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Peripheral nerve catheters in children: an analysis of safety and practice patterns from the pediatric regional anesthesia network (PRAN)

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Abstract

Background: Peripheral nerve catheters (PNCs) are used with increasing frequency in children. Although adult studies have demonstrated safety with this technique, there have been few safety studies in children. The main objective of the current investigation was to examine the incidence of PNC complications in children undergoing surgery.
Methods: This is an observational, multi-institutional study using the Pediatric Regional Anesthesia Network (PRAN) database. Data pertaining to PNCs were entered prospectively into a secure, online database by each participating centre. Patient characteristics, anatomic location, localization techniques, medications used, and complications were recorded for each catheter. All complications and any sequelae were followed until resolution.
Results: There were 2074 PNCs included in the study. 251 adverse events and complications were recorded, resulting in an overall incidence (95% CI) of complications of 12.1% (10.7–13.5%). The most common complications were catheter malfunction, block failure, infection, and vascular puncture. There were no reports of persistent neurologic problems, serious infection, or local anaesthetic systemic toxicity, resulting in an estimated incidence (95% CI) of 0.04% (0.001–0.2%). Patients who developed an infection had used the catheters for a greater number of days, median (IQR) of 4.5 (3–7) days compared with 3 (1–3) days in the patients who did not develop an infection, $P<0.0001$.
Conclusions: Our data support the safety of placing PNCs in children, with adverse event rates similar to adult studies. Catheter problems are common, yet minor, in severity.

Key words: analgesia; catheter; children; complication; nerve; paediatrics; pain

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Editor's key points

- Peripheral nerve catheters (PNCs) are widely used in children, although with limited studies on safety.
- This observational study used a regional database of more than 2000 PNCs to identify complications
- The majority of complications were minor, with an incidence of 12%, similar to adult practice.
- Using a multicentre paediatric network, to record standardized data may help identify uncommon PNC complications.

Peripheral nerve catheters (PNCs) offer the possibility of extended analgesia beyond the 12–16 hr of analgesia usually obtained from a single-injection block. They have been used extensively in adults and their use has been increasing in children.[1–3] PNCs have demonstrated similar analgesia when compared with neuraxial techniques in two single-institution randomized trials.[4 5] Peripheral techniques are also considered safer than neuraxial approaches because complications such as bleeding or infection are more easily treatable for the majority of peripheral blocks, and side-effects have been reported to be less frequent.[4 6]

Safety and ethical concerns have been commonly attributed as major barriers to conducting randomized studies in vulnerable paediatric patients.[7 8] There are limited reports in the paediatric literature, that contain large enough sample sizes, to address the safety of PNCs and accurately define the incidence and nature of complications, and fewer still that are prospective in design.[1 2 6] The Pediatric Regional Anesthesia Network (PRAN) is a multicentre project to prospectively collect information about paediatric regional anaesthetic techniques and complications.[9] Currently, the PRAN database has 20 participating sites, with more than 80 000 blocks recorded, and is audited regularly for accuracy and completeness.

The main objective of the current investigation was to evaluate safety of peripheral nerve catheters when used to minimize postoperative pain in children. Specifically, we sought to estimate the rate of overall and specific complications in the use of PNCs in children.

Methods

Details of the PRAN database, audits and methodology have been previously reported.[9] The PRAN database is a non-randomized, prospective, observational study of the details and adverse events associated with every paediatric regional anaesthetic performed by an anaesthetist at each participating centre. Data on every PNC placed from April 1, 2007, to May 31, 2013, were examined as a subset of the PRAN protocol. Approval for data collection was obtained from the local Institutional Review Board of each individual site participating in the PRAN. All centres were granted waivers of informed consent by their review boards because the data had no identifiers and were collected during the course of routine patient care. PRAN centres are listed in Supplementary material Appendix 1.

