Continuous Peripheral Nerve Blockade for Inpatient and Outpatient Postoperative Analgesia in Children

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BACKGROUND: This is an audit of the continuous peripheral nerve blockade (CPNB) program that was implemented at our institution to provide postoperative analgesia after orthopedic procedures in children.
METHODS: We reviewed the departmental regional anesthesia registry and the medical records of consecutive children who received CPNB for postoperative analgesia at The Children's Hospital of Philadelphia between February 2003 and July 2006. Patients were prospectively followed until cessation of the effects of CPNB and/or resolution of any related complications. Data collected contemporaneously included presence of sensory and motor blockade, pain scores in inpatients, opioid administration, and complications related to CPNB.
RESULTS: A total of 226 peripheral nerve catheters were placed in 217 patients. One hundred eight patients (112 catheters) were discharged home with CPNB. The ages ranged from 4 to 18 yr (13.7 ± 3.4). Local anesthetic solution (0.125% bupivacaine [$n = 164$], 0.1% ropivacaine [$n = 12$], or 0.15% ropivacaine [$n = 27$]) was infused at an initial rate of 2–12 mL/h based on patients' weights and locations of catheters. The mean duration of local anesthetic infusion was 48.4 ± 29.3 h (range 0–160 h). The percentage of patients who did not require any opioids in the first 8, 24, and 48 h after surgery was 56%, 26%, and 21%, respectively. The incidence of nausea and vomiting was 14% (13% in outpatients, 15% in inpatients). Complications were noted in 2.8% of patients. Three patients had prolonged numbness (>24 h) that resolved spontaneously; one developed superficial cellulitis that resolved with a course of antibiotics; one had difficulty removing the catheter at home and one developed tinnitus 24 h after starting CPNB that resolved quickly after clamping of the catheter followed by removal.
CONCLUSION: It is feasible to implement a CPNB program to provide an alternative method of inpatient and outpatient postoperative analgesia after orthopedic surgery in children when appropriate expertise is available. Patient and family education along with frequent follow-up are crucial to detect and address adverse events promptly.
(Anesth Analg 2007;105:1234–42)

Over the past few years, continuous peripheral nerve blockade (CPNB) for postoperative analgesia has emerged as a safe and effective technique in adults. Several prospective studies have demonstrated the benefits of CPNB after orthopedic surgery (1–4). The advantages include site-specific analgesia, fewer side effects when compared with other methods of analgesia, early discharge from the hospital, and significant reduction in health care utilization and costs (5). However, complications such as nerve injury and infection have also been reported with CPNB, particularly after femoral perineural catheters (6).

There is a paucity of data in the medical literature regarding the feasibility, safety and efficacy of CPNB in a pediatric population. Only a few case reports and small patient series have been published describing the use of CPNB in children (7–11) during the postoperative period, and in the only report in which children were sent home with nerve catheters, the CPNB was used to manage complex regional pain syndrome (10). In January 2003, we implemented a program to provide CPNB for postoperative analgesia in children after a variety of surgeries, including day-surgery procedures. Data were collected prospectively and entered into a departmental regional anesthesia registry.

The purpose of this review of our database was to determine the feasibility of placing peripheral nerve catheters in children and to analyze the problems

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Accepted for publication July 9, 2007.

Dr. Jeffrey M. Feldman, Section Editor for Technology, Computing, and Simulation, was recused from all editorial decisions related to this manuscript.

Conflict of Interest: None.

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DOI: 10.1213/01.ane.0000284670.17412.b6

faced after discharge home with a continuous infusion of local anesthetic.

METHODS

After obtaining approval from our IRB, we obtained data of all children who received CPNB for postoperative analgesia between February 2003 and July 2006 at The Children's Hospital of Philadelphia by accessing the departmental regional anesthesia registry and medical records. Patients were stratified in the following age groups: 4–8, 9–12, 13–16, and 17–18 yr.

The program to provide inpatient CPNB for postoperative analgesia was implemented after a strict protocol was established, which included obtaining appropriate informed consent, frequent follow-up by the pain management service and recording of pain scores, use of opioids, and complications. All data were collected contemporaneously on all children who received CPNB and entered into a departmental regional anesthesia registry. Another key component of the implementation of the program was education and continuing education of every nurse in the postanesthesia care unit (PACU) and on the surgical floors. This was achieved through lectures and by posting information on the hospital intranet web page. The education focused on the mechanisms of the infusion pumps used for drug delivery, monitoring of these patients on the floor and the clinical recognition of potential complications related to perineural catheters (infection at the insertion site, trauma to neural tissue, leakage, disconnection from the pump and dislodgement) as well as to the local anesthetic. In addition, patient and family education regarding the nerve block procedures was stressed. Two years after implementing and monitoring the CPNB program in inpatients, the outpatient CPNB program was implemented.

General Anesthesia Protocol

General anesthesia was induced using an inhaled anesthetic (sevoflurane) or IV with propofol (3–5 mg/kg). After placement of laryngeal mask airway or endotracheal intubation without neuromuscular blockade, anesthesia was maintained with desflurane or sevoflurane in 50% nitrous oxide in oxygen. Morphine or fentanyl was administered intraoperatively by the anesthesiologist in charge of the case before endotracheal intubation or when intraoperative analgesia was determined to be inadequate, based on hemodynamic variables.

