New developments in paediatric regional anaesthesia

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Introduction
Regional anaesthesia for children of all ages continues to develop since its re-introduction into clinical practice over 25 years ago. The need for the conscious patient to remain anaesthetized during surgery has been the driving force behind its continued growth in popularity worldwide. However, the analgesia so provided must be balanced against the risk of the regional technique. Improved equipment more suitable for children, the publication of large audits, and the introduction of portable ultrasound have all influenced clinical practice.

Risk benefit
Prior to performing any procedure, the risk should be balanced against the benefit. From the child's perspective, a block should be performed without risk or complications. Neonates and infants, as a group, are at greater risk under general anaesthesia and are also at greater risk of local anaesthetic toxicity. However, there is some evidence that the combination of general anaesthesia and regional anaesthesia may reduce the risks of both. Intravenous agents raise the toxic threshold of local anaesthetics, whilst lower concentrations of inhalational agents can be used in the presence of a successful block.

Most complications are easily treated and short-lived. The incidence of approximately 1 per 1000 blocks performed, is remarkably constant in a number of surveys. In the recent UK a udit 96 incidents were reported in 10633 epidurals placed in 21 centres over a 5-year period. A six monthly audit performed during the 5 year period, virtually eliminated some of the problems. For example, the incidence of pressure sores was virtually eliminated, by reducing the contact time between the analgesic infusion and the skin of the child. Only one child had residual effects after 12 months – this was an epidural catheter placed by the surgeon during spinal surgery. Nine serious incidents were reported over 5 years. Of these, five were nerve injuries - all resolved. Two were epidural abscesses, both from the same institution. Both of these grew staphylococcus aureus, representing two different decades, the risk of permanent injury is remarkably low compared to adults.5

Peripheral nerve blocks
As a consequence of the prospective ADARPEF study, the use of peripheral nerve blocks has increased, particularly in older children. Peripheral nerve blocks are challenging for a number of reasons. The landmarks are not easily identifiable and vary as the child develops; bony landmarks are poorly defined, particularly in non-weight-bearing infants; muscles are poorly developed - the younger the child the less the definition. Those with limb defects and abnormal anatomy add to the challenge.

From the child's perspective, the block should be performed without risk or complications. As a group, children are at a greater risk of toxicity. It would be of benefit if regional blocks could be performed with the smallest effective dose of local anaesthetic. Young children are generally uncooperative, fearful and lack the understanding to assist us in our endeavours to identify the relevant landmarks, or to perform the block. For this reason, regional blocks are usually performed under anaesthesia or sedation, where at least we can expect a stationary child. Although hotly debated in the medico-legal circles, there is little or no evidence that the placement of nerve blocks in anaesthetized children is dangerous.

The need for improved postoperative pain management in children has been the driving force behind its continued growth in popularity worldwide. However, the analgesia so provided must be balanced against the risk of the regional technique. Improved equipment more suitable for children, the publication of large audits, and the introduction of portable ultrasound have all influenced clinical practice.

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Large surveys have defined the risks in children.1-6 The retrospective and prospective ADARPEF studies were performed in the early 1990’s.2,5 Since then, equipment more suitable for use in children, particularly for infants and neonates, have been developed. The National Epidural Audit in the UK represents the risks in more recent times.7 In both these prospective studies, representing two different decades, the risk of permanent injury is remarkably low compared to adults.5

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Although the incidence of complications is relatively low, the close proximity of nerves to other vital structures places the infant at risk, if due care is not taken during the conduct of loco-regional anaesthesia. Anecdotal reports of serious complications following both neuraxial and peripheral nerve blocks are stark reminders that without attention to detail, potential disasters can and do happen. Recent reports of spinal cord injury following a thoracic epidural for appendicectomy8 bear testimony to this. Others include small bowel necrosis due to an unrecognized colonic puncture (requiring laparotomy) following an ilio-inguinal block,11 sacral osteomyelitis,12 and a sub-periosteal haematoma following caudal block.

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Many consider placement of blocks under anaesthesia as ‘best practice’. Those that extrapolate from adults and refuse to perform regional blocks in anaesthetized children, do children a disservice. This debate, however, is unlikely to be resolved, since no one is likely to perform a study to challenge this practice.

