Regional anesthesia in pediatrics: marching forward

Karen R. Boretsky

Purpose of review
This review highlights new data and current trends of well tolerated and effective paediatric regional anesthesia. Historically, the practice of paediatric regional anesthesia was based largely on information from adult studies, but recent literature contains information on paediatric specific risks and benefits of old and new techniques as well as the impact of new ideas and technologies.

Recent findings
Excellent pain relief with regional anesthesia is well demonstrated in children. Several databases of paediatric regional anesthesia (over 46,000 regional anesthetics) demonstrate overall safety and lack of major complications. Detailed analysis demonstrates additional safety and decreased failure rates of peripheral compared with neuraxial nerve blocks. Ultrasound technology confers additional safety and efficacy benefits.

Increasingly, data support the safety and efficacy of novel peripheral nerve blocks, transversus abdominis plane and ultrasound-guided paravertebral, and the use of perineural catheters for both inpatients and outpatients. Regional anesthesia as a sole agent for surgical anesthesia and the use of regional anesthesia for pain in nonsurgical pain patients remains underutilized.

Summary
Paediatric specific data for regional anesthesia are available to help guide optimal pain management. The paediatric regional anesthesia literature lags behind literature available for adult populations and increased studies are needed for additional information for informed decision-making.

Keywords
analgesia, pain management, paediatric, paediatric anesthesia, paediatric regional anesthesia, ultrasound-guided regional anesthesia

INTRODUCTION
Pain management is frequently suboptimal in paediatric patients. Physicians are increasingly using regional anesthesia techniques for pain management in infants and children [1,2,3] as part of a shift towards multimodal methods of pain management. This important shift advocates for opioids as a rescue therapy and no longer as first-line pain therapy [3,4]. The implementation of multimodal analgesia with the inclusion of regional anesthesia is especially important in paediatric populations in which the side-effects of opioid therapy are common and occasionally severe [5]. In addition, regional anesthesia can offer an alternate to the administration of general anesthesia or decrease the dose of general anesthesia drugs. Historically, the practice of paediatric regional anesthesia has been largely based on information from the adult literature, but paediatric data are nearing a critical value needed to guide paediatric-specific practices.

Available paediatric-specific data are discussed with implications for evidence-based decisions concerning efficacy, safety and optimal clinical applications for new ideas and technology.

SAFETY ISSUES
Patient safety must always be the most important consideration when choosing a pain management plan for infants and children. Anesthesia providers, when considering regional anesthesia, are charged with determining the lowest risk intervention that
**KEY POINTS**

- Regional anesthesia is well tolerated and effective in infants and children and should be used whenever possible.
- Peripheral nerve blocks should be used as an alternative to neuraxial when available.
- Portable ultrasound imaging confers many benefits and should be used for nerve localization whenever available.
- There are several techniques for transversus abdominis plane block that result in different duration of action and dermatomal coverage.
- Perineural catheter use is increasing in both the inpatient and outpatient settings.

Regional anesthesia in pediatrics is well tolerated and effective in infants and children and should be used whenever possible. Safety comes predominantly from two large databases with over 46 000 paediatric regional anesthetics [1,6]. The safety profile of regional anesthesia is very good with the overall incidence of serious complications (systemic/cardiac toxicity, apnoea, visceral puncture, dural puncture, nerve injury, infection requiring antibiotic therapy and hypotension) ranging from 0.12 to 0.15% [1,6] and no mortalities and no morbidities lasting greater than 1 year. Although these results are reassuring, catastrophic neurologic complications following regional techniques continue to show up in small series and case reports demonstrating that the risk is not zero [7^*]. More granular examination of the existing data shows an added safety advantage of peripheral nerve blocks (PNB) compared with neuraxial techniques [1,6]. The ADARPEF researchers report the incidence of serious complications following neuraxial and peripheral nerve blocks as 0.26 and 0.04%, respectively, although the Pediatric Regional Anesthesia Network (PRAN) data show the incidence of serious complications after neuraxial and peripheral nerve blocks being 0.23 and 0.02%, respectively. The six to 11-fold difference in serious events provides compelling reasons to favour placement of PNB whenever feasible. Regional block failure, although not considered a serious complication, is undesirable with the failure rate of neuraxial techniques being higher than that of neuraxial [7^*]. Safety, reliability and efficacy data will continue to refine the appropriate roles of neuraxial blockade and peripheral nerve blockade for specific purposes.