Sedation Protocol

Midazolam 0.02–0.05 mg/kg and/or fentanyl 0.5–2 μg/kg were administered IV. CPNBs were placed under sedation on the surgical floor for preoperative analgesia (in cases of trauma) or in the PACU, when the initial catheter placed under general anesthesia had failed. Continuous electrocardiogram and pulse oximetry were recorded; arterial blood pressure was obtained every 5 min.

Catheter Placement (Including Equipment) Protocol

All catheters were placed using sterile technique. Patients received antibiotic prophylaxis (Cefazolin 25 mg/kg, max 1500 mg; Clindamycin 10 mg/kg, max 900 mg in case of penicillin allergy) before catheter placement.

The following stimulating needles and catheters were used: UP-needle 19.5-gauge × 50 or 100 mm, with polyamide nonstimulating catheter 20-gauge × 50 cm (Pajunk Medical Systems, Tucker, GA) or the Plexolong needle UP 18-gauge × 50 or 100 mm with Stimulong catheter 20-gauge × 50 cm (Pajunk Medical Systems). The needle or the stimulating catheter was connected to the negative lead of a constant current nerve stimulator (Stimuplex HNS-11, B-Braun/McGaw Medical). Stimulation frequency was 2 Hz with a pulse width of 0.1 ms. Nonstimulating catheters were advanced through the needle after the initial bolus of local anesthetic. When placing stimulating catheters, the nerve was initially identified with the stimulating needle, and the catheter was then advanced while continuing to observe the response to stimulation via the catheter tip. The local anesthetic bolus was then administered via the catheter. The following local anesthetics (concentrations) were used for the bolus injections: bupivacaine (0.1%, 0.125%, or 0.25%) and ropivacaine (0.1%, 0.15%, or 0.2%). The bolus amount consisted of 0.5 mL/kg (max 20 mL) for sciatic blockade and 1 mL/kg (max 40 mL) for other blocks.

Tuohy needles (3.5 in.) with 20-gauge epidural catheters were used when catheters were placed under ultrasound guidance only (technique used only for placement of infraclavicular catheters). Ultrasound guidance was obtained using a SonoSite Micromaxx (SonoSite, Inc, Bothell, WA) ultrasound machine with an HFL38 (13–6 MHz), P10 (8–4 MHz), or SLA (13–6 MHz) transducer.

When there were doubts about the catheter placement (high stimulation threshold) or catheter effectiveness during surgery, the catheter's position was radiologically verified with contrast (Omnipaque 180, 3–5 mL) under fluoroscopy. Catheter placement was identified to be a failure if 1) the patient had an incomplete or absent sensory block on a physical examination in the postoperative period, 2) catheters became accidentally dislodged within 24 h after placement, 3) catheters were noted to be malpositioned on fluoroscopy and had a questionable efficacy clinically, and/or 4) an excessive leakage around the catheter at the insertion site was noted necessitating premature removal of the catheter.

The choice of the catheter location, the possibility of placing two catheters or blocking an additional nerve (i.e., anterior cruciate ligament [ACL] reconstruction surgery, where a single injection sciatic nerve block was performed in addition to the femoral CPNB)

depended on the extent of surgery and was discussed with the surgeons before the surgery for every patient.

PACU Protocol

After an initial examination by an anesthesiologist or a nurse practitioner on the pain management service to determine pain scores, distribution of sensory block and presence of motor block, a continuous infusion of local anesthetic through the catheter was initiated. No patient received an infusion or additional boluses of local anesthetic intraoperatively. All infusions were started at the end of surgery.

Local Anesthetic Infusion

The CADD-Prizm® PCS II Pump, Model 6101 (Smith Medical, St. Paul, MN) was used until April 2005 and the disposable Elastomeric ON-Q® pump (I-Flow Corporation, VQ OrthoCare, Irvine, CA) from May 2005 onwards. We switched to elastomeric pumps to improve safety by having a pump dedicated to CPNB infusions only and also to facilitate outpatient CPNB.

The continuous infusion of local anesthetic consisted of 0.125% bupivacaine, 0.15% ropivacaine, or 0.1% ropivacaine at a rate of 0.1–0.15 $mL \cdot kg^{-1} \cdot h^{-1}$ (max 12 mL/h). The choice of local anesthetic was based on the anesthesiologist's preference and the need to prevent a motor blockade. The infusion rate was based on the catheter location and patient's weight. The Elastomeric ON-Q pump has a rate selection of 2–14 mL/h (even numbers only); the reservoir can be filled with up to 400 mL of local anesthetic and can only be filled once. These pumps were filled by the hospital pharmacy. Bupivacaine 0.125% was the only local anesthetic available from our pharmacy until February 2006. It has been replaced since with ropivacaine.