Improving accuracy
Anaesthesiologists have sought aids to improve the success of the regional blocks that they perform. Although nerve blocks may be achieved with non-insulated needles,13 peripheral nerve stimulators5,16 and insulated needles were major advances, both as teaching aids, and as means to improve the success rate of peripheral nerve blocks. Surface nerve mapping,17 a technique whereby the motor component of a peripheral nerve may be stimulated transcutaneously, also has its value. Unfortunately, both are ‘blind’ techniques, and the practitioner is unable to determine the exact location of the needle in relation to the nerves and their neighbouring structures. It is not surprising that inadvertent puncture of adjacent structures and unpredictable failures still occur.

The use of ultrasound as an aid for accurate placement of local anaesthetics is gaining in popularity over landmark-based techniques, and neurostimulation.20-22 Experience with ultrasound as an aid in paediatric regional anaesthesia is still relatively limited and confined to a few centres, but it is fast becoming an important...
adjunct in regional anaesthesia.\textsuperscript{20} Ultrasonography allows non-invasive real-time imaging of the relevant anatomical structures, while the needle is placed under direct vision. The technique is easily taught but the learning curve is steep. Determining the exact location of the needle tip is a vital key to success.

Technological advancements have allowed the development of small portable ultrasound equipment that can be taken into the operating room (SonoSite 180+\textsuperscript{3} or Titan,\textsuperscript{4} Micromaxx\textsuperscript{5} unit, SonoSite\textsuperscript{3,4}, Bothell, WA, USA). Image resolution is dependant on the ultrasonic frequency, and also the size and depth of the needle. High frequency probes (10 -15MHz) that produce much higher image resolution are preferred. However, as the frequency increases, the depth of tissue penetration is reduced. Thus, a trade off exists between image resolution and tissue penetration. Put another way, high resolution of superficial structures can be obtained using high frequency probes, but penetration is limited.\textsuperscript{20} Deeper structures require lower frequencies, and thus the resulting images are of lower resolution. Frequencies of 10-15MHz can provide good resolution of nerves as small as 1mm, but the tissue depth where small nerves can easily be identified, is limited to approximately 3cm.

There are a number of reasons why ultrasound may be of greater value in paediatric regional anaesthesia. In sedated or anaesthetised children, direct visualisation of the nerve or neural structures, vessels, tendons and bones is possible. Using real time imaging, the ultrasound can therefore verify correct needle placement and local anaesthetic delivery around the nerve. In this way, the risk of intra-neuronal or intra-vascular injection is potentially reduced. Most peripheral nerves in children lie within range of portable ultrasound probes and good definition is obtained.\textsuperscript{21,22} A 5-10 MHz linear hockey stick probe provides high resolution, and is the most popular in children.

A number of recent studies have shown that considerably smaller volumes of local anaesthetic can be used to achieve block success.\textsuperscript{23,25,26} Proponents of ultrasound-guided regional anaesthesia claim earlier onset times,\textsuperscript{20,27,28} improved quality and duration of block, with fewer complications in children.\textsuperscript{20} Ultrasonography has also shown that the exact anatomical relations of nerves can vary widely.

A further advantage of ultrasound is that in neonates, particularly premature neonates, the vertebral column is less ossified, thus allowing ultrasound waves to reach the spinal cord. Ultrasound examination of the spinal cord may provide useful information prior to caudal, spinal or epidural placement in neonates. The skin epidural distance can be measured. The conus medullaris, dural sac and any abnormal anatomy can be identified. Identification of the epidural space, confirmation of local anaesthesia delivery and catheter placement within the epidural space is possible.\textsuperscript{27}

Continuous peripheral nerve blocks
Several peripheral nerve blocks can provide analgesia for a few hours only, whereas continuous nerve blocks can be used for days. Continuous peripheral nerve catheters have recently become available for use in children.\textsuperscript{20-23} The main indications are for children undergoing long painful procedures, or who have conditions that are associated with significant or prolonged postoperative pain.\textsuperscript{23} They can also be used to improve peripheral perfusion following micro-vascular surgery, or in the management of vaso spas tic disorders. Continuous infusions have been used to allow physical therapy in chronic regional pain syndromes,\textsuperscript{32} and also in selected cases for patient controlled analgesia.\textsuperscript{31,32} Blood levels reached during continuous brachial plexus infusions are less than those reached during continuous epidural analgesia. In the lower extremity, the main indication has been for the management of femur fractures, or for major trauma involving the lower limb.\textsuperscript{30} Catheters have also been placed for lumbar plexus (psosas compartment) blocks,\textsuperscript{30} or within the fascia iliaca compartments,\textsuperscript{30} to provide unilateral analgesia of the hip or thigh, and also in the popliteal fossa for foot surgery.\textsuperscript{31,24} The psoas compartment block provides a more reliable block of all three nerves of the lumbar plexus than the other techniques (e.g. “3-in-1” or iliaccus compartment block).\textsuperscript{28} The perpendicular distance from the posterior superior iliac spine to the intercrystalline line (Touffiers line) can be used as a guide to the depth of the psoas compartment in children of different ages (unpublished data).