**USE OF ULTRASOUND**

It has been just 10 years since the introduction of ultrasound to guide nerve blockade in a child [8], but the use of high-resolution, portable ultrasound technology has dramatically impacted paediatric regional anesthesia. Studies in adult populations have documented improved safety, reliability and efficacy with the addition of ultrasound guidance for neural blockade [9,10]. Large, appropriately powered studies are needed in children to determine the benefits of ultrasound, but existing paediatric studies demonstrate a trend towards faster onset time, decreasing local anesthetic dose requirement and lower block failure rates [11,12]. Several recent large adult studies show a reduction in the incidence of local anesthetic systemic toxicity (LAST) when ultrasound guidance is used [13,14^**],15–17]. The effect of using ultrasound on the incidence of neurologic injuries in adults shows promising trends [13,14^**],15,16]. The literature contains no paediatric-specific data on the effects of ultrasound guidance on the incidence of LAST or long-term neurologic injuries. There is an increasing body of data showing that the introduction of ultrasound for perineural blockade is facilitating a better product (reliability and efficacy) at a lower cost (less morbidity/mortality).

**SPECIFIC REGIONAL TECHNIQUES**

The availability of ultrasound visualization has driven interest in less common paediatric thoracoabdominal blocks such as the transversus abdominis plane (TAP) block and the paravertebral nerve block (PVNB). In 2008, the first TAP blocks under ultrasound guidance for paediatric patients were published [18,19] and the TAP block was successfully used initially as a single shot technique in paediatric patients of all ages including small infants and neonates [18–23]. Recent advances include ultrasound-guided techniques for insertion of continuous catheters in patients of all ages including small infants [24–26]. The addition of the TAP block offers alternatives to caudal and epidural when neuraxial techniques cannot be offered or are not desired. For lower abdominal surgeries, direct comparisons between TAP blocks, local infiltration and caudal analgesia favour the TAP block for its longer duration [26]. There are no comparisons between TAP block and thoracic epidural in paediatric patients. Of note, several techniques for performing the TAP block are described in the adult literature (lateral, posterior, subcostal, quadratus lumborum, transversalis fascia) with each resulting in different dermatomal distribution and duration of analgesia [27^*,28,29^**,30,31^*,32,33]. Despite this variation, all of these techniques are referred to as TAP blocks in the literature, which has led to spirited debate over interpretation and relevance of some results. It is not
surprising that similar variations in duration and spread effected by different TAP approaches are beginning to emerge in the paediatric literature [26,33,34]. Overall, the approach as described by Suresh and Chan [20], a lateral approach, provides analgesia sufficient for lower quadrant surgery [22,34]. No studies have been done in children to determine dermatomal spread or duration of block with a true posterior approach at the level of the transversalis fascia or quadratus lumborum. Personal experience favours posterior placement for both catheters and single shot blocks at the transversalis fascia at the termination of the transversus abdominis muscle for more prolonged duration and reliable extension up to T8 dermatome.

In spite of the introduction of PVNB in children by Lönnqvist in 1992 [35], the technique remains underutilized. Recently, PVNB may be experiencing a renewed interest for use in paediatric patients and placement with ultrasound guidance has been described [36]. PVNB is a very versatile block and can be bilateral or unilateral and used for either major or minor thoracic or abdominal surgeries in children [36,37,38–40]. PVNB catheters are being placed in almost all paediatric populations including infants and outpatients [36,41,42]. A single prospective, randomized study [43] in paediatric patients directly comparing PVNB to thoracic epidural demonstrates comparable analgesia with fewer side-effects and a higher success rate attributed to the PVNB, which is consistent with the more extensive adult literature. Similarly, a single comparison with caudal demonstrates longer duration and higher success rate when using a single-shot PVNB [40]. Controversy exists regarding the well tolerated use of thoracic epidural for analgesia following NUSs procedure for repair of pectus excavatum. The paravertebral block may be a viable alternative when an epidural is not offered and preliminary results, albeit sparse, are positive [37,38]. Contrary to adult data showing better dermatomal spread when injections into the paravertebral space are made at multiple levels, in children, a single paravertebral injection at a low thoracic level of 0.3–0.5 ml/kg covers a median of six to eight paravertebral spaces [44,45]. Absorption and pharmacokinetics is not yet well established in pediatric patients.

The feasibility and efficacy of continuous catheters in paediatric patients has been established and catheters now constitute from 35 to 75% of all paediatric regional anesthetics [2,6]. Continuous catheters offer the advantage of prolonged duration of analgesia and the ability to titrate to desired effect. Aside from technical issues related to the catheter itself, the placement of indwelling perineural catheters does not appear to increase the incidence of serious complications [6]. With the introduction of disposable ambulatory infusion pumps, successful use of perineural catheters in the outpatient setting in large numbers of children as young as 3 years of age has been reported [46]. Patient discharge to home with a perineural catheter has the advantages of decreased length of hospital stay, decreased opioid consumption and related side-effects, less inconvenience to patients and families and decreased hospital costs [46,47]. In some tertiary care paediatric institutions, the number of outpatient perineural catheters exceeds the number performed on patients being admitted to the hospital [46]. The use of regional anesthesia, both continuous catheters and single injection blocks, is increasing in the paediatric outpatient setting [46,48].