Pain Assessment and Supplemental Analgesia

A numeric, verbal rating pain scale, ranging from 0 to 10 was used in children 6 yr or older, and the FLACC scale, which also ranges from 0 to 10, was used in children <6 yr of age (12). Morphine (0.25–0.5 mg/kg) or fentanyl (0.5–1 μg/kg) boluses were administered to patients with a pain score >3 on a numeric scale and >4 on the FLACC scale. The distribution of the sensory block was assessed using response to a cold stimulus. If pain control was satisfactory and the discharge criteria were met, patients were then transferred to the floor (inpatients) or to the day-surgery unit to be discharged home later that same day.

Inpatient CPNB Protocol

Monitoring

Pulse oximetry, respiratory rate, arterial blood pressure, pain scores, and temperature were recorded every 4 h by nursing staff. Patients were examined by the pain management team twice a day or more frequently based on the clinical findings.

Supplemental Analgesia

Oxycodone 0.1 mg/kg (max 10 mg) with acetaminophen 15 mg/kg (max 650 mg) was administered every 4 h for numeric pain scores >3 or a FLACC score >4. When patients were not tolerating oral intake or if the pain score was >5, morphine 50 μg/kg (max 4 mg) IV was given occasionally pro re nata (PRN) every 3 h. If the patient needed morphine more frequently, morphine patient-controlled analgesia was instituted.

Outpatient CPNB Protocol

Patients were discharged home only if they were comfortable and it was thought that any further breakthrough pain could be managed with supplemental oral medications. Patients who experienced a motor block were discharged from the hospital only after the motor block had completely resolved. In these patients, the catheter was clamped, the infusion discontinued and then restarted at a slower rate or with a reduced local anesthetic concentration. If the motor block recurred despite these measures, CPNB was then discontinued.

Education

Before home discharge, every patient and their family received verbal and written education about the continuous infusion device system, techniques to remove the catheter, recognition of potential complications, catheter dislodgement, and inadequate pain control. Families were also given the emergency contact information for the pain service. Patients and families were cautioned to avoid weight bearing on the extremities that were weak and also to protect insensate areas from injury (e.g., from heat, cold, pressure, and other trauma).

Supplemental Analgesia

Oxycodone 0.1 mg/kg (max 10 mg) with acetaminophen 15 mg/kg (max 650 mg) was administered every 4 h PRN.

Follow-up

A once-a-day home nurse visit was organized until the catheter was removed. Patients and families were contacted by phone daily or twice a day by a physician or nurse practitioner until resolution of the sensory block or any side effects attributable to the technique had resolved. Parents were also asked to record the duration of the sensory block, adequacy of analgesia, intake of oral opioids, presence of motor blockade, leakage around the catheter, nausea, tinnitus, dizziness, vomiting, paresthesia, and dysesthesia during the follow-up period and report these data to the interviewer. A family member was asked to remove the catheter at home as instructed. If patients developed a motor block at home or side effects suggestive

Table 1. Surgical Procedures ($n = 220$)

Category	Procedure	No. cases (%)
Knee	Anterior cruciate ligament reconstruction	44 (20)
	Others (arthroscopy and drilling for osteochondritis, incision and drainage, arthrotomy, excision of knee mass, etc.)	67 (30.5)
Hip and femur	Hip (osteotomy, arthroscopy and core decompression, osteochondroma resection)	8 (3.6)
	Femur (osteotomy, osteochondroma resection, incision and drainage and open reduction, and internal fixation	25 (11.4)
Leg, foot, and ankle	Leg (tibia and fibula osteotomies, excision of leg mass, incision, and drainage of tibia)	21 (9.5)
	Foot and ankle (foot amputation and repair of degloving injury of the foot)	10 (4.5)
Shoulder	Shoulder arthroscopy and repair including Bankhart	15 (6.8)
Humerus, elbow, forearm, and hand surgery	Open reduction and internal fixations of fractures, elbow arthroscopy and others	30 (13.6)

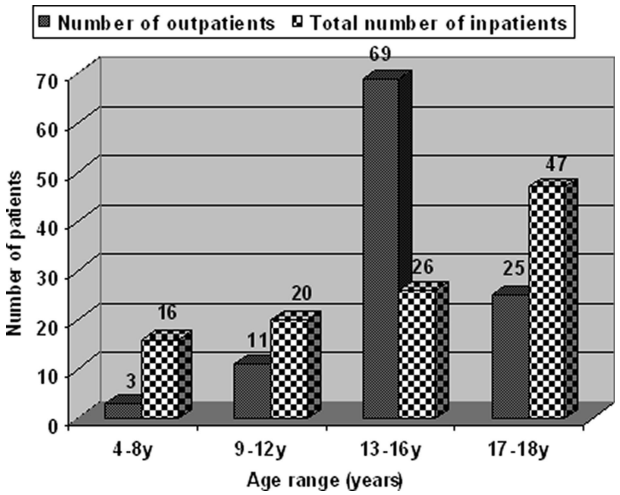

Figure 1. Age group distribution of outpatients and inpatients with continuous peripheral nerve blockade.

