid, and the doses needed were highly variable. The retrospective chart review by Schiessl et al included patients who died between January 1998 and January 2005 and were treated with a PCA during their last 7 days of life. Morphine was the primary opioid used, unless contraindications were present. The basal rate of the PCA pump was titrated to match the child's opioid dose at the time the PCA was initiated using standard conversion tables. Initially the pump was programmed to deliver bolus doses 1/24th of the child's daily basal opioid dose and was titrated to meet individual needs. The lockout time programmed in each pump was 10 minutes. This study did not differentiate between patients, family, or nurses triggering the bolus doses. The pump electronically recorded the boluses and events during its use. Pain was assessed and documented at regular intervals by a 0 to 10 numerical rating scale by the patient, parents, or a healthcare team member, not specified in the study. This information was manually transferred to a spreadsheet file for analysis and cross-checked for errors by an independent evaluator.⁵

Eight children met the inclusion criteria for this study; 7 patients died in the hospital and 1 at home.⁵ The median duration of PCA use was 9 days, ranging from 1 to 50 days. Based on inclusion criteria, 48 days of PCA use

could be analyzed for this study. Intravenous medication dose was expressed as a morphine equivalent dose referenced by body weight. The daily medication dose ranged from 0.32 to 18.76 mg/kg per day. Eighteen of the 48 treatment days (38%) showed an opioid increase of 30%. During the child's last week of life, the PCA parameters, including bolus dose, continuous infusion rate, and lockout interval, were changed in 7 of the 8 patients (up to 3 times daily). Results showed the medication dose increased greatly during the last week of life (median last day of life, 2.21 mg/kg per day). Adverse effects included pruritus and urinary retention (1 child each), and treatment required a change in opioid use. Supplemental drugs were administered, but no mention was made regarding the use of reversal agents. The median pain score during the last week of life ranged from 0 to 3 on a 10-point scale.

This study showed that during the last week of life, children treated with PCA analgesia had increasing and variable needs for opioids.⁵ However, pain scores remained constant despite titration of the opioid. Overall, this retrospective study showed PCA pumps to be an ideal analgesic for pain control based on clinical condition and individual needs. Emphasis was placed on the importance of continuous monitoring and assessment because changing parameters were imperative to meeting the analgesic needs of dying children, which are often underestimated.⁵

• *Postoperative Pain Relief.* Chiaretti et al² evaluated the safety and efficacy of a fentanyl PCA plus a midazolam infusion after neurosurgical procedures. This prospective study involved 16 children with an age range of 6 to 15.2 years old. The PCA pump was set to deliver a fentanyl bolus dose of 1 $\mu\text{g}/\text{kg}$ with a 7-minute lockout time, along with a midazolam infusion of 2 $\mu\text{g}/\text{kg}$ per minute. The participating physicians instructed the children on how to use the PCA device, and the authors stated that no child was neurologically or physically impaired. Blood pressure, heart rate, respiratory rate, and pulse oximetry were monitored and pain scores were recorded using the AFS, VAS, and Children's Hospital of Eastern Ontario Pain Scale (CHEOPS). Vital signs and pain scores were documented before treatment and in 4-hour intervals for a 48-hour period by a physician trained in pain relief therapy and pain intensity assessment.²

After the treatment period, the physician who initially instructed the child on the use of the PCA device administered a questionnaire regarding the child's compliance and the treatment modality. The questionnaire included 7 questions, desiring affirmative or negative answers from the children, ending with their individual overall opinion regarding the PCA treatment.² Sample questions from the questionnaire included "Are you satisfied from the pain relief," "Did you find any particular problem during the treatment," and "Did you find it important to manage your pain by yourself?". The postintervention question-

naire indicated a high level of patient satisfaction.

The study found pain scores were reduced after the intervention, along with a statistically significant reduction in respiratory rate, blood pressure, and heart rate.² Total fentanyl doses averaged 16.3 µg/kg in the 48-hour period and each patient self-administered a range of 6 to 25 boluses. Four of the 16 patients (25%) experienced minor side effects, including itching, vomiting, and maculopapular rash, which were treated with antihistamines and antiemetics.² No major side effects such as apnea and bradycardia were noted.

