BRIEF REPORT

Patient- and Nurse-Controlled Analgesia: 22-Year Experience in a Pediatric Hospital

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ABSTRACT

OBJECTIVES: Pediatric pain management has rapidly changed over the last 2 decades. In this study, we describe the changing practices and adverse events (AEs) related to patient-controlled analgesia (PCA) and/or nurse-controlled analgesia (NCA) over a 22-year period.

METHODS: After institutional review board approval, retrospective data from a single tertiary-care pediatric hospital were collected between 1994 and 2016. Subgroup analyses were done for surgical and medical case patients. We reported the number of times that PCA and/or NCA was ordered annually, the median and interquartile ranges for age, PCA and/or NCA duration and length of stay, and AE frequencies.

RESULTS: Over 22 years, 32 338 PCAs and/or NCAs were ordered in this institution. Morphine and hydromorphone were used most commonly. Between 1994 and 2006, initial orders for PCA and/or NCA increased 2.5-fold. After 2007, initial orders for PCA and/or NCA rapidly decreased; after 2013, the decrease continued at a slower rate, with a total of 1007 orders in 2016. This decrease occurred despite increased hospital admissions and surgeries. Between 2007 and 2012, peripheral nerve blocks rapidly increased (10-fold). After 2002, 146 AEs were reported (1.0%). Of those, 50.5% were nonintercepted, and 20.6% were intercepted AEs; 5.5% and 6.2% were preventable and nonpreventable AEs, respectively.

CONCLUSIONS: PCA and/or NCA usage continues to be common in pediatric patients, although usage has declined and stabilized in the setting of other emerging methods of analgesia and increases in the number of minimally invasive surgical procedures. The overall rate of AEs was extremely low. However, improvements to eliminate all errors are needed, especially with medications with a great risk of harm (such as opioids).

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Patient-controlled analgesia (PCA) allows for the patient administration of predetermined drug doses within safety limits via a computerized delivery system. Since initial research in adults was conducted in the 1970s,[1] PCA has been used for intravenous (IV) and subcutaneous opioids as well as epidural and peripheral nerve catheter infusions.[2,3] In nurse-controlled analgesia (NCA), a PCA pump is used to deliver nurse-initiated opioids for patients unable to press the PCA button because of age or physical or developmental disabilities. We examine PCA and/or NCA for the administration of IV opioids.

Pediatric PCA use began in the late 1980s for acute postoperative pain.[4] In the first pediatric PCA clinical trial, researchers reported lower pain scores when compared with intramuscular opioids.[5] Over time, pediatric PCA and/or NCA has become widespread for treating surgical pain,[4,6,7] hematologic conditions,[8] cancer, and patients receiving palliative care.[9,10] Benefits include the following: avoidance of delay, individualized titration and a sense of control,[11] and higher patient satisfaction.[12] Researchers have shown that PCA provided a statistically significant, although clinically small, pain score reduction with similar side effects when compared with non-PCA opioids.[13,14] PCA opioid sparing has been used as an ethically acceptable, pragmatic end point in pediatric analgesic trials.[15]

Despite widespread use, little information exists about trends in pediatric PCA and/or NCA use and overall safety. In this study, we analyzed PCA and NCA trends at a single institution over a 22-year period.

METHODS

Design

Institutional review board approval was obtained. Retrospective data from inpatients (age <19 years) who received PCA and/or NCA at a tertiary-care pediatric hospital (currently 404 beds) between 1994 and 2016 were collected. The PCA pump changed from Abbott Lifecare in the 1990s to Hospira LifeCare in ~2000, and it changed to Alaris in 2014.

In overlapping searches, information on hospital admissions and PCA and/or NCA administrations from multiple sources was retrieved (Fig 1). Parent-controlled analgesia is restricted to patients with life-limiting illnesses and is used for <1% of all PCA administrations; these patients are included in the totals.