**GENERAL ANESTHESIA SPARING PROPERTIES OF REGIONAL ANESTHESIA**

In contrast to the practice in adult populations, the majority of paediatric patients receive a regional anesthetic in addition to general anesthesia (GA) [1,2,6]. The exception to this is the use of spinal and caudal anesthesia in high-risk neonates and infants. The use of neuraxial anesthesia in this patient population and the avoidance of general anesthesia have been shown to decrease postoperative apnoea, and need for postoperative ventilator support. Current studies document remarkable hemodynamic stability with neuraxial anesthesia in infants with major comorbidities including cyanotic and noncyanotic congenital heart disease [49,50]. More recently, the neuroapoptosis seen in developing brain tissue following general anesthesia with possible long-term behavioural and intellectual sequellae make avoidance of GA and the use of regional anesthesia as a solo anesthetic increasingly desirable in all infants and young children. Although the use of regional anesthetic techniques for surgical procedures in the absence of a concomitant general anesthetic is well tolerated and effective [51–53], this approach remains underutilized. The use of regional anesthesia as a supplement to GA also partially spares exposure to GA medications.

**REGIONAL ANESTHESIA FOR NONSURGICAL PAIN**

Most paediatric regional anesthesia is confined to use in the perioperative period, but incrementally, regional anesthesia is being used to treat localized pain from neuropathic sources, trauma and painful
Regional anesthesia in pediatrics: Boretsky

SUMMARY

There is growing experience with the use of regional anesthesia in paediatric patients with positive results and many demonstrated advantages over conventional pain management. The paediatric literature lags behind the adult literature, but data are emerging to direct choices to highest efficacy and lowest risk regional anesthesia interventions. Continued progress in paediatric regional anesthesia will depend on large well designed studies to more precisely define the risks and benefits, pharmacokinetics of specific blocks, better defined dosing guidelines and appropriate application of new ideas and technologies. Patient safety and well-being must always remain our highest priority.

Acknowledgements

Karen R. Boretsky has approved the final manuscript. No funding was received for this study.

Conflicts of interest

Karen R. Boretsky acts as a consultant for Pajunk Medical Inc.; Analogics Corporation partially funds a paediatric regional anesthesia fellowship position at the Boston Children’s Hospital.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
- of special interest
- of outstanding interest


This study documents better pain relief when TAP block is used rather than wound infiltration: a cadaveric study. Eur J Anaesthesiol 2014. (Epub ahead of print)

This study documents better pain relief when TAP block is used rather than wound infiltration: a cadaveric study. Eur J Anaesthesiol 2014. (Epub ahead of print)

This is the largest series to date (27 031 patients) attributing safety advantages to ultrasound when performing regional anaesthesia. This study sets risk of nerve injury at 1.5/10 000 and LAST at 0.37/10 000.


This study documents better pain relief when TAP block is used rather than wound infiltration for minor outpatient procedure.


The first written evidence of clinical differences in different approaches to the TAP block.

Regional anesthesia in pediatrics: Boretsky

Regional anesthesia in pediatrics: Boretsky

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

0952-7907 © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins www.co-anesthesiology.com 559


The study of a new technique.


The first study to document the dose needed for TAP block for lower quadrant surgery in children.


The first study on technical aspect of insertion of PVNB with catheter using ultrasound guidance in paediatric patients.


Nice overview of the controversy surrounding epidural anesthesia and NUSSS repair.


42. Viscoiu M. Outpatient analgesia via paravertebral peripheral nerve block catheter and On-Q pump: a case series. Paediatr Anaesth 2014. [Epub ahead of print]


The first documented spread of injectate in paravertebral space in infants.


This study contains excellent radiographs of spread of local anesthetic in paravertebral space.


The first long-term, large retrospective analysis of prospectively collected data on paediatric outpatient with ambulatory nerve block device.


52. Keech K, Bosenberg A. Axillary block for PICC lines in critically ill neonates. Abstract Society for Pediatric Anesthesia (SPA) Annual Meeting; April 15-18, 2010; San Antonio, TX.


First attempt to review and track patterns within anecdotal information published concerning regional anesthesia in palliative care.