The results of this study suggest that PCAs are an appropriate method of providing postoperative pain control.² Advantages of PCA use compared with conventional analgesic regimens include patient satisfaction due to the autonomy associated with self-administering bolus doses and decreased delay between requesting analgesia and delivery. Recommendations include regular pain assessment and appropriate analgesic selection based on patient status, such as the combination of fentanyl and midazolam to allow postoperative pain and anxiety control.

- *Patient-Controlled Analgesia by Proxy.* Unique characteristics of the pediatric population, such as young age and impaired cognition, shine light on the issue of PCA use by proxy, which is the delivery of medication from a PCA device by somebody other than the patient. Voepel-Lewis et al⁶ performed a study in opioid-naïve children with the purpose of comparing the adverse outcomes in children who self-administered PCA analgesia versus those receiving PCA by proxy for postoperative pain relief. This retrospective study included data from 302 patient hospital records; 145 children received PCA by proxy and 157 self-administered PCA. Morphine was the primary opioid in 95% of the PCA-by-proxy patients and in 91% of the traditional PCA patients, with hydromorphone being used in the remaining patients. The mean morphine continuous infusion rates were 0.001 ± 0.005 mg/kg per hour and 0.008 ± 0.006 mg/kg per hour for the PCA-by-proxy and self-administering PCA groups, respectively. Bolus doses ranged from 0.26 ± 0.05 mg/kg per 4-hour lockout for both groups.

Data were obtained hourly for the first 4 hours after surgery, every 4 to 8 hours for 24 hours, and then daily through 72 hours postoperatively.⁶ Information obtained included total opioid, benzodiazepine, and analgesic administration, highest sedation and pain score, supplemental oxygen administered, and lowest oxygen saturation and respiratory rate. The FACES scale or a numeric 0 to 10 scale was used to assess pain, and the FLACC (Face, Legs, Activity, Cry, Consolability) tool was used for a behavioral assessment. The Pediatric Pain Service assessed all patients in the study at least 2 times daily, and continuous monitoring included pulse oximetry. Adverse events included bradypnea (respiratory rate < 16/min for ages <6 months; <12/min for ages 6 months to 1 year; <10/min for

ages 3-10 years; <8/min for ages >10 years), minor and major oxygen desaturation (minor desaturation was defined as >5% to <10% decrease from baseline, and major desaturation was >10% decrease), and oversedation (difficult to arouse, unarousable, or deep sedation).⁶

This study found a large number of children experienced adverse events. The PCA-by-proxy group was at an increased risk of adverse events requiring rescue interventions such as airway management (bag-mask ventilation or artificial airway), naloxone, or admission to the intensive care unit, whereas the self-administered PCA group experienced threshold events requiring interventions such as supplemental oxygen or decreased opioid use. The increased severity of adverse events in the PCA-by-proxy group may be related to the prevalence of cognitive impairment in the PCA-by-proxy group. Additionally, increased opioid use and cognitive impairment on postoperative day 1 were independent risk factors for adverse events. Recommendations from this study included continuous pulse oximetry and sedation monitoring during PCA and PCA-by-proxy use, to assist in early recognition of respiratory depression and adverse outcomes.⁶

Angelescu et al⁷ evaluated the safety of PCA by proxy in pediatric oncology patients at St Jude Children's Research Hospital in Memphis, Tennessee, from February 1999 until December 2003. During 4,972 24-hour periods of PCA use, 1,011 were examined. In 576 of the 24-hour periods a PCA-by-proxy technique was used (11.6%) and the remaining PCAs were self-managed (or standard). The PCA-by-proxy criteria included a younger age group, terminal disease, neuromuscular limitation, and the expectation of repeated and painful procedures. Results showed major complications during 70 of the 4,972 24-hour observations, with 35 (0.7%) being neurologic, 28 (0.56%) respiratory, and 7 (0.14%) both. Of the 576 PCA-by-proxy observations, only 4 situations resulted in complications: 2 respiratory and 2 neurologic. The use of naloxone to reverse opioid-related respiratory distress was required in 3 cases: 2 in the standard PCA group and 1 in the PCA-by-proxy group.