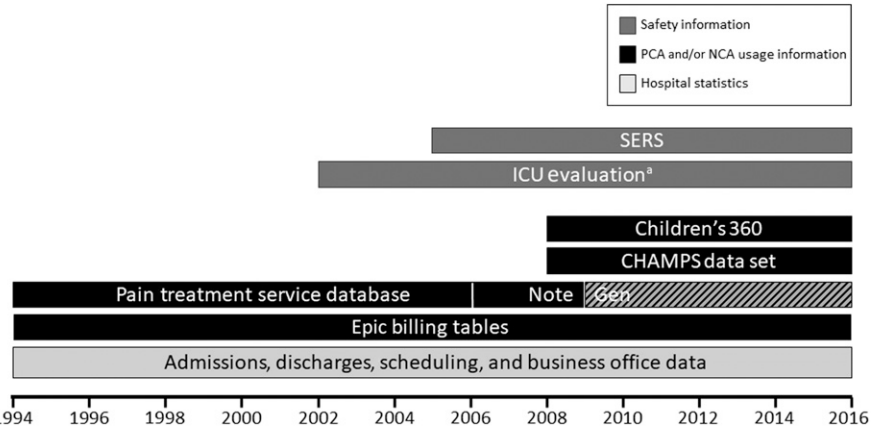

FIGURE 1 Data sources by year. CHAMPS contains the information on the Cerner-based electronical medical record. Children's 360 is an informatics platform that allows for the querying for and reporting of clinical data managed by the Information Services Department. [a] The ICU evaluation's database did not include data on PCA errors. CHAMPS, Children's Hospital Applications Maximizing Patient Safety; SERS, Safety Event Report System.

Subgroups

The surgical subgroup included patients with PCA and/or NCA and a *Current Procedural Terminology* (CPT) code for major surgery. Patients undergoing spinal fusions were analyzed independently because historically they had high opioid use. The medical subgroup included patients with PCA and/or NCA and without documented CPT codes. Patients presenting with sickle cell disease and vaso-occlusive episodes (VOEs) were analyzed separately because of high pain scores and frequent PCA and/or NCA usage.[16]

Safety

We used standard definitions of medical errors as preventable failures in the process of care and definitions of adverse events (AEs) as both preventable and nonpreventable, unintended consequences of medical care that potentially lead to patient harm.[17,18] Safety data were collected since 2002 from the Safety Event Report System, ICU transfers and evaluations, and NoteGen databases (Fig 1). Two authors (C.D. and J.S.) reviewed and classified AEs in agreement as the following: preventable if the error led to injury or harm, nonintercepted potential if the error had potential for harm but failed to adversely affect the patient, intercepted potential if a potentially harmful error did not reach the patient because of clinician intervention, error with little potential for harm, and nonpreventable if injury or harm occurred with no error.[17]

Statistical Methods

An Excel database containing PCA and/or NCA administrations (1994–2016) was created. The total number of times PCA and/or NCA were ordered per year, the median and interquartile ranges (IQR) for age, and PCA and/or NCA duration and length of stay (LOS) are reported; differences between years were assessed by using the Wilcoxon rank test. Linear regression and a structural change analysis were conducted for trends over time by using R[19] (strucchange package).[20] AE frequency tables and reports of individual case patients are described.

RESULTS

PCA and/or NCA Administrations

Over the 22 years, a total of 32 338 PCA and/or NCA initial orders were reported. The structural change analysis of the PCA and/or NCA administration trends over time revealed the best fit at 4 break points: 1996, 1999, 2007, and 2013 (Bayesian information