Table 2. Date of Discharge of Patients After Surgery who Went Home with Indwelling Peripheral Nerve Catheters

Catheter location and total number ($n = 112$[a])	POD # 0	POD # 1	POD # 2 and later
Interscalene ($n = 11$)	4	6	1
Infraclavicular ($n = 11$)	3	6	2
Lumbar plexus ($n = 2$)	0	1	1
Femoral ($n = 82$)	31	47	4
Sciatic ($n = 6$)	1	4	1

POD = postoperative day.

[a] Number of patients who were discharged home with catheters was 108 (four patients had dual catheters; hence $n = 112$).

of local anesthetic toxicity, the parents were asked to clamp the catheter and then told to unclamp it when the motor block resolved. Parents were asked to remove the catheter if the motor block recurred. If patients developed side effects suggestive of local anesthetic toxicity, parents were asked to clamp and remove the catheter.

Statistical Analysis

All data were analyzed using descriptive statistics. Data are represented by mean ± SD unless stated otherwise. Kaplan–Meier survival analysis curves were obtained using STATA statistical software (STATA Corporation, College Station, TX). χ^2 Test was used to compare categorical variables and Fisher's exact test was used when appropriate. A P value of <0.05 was considered to be statistically significant.

RESULTS

A total of 226 peripheral nerve catheters were placed in 217 patients (111 males and 106 females). The mean age was 13.7 ± 3.4 yr (range 4–18). One hundred eight patients with 112 catheters were discharged home with a CPNB (Table 1). Their mean age was 14.6 ± 2.5 yr (range 4–14). The age distribution of inpatients and outpatients are shown in Figure 1. Six pediatric anesthesiologists placed these 226 catheters. Four of the 217 patients had simultaneous dual catheters placed (three patients had bilateral femoral catheters and one patient had a femoral and a sciatic catheter). These patients were discharged home with two independent elastomeric pumps. Catheters were replaced in the operating room at the end of surgery in three patients (two femoral and one infraclavicular) and in the PACU in two patients (two lumbar plexus catheters, which were replaced with femoral catheters).

Table 2 shows the distribution of surgical procedures. Both stimulating ($n = 130$) and nonstimulating ($n = 96$) catheters were used. The initial bolus injection in the operating room via the needle or the catheter was performed using bupivacaine 0.1% ($n = 9$), bupivacaine 0.125% ($n = 147$), bupivacaine 0.25% ($n = 4$), ropivacaine 0.1% ($n = 31$), ropivacaine 0.15% ($n = 32$), and ropivacaine 0.2% ($n = 3$). The bolus amount consisted of 0.5 mL/kg (max 20 mL) for sciatic blockade and 1 mL/kg (max 40 mL) for other blocks. Opioids were administered in 59 patients while in the operating room (18 patients received 1–2 μg/kg of fentanyl and 41 patients received 0.03–0.1 mg/kg of morphine). An infusion of 0.125% bupivacaine ($n = 164$; 78 outpatients and 86 inpatients), 0.1% ropivacaine ($n = 12$; five outpatients and seven inpatients), or 0.15% ropivacaine ($n = 27$; 19 outpatients and eight

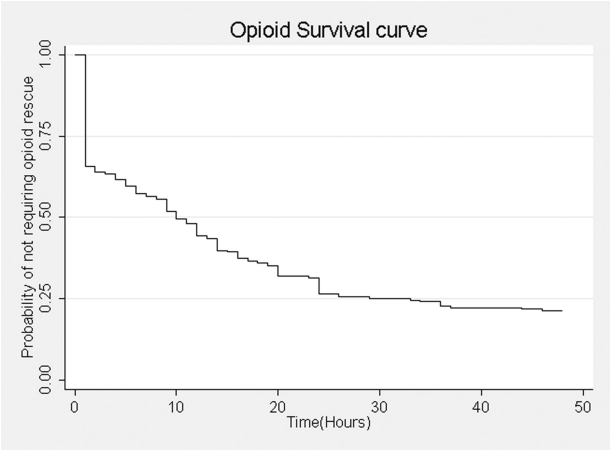

Figure 2. Kaplan–Meier survival curve showing the fraction of patients who did not receive any opioids (oral or IV) rescues, independently from the intraoperative administration of opioids, over a postoperative period of 48 h (Time 0–1 h represents time in the postanesthesia care unit).

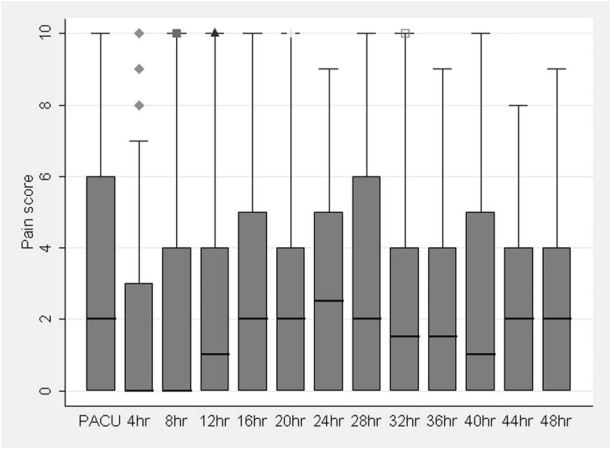

Figure 3. Maximal inpatient pain score in the postanesthesia care unit and in the 48-h postoperative period after placement of continuous peripheral nerve blockade. The boxes represent the 25–75th percentile and the extended bars the 10–90th centile. The diamonds, squares, and triangles represent the outliers. Please note that the median pain scores at 4 and 8 h was zero.