Technical data collected included the patient state at the time of the block (awake, sedated, or anaesthetized with or without neuromuscular block), technology used to perform the block, and whether a test dose was given. The type and dose of local anaesthetic administered were recorded, as were the doses of any adjuvants. The time of catheter removal and reason for removal were also collected. Complications and adverse events were defined by the presence of at least one of the following intraoperative and/or postoperative factors: catheter malfunction (dislodgment/occlusion), infection, block failure (abandoned or failed), vascular (blood aspiration/haematoma), local anaesthetic systemic toxicity, excessive motor block, paresthesia, persistent neurologic deficit, and any other identified complication or adverse event was followed until the complication resolved, in most patientss by clinicians on the pain service. Every complication and adverse event (rather than a selected sample) was audited at each site before uploading to the database.

Similar to what we reported in our earlier paper,[9] there were rare instances when a complication or adverse event could not be definitively assigned to a specific block because multiple blocks were performed during a single operation, and it was not clear during data analysis which block was associated with the complication. In order to ensure the most conservative risk estimation for each single type of block, we assigned the complication to both, but the complication would not be counted twice in the final tally of all complications in a given category.

Normally distributed interval data are reported as mean and standard deviation (SD). Non-normally distributed interval and ordinal data are reported as median, range or interquartile range (IQR), and were evaluated using the Mann-Whitney *U*-test.[10 11] Categorical variables were presented as counts and were evaluated using Fisher's exact test. The 95% binomial confidence interval for the incidence of peripheral nerve catheter complications was calculated using the Jeffreys' method. The coverage properties of that method are similar to others, but it has the advantage of being equal-tailed (e.g. for a 95% confidence interval, the probabilities of the interval lying above or below the true value are both close to 2.5%).[12]

The Clopper-Pearson exact method was used in binomial interval estimations when zero successes were observed.

As not enough information is available regarding dosage of local anaesthetics used in the peripheral nerve catheters for children, an exploratory analysis was also performed to identify patterns of local anaesthetic dose and patient characteristics. When the block was performed using ropivacaine, equipotent doses of ropivacaine were converted to bupivacaine (0.7 mg of bupivacaine=1 mg of ropivacaine).[13] A two-tailed $P<0.05$ was used in order to reject the null hypothesis. Data were analysed using STATA version 13 (StataCorp, College Station, Texas, USA).

Results

Patient characteristics

There were 2074 truncal, upper extremity, or lower extremity PNCs included in the current analysis. Patient and catheter characteristics of subjects are presented in Table 1. Catheter insertion by age and anatomic site is described in Table 2. The majority of catheters were lower extremity catheters placed in children aged 10 yr or older.

Ultrasound guidance was used to place 90% of upper extremity, 78% of lower extremity, and 82% of truncal catheters. In lower extremity catheters, the less frequent use of ultrasound was primarily as a result of a low utilization of ultrasound for lumbar plexus catheters (13%), for which the majority of catheters (81%) were placed with nerve stimulation. Excluding lumbar plexus, ultrasound was used in 93% of lower extremity catheters. Ultrasound was combined with nerve stimulation for 16% of upper extremity catheters and 25% of lower extremity catheters, excluding lumbar plexus catheters (Table 3).

Postoperative local anaesthetic infusion data were provided for 92% of PNCs. Of the blocks with available data, ropivacaine

Table 1 Patient and catheter characteristics. Data are presented as median (IQR) and counts (n)

	Subjects (*n*=2074)
Age (yr)	13 (10–15)
Gender	
Male	1084
Female	990
Weight (kg)	52.5 (36.3–66.7)
ASA class	
I	944
II	815
III	306
IV	9
Calendar year of block performance	
2007	69
2008	145
2009	248
2010	295
2011	379
2012	564
2013	374
Catheter location	
Upper extremity	173
Lower extremity	1754
Truncal	147
Patient state during catheter placement	
Awake or sedated	207
General anaesthesia	1867
Local anaesthetic type	
Bupivacaine	186
Ropivacaine	1713
Unknown/Other	175

Table 2 Number of patients receiving each catheter type. 3 catheters of unknown type. Totals do not equal 2074 as a result ofsome patients receiving >1 PNC