The authors suggested that the low incidence of serious side effects in the PCA-by-proxy group (0.87%) compared with the standard PCA group (1.48%) may be due to the characteristics of St Jude Hospital's patients and families. Families are often extremely involved in care and skilled at assessing their child's status and symptoms. Additionally, the children are often not opioid-naïve. This is a limitation of the study and may decrease the generalizability of its findings to other populations.

The findings suggest that PCA by proxy is a safe means of administering analgesia. Recommendations to increase safety included education of proxy users, accurate clinical documentation, careful adherence of institutional guidelines, and careful selection of eligible patients.⁷

Monitto et al⁸ describe parent-nurse-controlled analge-

sia (PNCA) in patients younger than 6 years of age who received PNCA for the treatment of postoperative pain or painful medical conditions. The observational study aimed to determine patient demographics, effectiveness of analgesia, and the incidence of complications with PNCA use. The analgesic effects were found to be similar to those seen in previous studies in older children receiving bolus only or PCA plus basal infusion. It was noted that direct comparison to PCA is limited because the younger patients had their pain assessed by nurses using observational pain scales versus the VAS used in older children. In addition, surrogate measures of pain, such as crying, can be caused by other factors, which can contribute to incorrect measures of pain. As can be anticipated from the previously mentioned studies, the most noteworthy opioid-induced side effect was respiratory compromise. Nine of the 212 patients were treated with naloxone because of severe respiratory compromise. It is difficult to determine whether these incidents are the result of overdosage, the concomitant use of other sedative drugs, coexisting disease, and/or the use of analgesia by parent or nurse. Although the use of PNCA was deemed as safe, close monitoring and treatment protocols are essential.

A study by Choi et al⁹ assessed the optimal basal infusion dose of fentanyl by parent-controlled analgesia to preverbal children undergoing cleft palate repair, along with their parents' satisfaction with participating in care. The patients in this study had a mean age of 1.2 years and a mean body weight of 10.2 kg. Postoperatively, all patients received a continuous basal dose of fentanyl by PCA. At this time the parents were educated on the PCA device, Wong-Baker FACES Pain Rating Scale, and monitoring for adverse outcomes. Their role included delivering bolus doses, assessment of analgesic response, and monitoring for adverse effects such as respiratory depression, nausea, and vomiting. The results showed that an optimal basal dose of fentanyl for preverbal children undergoing cleft palate repair was 0.63 µg/kg per minute. Additionally, there was an 87% parent satisfaction rating regarding participation in analgesia delivery.⁹

Discussion

Patient-controlled analgesia has proved to have positive outcomes for the pediatric postsurgical population by facilitating pain relief in the postoperative period, increasing autonomy, and maintaining stable hemodynamics. However, a limited understanding of the pharmacokinetics and pharmacodynamics of opioids in children raises a valid concern about the safety of PCA.³ The anticipated risk of opioid overdose and respiratory depression often results in suboptimal analgesia and inappropriate dosing intervals. The result of this concern is further augmented by the fact that many anesthesia providers have a lack of experience in assessing pain in the non-verbal pediatric population.

This review of the literature presents the findings of multiple studies validating the safe use of PCA in the pediatric population. There was, however, an emphasis placed on the need for continuous monitoring to quickly detect and treat adverse outcomes.^{4,6,7,10} The development of institutional policies regarding appropriate monitoring, availability of reversal agents, and treatment protocols may increase provider comfort with using PCA in the pediatric population. Recommendations were also made regarding education for parents, as their involvement is frequently associated with positive outcomes.^{8,9} Overall, it may be assumed that with an adequate understanding of developmental pharmacology and physiology, PCA pumps are an excellent form of postoperative pain management.

An important factor in safely instituting and managing PCAs in the pediatric population is using reliable subjective and objective tools to assess pain. The above studies used the AFS, VAS, 10-point scale, CHEOPS, Wong-Baker FACES scale, posttreatment questionnaires, and/or vital signs to assess pain level. The chosen method of assessing pain should encompass both subjective and objective pain scales and be based on a combination of the child's age, cognitive and physical status, and clinical situation.