inpatients) was started in the PACU at an initial rate of 0.1–0.15 $mL \cdot kg^{-1} \cdot h^{-1}$ based on patients' weights and types of blocks. The duration of the local anesthetic infusion was on average 48.4 ± 29.3 h (range 0–160 h). The infusion pump was kept for a longer period of time in patients discharged home (59 ± 19 h; range 0–144) compared with patients who were hospitalized (48 ± 37 h; range 0–160) ($P = 0.0032$). The CADD-Prizm PCS II Pump was used in 40 patients (all inpatients) and the Elastomeric ON-Q pump in 163 patients (inpatients and outpatients).

Efficacy

When considering the postoperative requirements of opioids, 56%, 26%, and 21% of the patients did not require any opioids in the first 8, 24, and 48 h, respectively, after surgery (Fig. 2). Fifty-nine (27%) patients received opioids intraoperatively: 20 for failed catheters and 39 for intubation or tourniquet pain. In the latter group of patients small doses of fentanyl (1–2 μg/kg) or morphine (30–50 μg/kg) were used. Thirty-nine patients (18%) did not use any opioids after surgery, 106 patients (49%) required PRN opioids and 72 patients (33%) used opioids around the clock. In 89 (50%) of the 178 patients who received opioids postoperatively, pain was managed with oral medications only. Figure 3 shows the distribution of the maximal pain scores during the first 48 h.

Only one of the patients discharged home with a catheter (1%) returned to the hospital for inadequate pain control (score >8) after being discharged on postoperative Day 1. After physical examination and detection of incomplete sensory block, her femoral catheter was pulled back by 5 cm (originally threaded 12 cm into the space) and a bolus injection of local anesthetic was injected resulting in complete pain relief within 20 min. The patient returned home soon after and had good pain control for the remaining duration of the local anesthetic infusion (28 h).

The overall failure rate was 15%. Table 3 shows the failure rate for each type of catheter and the reasons for failure. Every failed interscalene catheter ($n = 5$) was due to premature dislodgement. In two patients the catheter dislodged during positioning for surgery in the operating room. In two other patients, the catheters had dislodged in the recovery room; one during a dressing change and the other when the patient accidentally dropped the elastomeric pump, which dragged the catheter out. The fifth patient's catheter was dislodged after the patient was transported to the floor and the elastomeric pump fell of the bed and dragged the catheter out. In all five of these patients the catheter was shown to be in good position on contrast study and clinically by an appropriate sensory block with the initial bolus.

Side Effects and Complications

Motor blockade was observed in 24 patients (11%) and it was most common after a sciatic nerve block (13 patients, 6%). The overall incidence of nausea and vomiting was 14% (30 of 217) (13% in outpatients and 15% in inpatients). Nausea and vomiting were significantly more frequent in those patients who received intraoperative opioids (27%), compared with those patients who did not (9%) ($P = 0.001$), independently from the postoperative usage of opioids.

Sensory complications were noted in six patients (2.8%) (Table 4). Two patients reported prolonged numbness (numbness lasting >24 h after cessation of infusion) that lasted for 36 and 72 h after removal of a femoral and an infraclavicular catheter, respectively. In another patient numbness lasted for 60 days after removal of a femoral catheter. The numbness resolved spontaneously in all three patients. There was no motor deficit in any of the cases. Prolonged numbness was considered a surgical complication in three patients. Other catheter-related complications included

Table 3. Location of Catheters Placed, Failure Rate and Reasons for Failure

		Reasons for catheter failure				
Catheter location	No. catheters failed (%)	Premature catheter dislodgement (n = 13)	Partial sensory block (n = 4)	No sensory block (n = 9)	Malpositioned catheter on radiograph (n = 7)	Catheter leakage (n = 1)
Axillary (n = 1)	0 (0)					
Femoral (n = 129)	17 (13.2)	5	2	3	6	1
Infraclavicular (n = 30)	5 (16.7)	1	1	2	1	
Interscalene (n = 16)	5 (31.3)	5				
Lumbar plexus (n = 20)	6 (30)	1	1	4		
Sciatic (n = 30)	1 (3.3)	1				

Table 4. Complications

	Complications and number			
Catheter location	Prolonged numbness	Superficial cellulitis	Difficulty removing catheter	Tinnitus
Femoral (n = 129)	2	1		1
Infraclavicular (n = 30)	1		1	

one patient who developed a superficial cellulitis 48 h after placement of a femoral catheter. The cellulitis resolved after removal of the catheter and a course of outpatient oral antibiotics. An infraclavicular catheter that could not be removed by a family member was successfully removed by gentle traction in the pain clinic. One patient with a femoral catheter developed tinnitus 36 h after an infusion of bupivacaine 0.125%, which resolved soon after the infusion was terminated. In five patients (2.3%) leakage occurred at the site of the catheter insertion. However, the catheter was removed in only one patient.