	Upper Extremity	Lower Extremity	Truncal	Total
Neonate	0	1	1	2
1 month to <6 months	1	2	2	5
6 months to <1 yr	2	18	4	24
1 yr to <3 yr	14	45	10	69
3 yr to <10 yr	28	241	33	302
≥10 yr	128	1192	61	1381

0.2% was used in 73% of PNCs, followed by ropivacaine 0.1% (15%). The average dose of ropivacaine was 0.22 (0.11) mg kg^{-1} hr^{-1}. There were 14 (0.7%) PNCs with doses that exceeded 0.5 mg kg^{-1} hr^{-1} bupivacaine equivalents.

Adverse events and complications

There were 251 adverse events and complications recorded, resulting in an overall incidence (95% CI) of complications of 12.1% (10.7–13.5%). The incidence of specific complications are presented in Table 4. There were no reports of persistent neurologic problems, deep infection, or local anaesthetic toxicity, resulting in an estimated incidence (95% CI) of serious complications of 0.04% (0.001–0.2%). The most common complications were catheter problems, superficial infection, and vascular puncture. The incidence of catheter complications was similar among different anatomic sites. There were 9 abandoned blocks and 18 block failures. Combining abandoned and failed blocks, the overall catheter failure rate was 1.3% (0.8–1.7%). Catheters were removed because of a complication on postoperative days (POD) 0–2 in 126 (6.1%) patients.

The majority of catheter problems were because of accidental dislodgement, and the incidence was not different in patients whose catheters were placed under general anaesthesia, 135 out of 1867 (7.2%) compared with 17 out 207 (8.2%) of patients who received the catheter awake or sedated (P=0.57). Catheter dislodgment was also not different according to different catheter site locations (P=0.21). We did not find an association between age and catheter dislodgement. The mean (SD) age of patients who did not have a dislodgment was 12.2 (4.3) years compared with 12.6 (4) years in those who had catheter dislodgment (P=0.25).

Insertion site infections were reported in 12 patients, 6 of whom had 2 catheters, for a total of 18 infected catheters (0.9%, 95% CI 0.5–1.4%). In 3 additional patients, catheters were removed because of fever without signs of catheter site infection. The incidence of infection was not different between the types of catheters. The only factor associated with greater incidence of catheter-related infection, was the total number of days before removal of the catheter. Patients who developed an infection had the catheters used for a greater number of days, median (IQR) of 4.5 (3–7) days compared with 3 (1–3) days in the patients who did not develop an infection (P<0.0001). All reported infections were minor and superficial. No patient developed a deep tissue infection, abscess or sepsis.

There were few neurologic problems reported: 1 patient with temporary Horner's syndrome with a supraclavicular catheter and 1 post-dural puncture headache from a lumbar plexus catheter that did not require a blood patch. There were 13 patients with excessive motor blockade, a qualitative diagnosis based on the physician's assessment in the given clinical setting, 12 of which were in lower extremity catheters. There were two patients (1 femoral, 1 saphenous) of difficult catheter removal reported, one of which required a return to the hospital ED for removal.

While there was a trend toward a lower incidence of vascular puncture when utilizing real-time imaging for block performance, the difference was not statistically significant. The incidence of vascular puncture in image-guided blocks was 13 of 1673 compared with 6 of 401 in blocks that were not performed with imaging (P=0.24). Vascular complications were not different among catheter sites (P=0.48). There was one postoperative haematoma, extending from T1-T10 without cord compression, reported following bilateral paravertebral catheters placed with ultrasound guidance in a 14-year-old girl, undergoing total pancreatectomy. It was not accompanied by neurologic deficits and resolved within 72 hr.