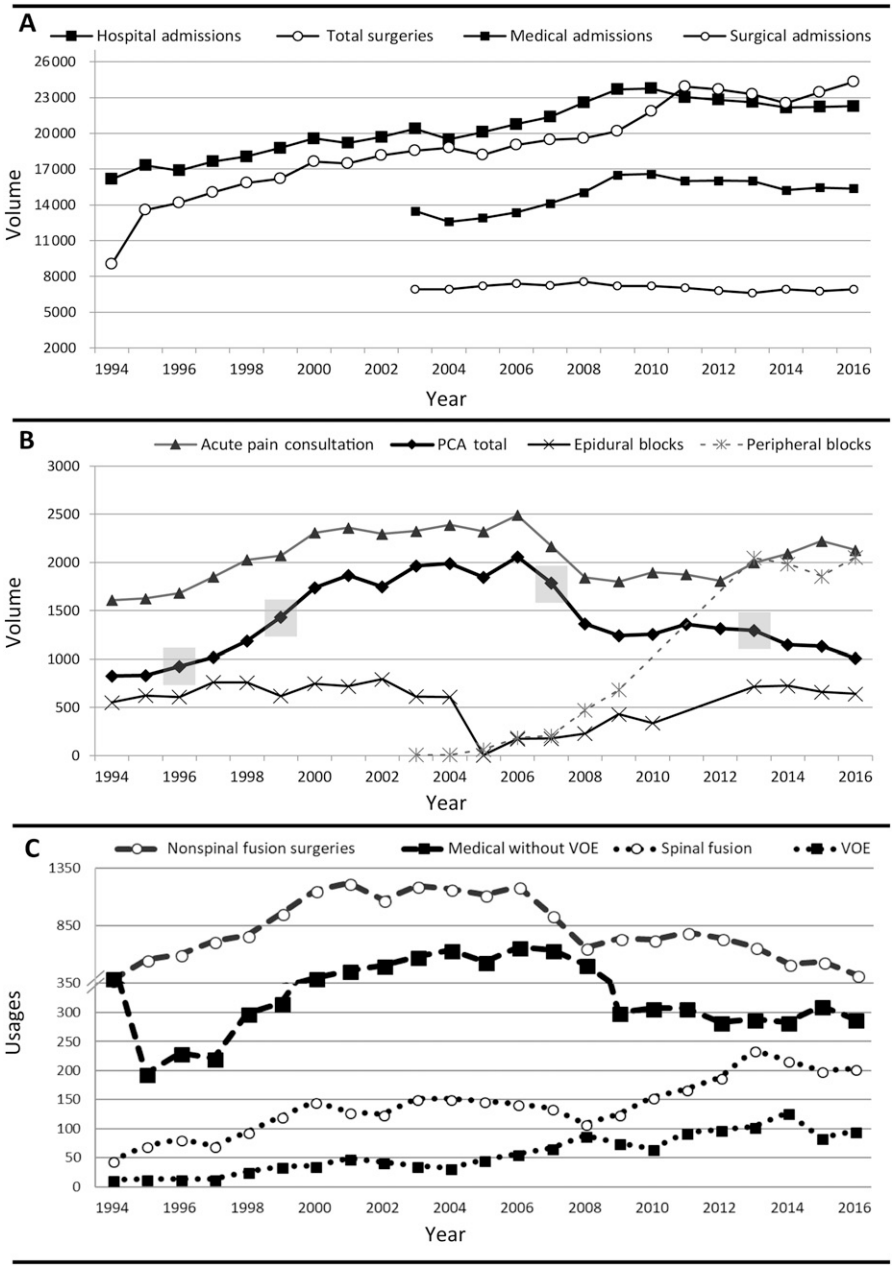

FIGURE 2 Trends over time for admissions, surgeries, and PCA and/or NCA administrations. A, Patient volume. Data on surgical and medical admissions were unavailable before 2013. B, Acute pain service patient volume. Acute pain consultation refers to inpatients exclusively. Peripheral blocks include both inpatients and outpatients. Shadow panels reflect time series structural change break points. C, Total number of PCA usages.

criterion: 306.9). Between 1999 and 2007, PCA and/or NCA administrations increased 1.3-fold. After 2007, PCA and/or NCA administrations rapidly decreased; then, after 2013, the decrease continued at a slower rate (Fig 2B). This decrease occurred despite increased hospital admissions (16 162 in 1994, 20 756 in 2006, and 22 284 in 2016; $P < .001$) and surgeries (9023 in 1994, 19 015 in 2006, and 24 327 in 2016; $P < .001$; Fig 2A). After 2007, the number of peripheral nerve blocks increased: 208 in 2007, 2047 in 2013, and 2056 in 2016 ($P < .001$; Fig 2B). Most peripheral nerve blocks were single-shot injections (73%) versus continuous infusions (27%).

Morphine and hydromorphone were the most common opioids used among PCA and/or NCA administrations for both medical and surgical patients. Over time, the percentage of PCA and/or NCA administrations in which morphine was used decreased (94% in 1994 and 72% in 2016; $P < .001$), whereas the percentage in which hydromorphone was used increased (1% in 1994 and 28% in 2016; $P < .001$). Fentanyl administrations were infrequent among both surgical (1%) and medical patients (5%).

Subgroups

Although the number of surgical patients increased 2.7-fold between 1994 and 2016 (Fig 2A), the percentage of inpatient surgeries decreased (37% in 2003, 32% in 2010, and 28% in 2016). Over 22 years, the PCA and/or NCA duration for surgical patients (excluding patients undergoing spinal fusions) remained ~1 day (1994: IQR 1–1 day; 2016: IQR 1–3 days; $P < .001$), whereas the median LOS increased from 3 days (IQR 2–5 days) to 6 days (IQR 4–11 days; $P < .001$). PCA and/or NCA administrations for patients undergoing spinal fusions increased 4.5-fold (Fig 2C), which is consistent with the increases in the number of spinal fusions performed. The median PCA and/or NCA duration decreased from 3 days (IQR 2–4 days) to 1 day (IQR 1–1 day; $P < .001$), and LOS decreased from 7 days (IQR 6–8 days) to 4 days (IQR 3–5 days; $P < .001$).

Medical admissions increased slowly (1.1-fold between 2003 and 2016). Between 1994 and 2016, medical patients (excluding those with VOEs) had a median PCA and/or NCA duration that increased from 1 day (IQR 1–3 days) to 5 days (IQR 3–11 days; $P < .001$), and LOS increased from 6 days (IQR 3–11 days) to 15 days (IQR 5–33 days; $P < .001$). Annual PCA and/or NCA administrations in patients with VOEs increased ~10-fold; the median PCA and/or NCA duration went from 4 days (IQR 2–5 days) to 3 days (IQR 2–4 days; $P = .077$), and LOS went from 7 days (IQR 5–9 days) to 4 days (IQR 3–5 days; $P = .0039$).