DISCUSSION

Our data show that it is feasible to implement a pediatric regional anesthesia program using peripheral nerve catheters to provide both inpatient and outpatient postoperative analgesia. During the period of data accumulation, updated equipment (stimulating catheters and ultrasound) and local anesthetic infusions (ropivacaine 0.1% and 0.15%) were incorporated into our practice. Hence, we cannot, based on our audit, draw any conclusions with respect to efficacy among the different techniques used.

Problems that families and patients can potentially face after being discharged home with CPNB include local anesthetic toxicity, infection, difficulty in removing the catheter, inadequate analgesia, leakage at the insertion, and injury resulting from a fall or trauma to an insensate extremity. To recognize and appropriately manage these potential problems, it is essential to implement an appropriate follow-up program.

Implementation of the Program

The success of this kind of program relies on the continuous education of parents and nursing staff on the appropriate monitoring of children with peripheral nerve catheters as well as on a rigorous follow-up of these patients.

An essential part of the outpatient program was the involvement of the home nursing services. The home nurse visit program carries an additional cost of approximately $250 for a 2-h period. We organized these visits in an effort to guarantee an accurate patient follow-up and to collect more precise data on the clinical outcomes of these patients. This additional cost is a fraction of the cost of a day's hospitalization at our institution, which amounts to approximately $1450 per day, not including charges for IV fluids, medications, pharmacy charges, or pain team consults.

Safety

In a large prospective study (13), no complications related to peripheral nerve blockade performed in anesthetized children were reported. However, there were no cases of CPNB in this study and complications were followed-up only when spontaneously reported, and not actively sought for in each patient. All 217 patients in our series were actively followed and specifically questioned for any potential complications. The incidence of neurological complications observed in our audit was quite low (1.3%) compared with the 6.6% incidence of neurological adverse events reported in a prospective study conducted in adults (6). Every neurological complication in our series resolved spontaneously without any residual effects. A physical examination conducted by an anesthesiologist and the surgeon helped determine if the observed complications were related to the CPNB or the surgical procedure.

Before placing a CPNB in patients undergoing procedures with a higher risk of compartment syndrome (i.e.,

tibial fractures), the anesthesiologist must discuss the plan with the surgeon, as some of them do not support the use of regional anesthetic techniques in these types of cases. If and when a decision is made to perform a CPNB in these patients, it may be prudent to use dilute concentrations of local anesthetics as this may facilitate earlier identification of compartment syndrome compared to when higher concentrations are used (14). Although there is very little evidence to suggest that regional anesthesia may mask symptoms and signs of compartment syndrome, some investigators have suggested this possibility (15,16).

The importance of frequent follow-up with repeated phone calls and nurse visits cannot be overemphasized. The report by a home visiting nurse of redness and swelling at the site of a femoral catheter insertion alerted us about the possibility of a local infection. The report over the phone by a family member of symptoms compatible with an intravascular infusion of the local anesthetic prompted us to recommend immediate removal of the catheter at home.

Four patients were discharged to home with multiple (dual) nerve catheters. Several authors have shown that plasma bupivacaine levels are within safe ranges when infused at a rate below 0.375 $mg \cdot kg^{-1} \cdot h^{-1}$ (17–19). The recommended infusion rate for ropivacaine is 0.2–0.4 $mg \cdot kg^{-1} \cdot h^{-1}$ (19). The total infusion rate in our patients ranged from 0.1 to 0.3 $mg \cdot kg^{-1} \cdot h^{-1}$ for bupivacaine and 0.05 to 0.3 $mg \cdot kg^{-1} \cdot h^{-1}$ for ropivacaine; both of which are below the recommended upper limit (19).

Data suggest that leaving an indwelling catheter for more than 48 h may be an independent risk factor for catheter colonization and local inflammation (6). Every patient in our study received prophylactic antibiotics before placement of the catheter. The absence of antibiotic prophylaxis has been shown to be an independent risk factor for superficial inflammation (6).

In the past, single-injection interscalene blocks were performed in awake or very lightly sedated children because of concerns about placement of this block in subjects under general anesthesia (20). However, the insertion of interscalene catheters in awake children and adolescents proved to be challenging because of the larger size of the block needles and the need for more manipulations to advance the catheters (21), manipulations that were extremely uncomfortable to our patients. After the introduction of real-time imaging with ultrasound for nerve localization, interscalene blocks are routinely placed under general anesthesia in our practice. The use of radiological imaging allows for a visualization of the final position of the interscalene catheters, again confirming their correct position. These additional interventions may increase the safety of interscalene catheter placement under general anesthesia (22).

Feasibility

Our data demonstrate that CPNB can be successfully performed in children by a group of pediatric anesthesiologists with interest in regional anesthesia. This audit also demonstrates the feasibility of providing CPNB in a home environment.