Major advantages of PCA pumps include a decreased need for uncomfortable intramuscular injections and a continuous opioid blood level titrated to the patient's individual needs.³ Ruggiero et al⁴ evaluated the use of PCA specifically in children with cancer pain but found safety in using fentanyl PCA, rapid and effective pain control, no need for additional analgesics, and high levels of patient satisfaction. Specifically, this study found a continuous background infusion to be advantageous in this population, as analgesia was delivered during sleep and with patient movement, resulting in constant pain relief.⁴ Ruggiero et al found effective and safe doses for fentanyl PCA in the pediatric population to be 1 µg/kg per hour with bolus doses of 1 µg/kg. Another study, performed by Choi et al,⁹ found safe basal doses of fentanyl for preverbal children to be 0.63 µg/kg per minute, which may be used as a baseline for anesthesia providers. Furthermore, the use of a PCA pump benefits the patient and families, providing the opportunity for children to control their pain and to feel directly involved in the management of their illness.⁹

Ruggiero et al, Choe et al, and Chiaretti et al² used intravenous fentanyl as the primary opioid in their studies, whereas Schiessl et al⁵ used morphine. Although the results remain similar, special attention must be given to the pharmacologic differences between fentanyl and morphine. Morphine is a hydrophilic opioid; it may have a slower onset and longer duration of action. On the other hand, fentanyl, a lipophilic opioid, has a more rapid onset, shorter half-life, and lacks some of the cardiovascular and respiratory side effects often associated with less lipophilic agents.² These drug characteristics allow fentanyl to be an ideal agent for intravenous PCA titrateability.²

Contraindications to self-administering a PCA in the pediatric population include young age and physical or cognitive disabilities due to an inability to understand the entire process.¹¹ It may be difficult for children to comprehend that immediate pain relief after activating the PCA pump is impossible. Parents should also be educated regarding the onset time necessary for analgesics to reach their peak effect. For appropriate self-administration of a PCA, the child should have an understanding of the relationship among pain, pushing the button, and pain relief. The child should also have the ability to verbalize increasing or decreasing pain so that appropriate adjustments can be made to the PCA. Therefore, a combination of age, cognitive ability, and physical ability should be thoroughly evaluated before using a PCA. Studies have shown success with children 8 to 9 years old, and some success with children 4 to 7 years old.¹¹

The previously discussed issue has resulted in the advent of family- and nurse-controlled analgesia. Family- and nurse-controlled analgesia, collectively referred to as PCA by proxy, in the pediatric population presents diversity from traditional PCA use. Nurse-controlled analgesia is done in the same manner as “as-needed” (prn) dosing and is a desirable choice for titrating postoperative analgesia for children with developmental disabilities.¹¹ Family-controlled analgesia is used when the child is deemed inappropriate to control the PCA for reasons such as young age, terminal disease, expectation of repeated or painful procedure, and cognitive or physical deficits.⁷ Current literature strongly advocates for the safety and efficacy of PCA by proxy. Because parents are often involved in delivering analgesia to their children by PCA, it is important to receive input from parents regarding their perception on the effectiveness of pain relief. Choi et al⁹ studied parents’ feelings regarding their involvement in pain relief and found a high level of satisfaction.

Pediatric patients are at risk of adverse events resulting from opioid administration because of their weight, age-related pharmacokinetics and pharmacodynamics, and clinical condition.¹¹ Multiple studies suggest that the adverse events associated with PCA and opioid administration include respiratory depression, oversedation, nausea, pruritus, constipation, urinary retention, and dysphoria.³ Lehr and BeVier¹¹ suggest that the risk of respiratory depression associated with PCA use is augmented by the concurrent use of sedatives, hypnotics, and antihistamines. However, Chiaretti and colleagues² advocate for the addition of a basal midazolam infusion, as it appears to normalize the sleep-wake pattern and reduce anxiety. Treatment modalities included antiemetics for nausea, antihistamines for pruritus, reversal agents for

oversedation and/or respiratory depression, and discontinuing and/or changing the specific medication being administered. The authors’ findings further support standard dosage protocols and adjustments according to individualized response. In addition, continuous age-appropriate assessment and monitoring via pulse oximetry, respiratory rate, and level of consciousness are vital to preventing adverse events.¹¹

Summary

Children undergoing surgical procedures often experience severe postoperative pain. This review of the literature addressed the positive outcomes, safety and efficacy, indications, contraindications, side effects, and variations of PCA use in the pediatric population. It may be used as a guide for anesthesia providers to educate themselves and provide excellent postoperative pain management to pediatric patients.

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