Discussion

The most important finding of the current investigation was the demonstration of safety in the use of catheters for nerve blocks in children to control pain after surgery. Complications associated with catheters were generally minor and did not result in long-term sequelae. The overwhelming majority of PNCs in children

Table 3 Technology used by block type. NS, nerve stimulator; US, ultrasound; US/PNS, combined ultrasound/nerve stimulator; FL, fluoroscopy; NE, nothing entered; TAP, transversus abdominis plane. 1 popliteal and 5 lumbar plexus catheters that used fluoroscopy also used nerve stimulation

	NS	US	US-PNS	FL	None	NE	Totals
Upper Extremity							
Interscalene	2	28	7	0	6	0	43
Supraclavicular	1	45	2	0	0	0	48
Infraclavicular	0	54	12	0	3	1	70
Axillary	0	5	3	0	0	0	8
Other	0	2	1	0	1	0	4
Totals	3	134	25	0	10	1	173
Lower Extremity							
Lumbar Plexus	228	17	25	7	38	3	318
Fascia Iliaca	0	11	0	0	2	0	13
Femoral	11	454	142	1	12	17	637
Sciatic	20	268	107	1	12	5	413
Popliteal Fossa	2	155	68	1	4	3	233
Saphenous	0	122	2	0	6	3	133
Other	1	3	1	0	1	1	7
Totals	262	1030	345	10	75	32	1754
Truncal							
Ilioinguinal	0	7	0	0	0	0	7
Paravertebral	0	67	0	1	8	2	78
TAP	0	56	0	0	1	1	58
Other	0	1	0	1	1	1	4
Totals	0	129	0	2	10	6	147

Table 4 Incidence of Specific Adverse Events and Complications

Complication	Incidence (95%CI)
Catheter malfunction (e.g. dislodgement, occlusion)	7.3% (6.2–8.5)
Abandoned or block failure	1.3% (0.8–1.7)
Catheter related infection	0.9% (0.5 to 1.4)
Vascular (e.g. blood aspiration, haematoma)	0.9% (0.5–1.3)
Excessive motor block	0.6% (0.3–1)
Difficult catheter removal	0.1% (0.04–0.3)
Other (e.g. foot swelling, muscle spasms, dizziness, burning sensation, adverse drug reaction, nausea and vomiting, contact dermatitis)	1% (0.6–1.5)

are placed using ultrasound guidance, occasionally supplemented with nerve stimulation. This continuing shift away from peripheral nerve stimulation as a sole technique has been reflected in longitudinal adult studies,[14] and our data show perhaps an even greater use of ultrasound as a sole technique.

No severe complications were seen in this cohort of PNCs in children. It is important to note that the vast majority of our cohort were children greater than 10 yr of age. Our results may not be generalizable to children under 3 yr old, who made up less than 5% of the cohort, similar to other paediatric studies.[1] Adverse event rates compare favorably with neuraxial techniques at the same centres,[9] and are in agreement with other large audits.[6] The overall rate of complications in the PRAN database is relatively high, as a result of a broad scope of examination and conservative reporting. For example, in the current iteration of the database, when multiple blocks are placed and a complication is reported, that complication is counted toward both blocks if the culprit block is not easily identified. For this reason, we reported a relatively high rate of infection because of a number of patients having two PNCs.

Overall, infection rates among this and other large paediatric PNC cohorts are low, and there have not been reports of abscess or systemic infection. More importantly, we detected that placement of a catheter for longer number of days is associated with greater incidence of insertion site infection. We believe that the data from this study population suggest that PNCs in older paediatric patients should be removed three days after their initial placement, unless clinical benefit is perceived to outweigh this important clinical risk. The low incidence of infection also highlights the importance of close follow-up and, in the case of outpatient PNCs, specific patient and family education regarding the early signs of infection.

It was reassuring to note that no patients with local anaesthetic overdose were observed. This is in contrast with a higher incidence of potential local anaesthetic overdose in single-injection blocks such as caudal and transversus abdominis plane blocks,[15 16] but also expected as a result of the lower dose of local anaesthetic often used for postoperative infusions. There have been very few reports of local anaesthetic toxicity in the PRAN database, and almost all were in infants receiving neuraxial blocks.[17] Although published guidelines advise similar dosing for bupivacaine and ropivacaine,[18] pharmacokinetic modeling suggests that higher doses of ropivacaine are likely safe in children.[19] However, even in adult patients, it remains unknown what factor (dose, volume, or concentration) determines the efficacy of the peripheral nerve catheters.[20] Future studies to guide local anaesthetic delivery regimens in paediatric regional anaesthesia are warranted.