Thirty-nine of the 217 patients (18%) were discharged home the same day of surgery and another 69 patients (32%) were discharged subsequently with catheters. All but one patient did not have to return to the hospital or go elsewhere because of inadequate pain relief. One hundred eleven of 112 catheters (99%) were successfully removed by family members at home. Therefore, patients need not return to the hospital for removal of catheters. Elastomeric pumps are single use and do not have to be returned.

The incidence of catheter leakage was consistent with a similar observation in the previously mentioned adult study (6). The amount of leakage appeared to be limited in most of our patients. Only one catheter (femoral) had to be removed prematurely because of excessive leakage. The high rate of dislodgement observed with interscalene catheters may be explained by the fact that only a short segment of the catheter could be advanced in the interscalene area because of anatomical reasons. Interscalene catheters are now secured using Dermabond® (Ethicon, Raleigh, NC), a topical skin adhesive, at the point of skin entry and covered by a transparent dressing, Sorbaview® (3M, St. Paul, MN) to better fix these catheters. After this audit, an additional 12 interscalene catheters have been placed and only one premature dislodgement was observed (8%). Tunneling interscalene catheters may also help prevent catheter dislodgement (23).

Efficacy

The improved quality of postoperative analgesia using CPNB has been demonstrated in multiple studies (1–4,6,24,25). We did not compare CPNB with other methods of postoperative analgesia. Henceforth, it is impossible for us to demonstrate the superiority of CPNB. However, since the implementation of the program, it has been possible to discharge children home who would have otherwise been hospitalized for at least 24 h to manage postoperative pain after operations such as ACL reconstruction and Bankhart procedures. To avoid motor blockade, particularly in patients discharged home with a catheter, dilute concentrations of local anesthetics were used for CPNB. This may explain the increased need for oral opioids in our patients compared with what has been reported in the adult literature.

We observed a relative low incidence of nausea and vomiting (14%) compared with a 25%–34% incidence reported in an adult population receiving IV morphine after orthopedic procedures (26). The incidence of postoperative nausea and vomiting in our patients is similar to that seen in a randomized study (13%) evaluating CPNB in adults (27). The use of CPNB may

have resulted in a sparing effect on the use of IV opioids, with a subsequent lower incidence of nausea and vomiting.

A significant increase in the need for first opioid rescue over time was seen in our audit and has also been reported by other authors (6,28). There are several explanations for this observation. It is often difficult to achieve the same spread of local anesthetic as seen after the initial bolus with an infusion at the rates used in this series of patients. An elastomeric pump with a mechanism for patient-controlled boluses could solve this problem (27). Also many of our patients (i.e., ACL reconstruction, tibial, and fibular osteotomies) may have benefited from the placement of two catheters. A higher concentration of local anesthetic may offer additional analgesia although it may increase the incidence of motor blockade. The high rate of opioid rescue (35%) during time in the PACU may have been due to a combination of residual tourniquet pain, use of low concentrations of local anesthetic, incomplete sensory coverage by the peripheral nerve block and possibly emergence delirium. Although possible, it is unlikely that the rescue needs were related to the timing of initiation of the local anesthetic infusion as the initial bolus effect lasts for 13.2 ± 5 h as shown in one of our earlier studies (29). The use of diluted local anesthetics has, however, limited the incidence of postoperative motor blockade, which is often unsettling to surgeons, children, and their parents.

This article has significant limitations. Specifically, there is no comparison group to truly assess outcome. In addition we did not measure pain scores during rest and movement or quantify opioid use. Also, because of the limited number of patients examined in this study, the incidence of rare serious adverse events could have been underestimated. Even with these limitations, we conclude that it is feasible to set up a CPNB program to provide postoperative analgesia to children, both in the hospital and at home. Additional randomized, prospective, controlled studies are required to determine the safety and efficacy of CPNB versus other forms of postoperative analgesia in children and to determine if there is an economic benefit of CPNB for postoperative analgesia in children.