Safety

No fatalities or permanent changes in patient condition were ascribed to PCA and/or NCA usage (Table 1). Between 2002 and 2016, there were 16 806 PCA and/or NCA administrations and 146 errors (~1.0%).

Two patients were transferred to the ICU for PCA- and/or NCA-related AEs. Neither required ventilatory support. Six patients required ICU evaluation, but none required transfer because of PCA and/or NCA AEs (eg, somnolence, bradypnea, and desaturations resolved by stimulation, oxygen, and decreased dosage). Thirty events were intercepted with the potential for harm, including dosing errors discovered by nurses and/or clinicians during independent double-checking at the transfer of care. Seventy-four were nonintercepted with the potential for harm. The most common errors were the transposition of bolus versus infusion doses and 1-hour–limit programming errors. Twenty-five errors were errors with little potential for harm, such as inadvertently clamping or flushing tubing.

We are aware of several incidences of opioid misuse. Five patients clamped tubing, pressed the PCA button several times, and then unclamped the tubing to receive a bolus several times greater than the programmed dose. One patient inserted a pen into the Abbott Lifecare PCA pump where the PCA tubing exited to self-administer opioid by depressing the plunger on the syringe, which led to excess drug administration without record on the pump. We approximated this patient's use to be 204 mg of hydromorphone (93 mg undocumented) over 5 days.

TABLE 1 PCA- and/or NCA-Related AEs, $N = 146$

AEs	*n*	%
Preventable AE		
Severe	2	1.4
Mild to moderate	6	4.1
Nonintercepted potential AE	74	50.7
Intercepted potential AE	30	20.6
Error with little potential for harm	25	17.1
Nonpreventable AE	9	6.2

DISCUSSION

PCA and/or NCA usage continues to be common in pediatric patients, although usage has declined since 2006, and admissions continued to increase. These trends seem to correspond to several factors, including increased numbers of minimally invasive surgeries, peripheral nerve and plexus blocks, and use of opioid-sparing medications.

Minimally invasive surgeries have decreased LOS and opioids administered via PCA and/or NCA.[21,22] For example, in this institution, patients often received postoperative PCA and/or NCA after an open pyeloplasty. The first laparoscopic pyeloplasty was performed in 2000 (2 laparoscopies versus 44 open); currently, this is more common than the open procedure (39 laparoscopies versus 19 open), decreasing the need for PCA and/or NCA. There are similar trends in other surgical specialties. In our sample, surgical patients had an increased LOS, whereas PCA and/or NCA duration stayed stable. We hypothesize that otherwise healthy patients after minimally invasive surgeries no longer receive PCA and/or NCA, whereas patients with complex conditions remain hospitalized and receive PCA and/or NCA.[23]

In the past decade, there has been an emphasis on opioid-sparing analgesic approaches, including regional anesthesia, acetaminophen (including IV), nonsteroidal anti-inflammatory drugs, gabapentin, and low-dose ketamine.[24,25] The use of local anesthetic infusions via peripheral nerve catheters increased ~10-fold (2003–2016). Wider application of regional anesthesia was facilitated by a dedicated team to perform ultrasound-guided blocks.

In previous studies, researchers suggested a range of severe AEs of 0.4%[26,27] to 24%.[28] In our study, we showed a low rate of severe AEs (1 in 10 000 PCA and/or NCA orders) and close to 1% of errors. PCA and/or NCA are relatively safe when administered within a comprehensive management system. In this institution, pain treatment service providers write all PCA and/or NCA orders for surgical patients and/or directly manage or consult all patients on PCA and/or NCA. Once written, PCA and/or NCA dosing requires an independent check by 2 nurses and a pharmacist on initiation and with each dose change. A pain treatment service nurse practitioner or fellow is in-house 24/7. PCA and/or NCA events are reviewed for continuous quality improvement. Over the years, we have standardized PCA and/or NCA concentrations and clarified order sets, the formulary, and policies. There are monitoring guidelines for patients who are at risk. Our current PCA pump (Alaris) has weight bands with hard and soft limits.[29] Automated dose range checking, which is available for most medications in the electronic medical records, may reduce PCA errors.

Our study was limited by the retrospective design; the use of multiple, overlapping data sets that have evolved over time; and the use of CPT and *International Classification of Diseases, Ninth* and *Tenth Revision* codes, which may not be accurate for classifying patients.

CONCLUSIONS

PCA and/or NCA remain important means for administering opioids for pediatric patients undergoing major surgery, with VOEs, with severe cancer pain, and with advanced illness with short longevity. Pediatric PCA and/or NCA had good safety in this series. A comprehensive institutional approach is recommended to foster safety and effectiveness.

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