Catheter problems such as disconnection or leakage are common, and overall are the most common adverse event in this and other studies.[1 2] Fortunately, catheter problems are usually minor in severity, and efforts should focus on improving techniques for placing and securing catheters so that an appropriate duration of analgesia can be provided for all patients.[13 21] In the future, the PRAN will collect data to compare methods for catheter fixation. However, even with proper catheter fixation at the insertion site, subcutaneous catheter migration can result in 'secondary failure' of the block. Although this is not a specific complication recorded by the PRAN, it has been shown to be relatively common in an adult volunteer study.[22]

Comparisons with other studies are difficult because of heterogeneity in defining adverse events and complications. Ecoffey and colleagues [6] included 1164 PNCs in a one-year multicenter audit of more than 30 000 regional procedures. They focused on serious complications only and reported a fractured femoral catheter and an intrapleural paravertebral catheter, but there were no long-term sequelae.[6] Dadure and colleagues [2] reported 339 PNCs from a single institution. They noted a higher rate for catheter problems (20.1%) and similar results for superficial infections (0.9%). They also reported paresthesias in 6.5% of catheters, but none persisted after the infusion was discontinued.[2] More recently, Gurnaney and colleagues [1] published their experience with 1492 outpatient PNCs. They reported relatively similar rates for both catheter problems (4.2%) and catheter failure rates (1.9%), but noted only 1 (0.07%) episode of local inflammation.[1] To the best of our knowledge, this is the largest study examining the safety of PNCs in children.

A recent review of adult PNC studies estimated the incidence of transient neurologic problems at 0–1.4%, but permanent neurologic problems were exceedingly rare (0.07%), which is similar to the estimated incidence (based on a zero numerator) in the PRAN.[20] It is notable that there have been few transient and no major neurologic complications reported in our investigation and other large paediatric studies performed thus far, which total more than 5000 PNCs.[1 2 6] Indeed, we did not have a single paresthesia reported in more than 2000 PNCs. It is possible that there were minor paresthesias that patients perhaps did not feel compelled to report to a clinician. Additionally, telephone follow-up for outpatient catheters varies among centres, so it is also possible that paresthesias were noted after discontinuation of the local anaesthetic infusion. It may be useful to have additional follow-up by telephone after a defined period of time from catheter removal.

Our study should only be interpreted within the context of its limitations. Although the PRAN has a rigorous validation and audit structure for complications, we rely on self-reporting like other multicentre databases, so there is always a risk of underreporting certain data elements.[23] Many PRAN centers utilize outpatient PNCs, but during the time of this data cohort the PRAN did not differentiate between inpatient and outpatient status, so comparisons between these two groups cannot be made. The PRAN data is deidentified, so we cannot account for variation in complication rates among centres. Another limitation of the study is related to the multivariate use of different blocks and the use of other kinds of postoperative analgesia. Finally, the PRAN is not designed to gather data on catheter efficacy, so data on postoperative pain scores and opioid use are not available. These questions are better answered with prospective, randomized trials.

In conclusion, our study adds to the paediatric literature on the safety of PNCs performed at a diverse group of children's hospitals. Our data show that PNCs in children and adolescents have low failure and complication rates that are similar to adult practice. Most importantly, the majority of complications were minor and there were no reports of permanent injury. Our study proves that safety concerns should not hinder the further study of the proposed benefits of peripheral nerve catheters in children.

Authors' contributions

Study design/planning: B.J.W., J.B.L., G.S.D., D.P., S.S.
Study conduct: B.J.W., J.B.L., G.S.D., P.S., C.S., D.P., S.S.
Data analysis: B.J.W., J.B.L., G.S.D.
Writing paper: B.J.W., J.B.L., G.S.D., P.S., C.S., D.P., S.S.
Revising paper: All authors

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Declaration of interest

None declared.

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