REFERENCES

1. Ilfeld BM, Morey TE, Enneking FK. Continuous infraclavicular brachial plexus block for postoperative pain control at home: a randomized, double-blinded, placebo-controlled study. Anesthesiology 2002;96:1297–304
2. Ilfeld BM, Morey TE, Wang RD, Enneking FK. Continuous popliteal sciatic nerve block for postoperative pain control at home: a randomized, double-blinded, placebo-controlled study. Anesthesiology 2002;97:959–65
3. Ilfeld BM, Morey TE, Wright TW, Chidgey LK, Enneking FK. Continuous interscalene brachial plexus block for postoperative pain control at home: a randomized, double-blinded, placebo-controlled study. Anesth Analg 2003;96:1089–95
4. Klein SM, Grant SA, Greengrass RA, Nielsen KC, Speer KP, White W, Warner DS, Steele SM. Interscalene brachial plexus block with a continuous catheter insertion system and a disposable infusion pump. Anesth Analg 2000;91:1473–8
5. Evans H, Steele SM, Nielsen KC, Tucker MS, Klein SM. Peripheral nerve blocks and continuous catheter techniques. Anesthesiol Clin North America 2005;23:141–62
6. Capdevila X, Pirat P, Bringuier S, Gaertner E, Singelyn F, Bernard N, Choquet O, Bouaziz H, Bonnet F. Continuous peripheral nerve blocks in hospital wards after orthopedic surgery: a multicenter prospective analysis of the quality of postoperative analgesia and complications in 1,416 patients. Anesthesiology 2005;103:1035–45
7. Ilfeld BM, Smith DW, Enneking FK. Continuous regional analgesia following ambulatory pediatric orthopedic surgery. Am J Orthop 2004;33:405–8
8. Tobias JD. Continuous femoral nerve block to provide analgesia following femur fracture in a paediatric ICU population. Anaesth Intensive Care 1994;22:616–8
9. Dadure C, Pirat P, Raux O, Troncin R, Rochette A, Ricard C, Capdevila X. Perioperative continuous peripheral nerve blocks with disposable infusion pumps in children: a prospective descriptive study. Anesth Analg 2003;97:687–90
10. Dadure C, Motais F, Ricard C, Raux O, Troncin R, Capdevila X. Continuous peripheral nerve blocks at home for treatment of recurrent complex regional pain syndrome I in children. Anesthesiology 2005;102:387–91
11. Sciard D, Matuszczak M, Gebhard R, Greger J, Al-Samsam T, Chelly JE. Continuous posterior lumbar plexus block for acute postoperative pain control in young children. Anesthesiology 2001;95:1521–3
12. Merkel SI, Voepel-Lewis T, Shayevitz JR, Malviya S. The FLACC: a behavioral scale for scoring postoperative pain in young children. Pediatr Nurs 1997;23:293–7
13. Giaufre E, Dalens B, Gombert A. Epidemiology and morbidity of regional anesthesia in children: a one-year prospective survey of the French-Language Society of Pediatric Anesthesiologists. Anesth Analg 1996;83:904–12
14. Dadure C, Capdevila X. [Perioperative analgesia with continuous peripheral nerve blocks in children]. Ann Fr Anesth Reanim 2007;26:136–44
15. Dunwoody JM, Reichert CC, Brown KL. Compartment syndrome associated with bupivacaine and fentanyl epidural analgesia in pediatric orthopaedics. J Pediatr Orthop 1997;17:285–8
16. Ross O. Central neural blockade and the compartment syndrome. Anaesthesia 1999;54:297
17. Johnson CM. Continuous femoral nerve blockade for analgesia in children with femoral fractures. Anaesth Intensive Care 1994;22:281–3
18. Paut O, Sallabery M, Schreiber-Deturmeny E, Remond C, Bruguerolle B, Camboulives J. Continuous fascia iliaca compartment block in children: a prospective evaluation of plasma bupivacaine concentrations, pain scores, and side effects. Anesth Analg 2001;92:1159–63
19. Ross AK, Eck JB, Tobias JD. Pediatric regional anesthesia: beyond the caudal. Anesth Analg 2000;91:16–26
20. Benumof JL. Permanent loss of cervical spinal cord function associated with interscalene block performed under general anesthesia. Anesthesiology 2000;93:1541–4
21. Singelyn FJ, Seguy S, Gouverneur JM. Interscalene brachial plexus analgesia after open shoulder surgery: continuous versus patient-controlled infusion. Anesth Analg 1999;89:1216–20
22. Soeding PE, Sha S, Royse CE, Marks P, Hoy G, Royse AG. A randomized trial of ultrasound-guided brachial plexus anaesthesia in upper limb surgery. Anaesth Intensive Care 2005;33:719–25
23. Boezaart AP. Continuous interscalene block for ambulatory shoulder surgery. Best Pract Res Clin Anaesthesiol 2002; 16:295–310
24. Borgeat A, Schappi B, Biasca N, Gerber C. Patient-controlled analgesia after major shoulder surgery: patient-controlled interscalene analgesia versus patient-controlled analgesia. Anesthesiology 1997;87:1343–7
25. Capdevila X, Barthelet Y, Biboulet P, Ryckwaert Y, Rubenovitch J, d'Athis F. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. Anesthesiology 1999;91:8–15

26. Larsson S, Lundberg D. A prospective survey of postoperative nausea and vomiting with special regard to incidence and relations to patient characteristics, anesthetic routines and surgical procedures. Acta Anaesthesiol Scand 1995;39:539–45
27. Capdevila X, Dadure C, Bringuier S, Bernard N, Biboulet P, Gaertner E, Macaire P. Effect of patient-controlled perineural analgesia on rehabilitation and pain after ambulatory orthopedic surgery: a multicenter randomized trial. Anesthesiology 2006;105:566–73
28. Grant SA, Nielsen KC, Greengrass RA, Steele SM, Klein SM. Continuous peripheral nerve block for ambulatory surgery. Reg Anesth Pain Med 2001;26:209–14
29. Cucchiaro G, Ganesh A. The effects of clonidine on postoperative analgesia after peripheral nerve blockade in children. Anesth Analg 2007;104:532–7