Several manufacturers now provide insulated Tuohy needles of ‘child friendly’ length, through which an appropriate sized catheter can be passed. The role of stimulating versus non-stimulating catheters for continuous peripheral nerve blocks, is the subject of ongoing research and debate.

After an initial bolus dose, the dosage recommended for continuous infusions is 0.1 to 0.2 ml.kg\textsuperscript{-1} hr\textsuperscript{-1} of either bupivacaine or levobupivacaine (0.125% to 0.25%), or ropivacaine (0.15 to 0.2%). The lower rates are generally used for upper extremity catheters, and the higher rates for lower extremity plexus analgesia. The infusion rate may be adjusted up to a maximum rate of 0.2 mg.kg\textsuperscript{-1} hr\textsuperscript{-1} for infants of <6 months, and 0.4 mg.kg\textsuperscript{-1} hr\textsuperscript{-1} in children of >6 months if necessary.\textsuperscript{33,34} Disposable infusion pumps, which may be programmed to deliver local anaesthetic based on a child’s weight, are now available, and may offer an option for outpatient paediatric pain control in the future. An elastomeric disposable pump has been used successfully in children.\textsuperscript{35} To date the reported complications of continuous peripheral nerve blocks have been low, but include catheter-induced infection, particularly in immuno-compromised patients, and also haematoma formation, catheter breakage, and knot formation on removal.\textsuperscript{36}

New blocks
It is not often that a “new” block is described that offers a genuine alternative to epidural analgesia following abdominal surgery. The TAP block, or the transversus abdominis plane block,\textsuperscript{37} is based on the fact that the lower intercostal nerves i.e. those that supply the abdominal wall, run in the plane between the internal oblique and the transversus abdominis muscles. MRI and radiological studies on volunteers have demonstrated uniform spread within that plane, to the level of the costal margin.\textsuperscript{38}

In adults, the TAP block is performed through the “triangle of petit” just above the highest point of the iliac crest. The “triangle of petit” is bordered by the lattisimus dorsi posteriorly, the external oblique anteriorly, with the iliac crest at the base. A “two-pop” technique as the needle penetrates the fascia of the internal oblique and enters the transversus abdominis is described.\textsuperscript{37} The local anaesthetic can be deposited blindly,\textsuperscript{29} or, more accurately, under ultrasound guidance.\textsuperscript{36}

In children the “triangle of petit” is not easy to palpate. However, the muscle layers are easily identified with ultrasonography, and using ultrasound guidance, the needle can be directed to the correct tissue plane.\textsuperscript{28} The nerves must be blocked posterior to the mid-axillary line i.e. before the intercostal nerves give off the lateral cutaneous branches. Dosage guidelines have not been described in children, but 0.3-0.4ml.kg\textsuperscript{-1} is effective for lower abdominal incisions such as appendicectomy, renal transplant recipients, or laparoscopic surgery, where the ports are placed in the lower abdomen. Bilateral TAP blocks have been used successfully for laparotomy incisions in adults.

Management of local anaesthetic toxicity
Resuscitation of a patient from local anaesthetic toxicity may be
difficult. A wide range of agents have been used historically with varied success. These include anti-arrhythmics (phenytoin, bretylium), positive inotropes (epinephrine, isoproterenol, amrinone), and vasopressors (vasopressin, epinephrine), and even extracorporeal circulation. Recent reports of successful management of local anesthetic toxicity – one of immediate onset following a combination of bupivacaine and meivacaine and another of delayed onset following ropivacaine - using 20% Intralipid solution, after initial resuscitation attempts failed, has stimulated renewed interest in this method of resuscitation.45

The first successful resuscitation of a 12-year old child was presented at the recent ASA in San Francisco.

Lipid emulsion has been shown to increase the survival rates of both rats and dogs after local anaesthetic intoxication.44,45 The mechanism of action remains unclear. The lipid emulsion may act as a “lipid sink”, that extracts the lipophilic bupivacaine or ropivacaine from the aqueous plasma phase, and therefore out of the myocardial tissue. Alternatively, the lipid diffuses directly into the tissue, where the high concentration of triglycerides overwhelms the inhibition by bupivacaine, of the carnitinedependent fatty acid transport into the myocardial mitochondria.46

In a recent study using the isolated heart of Sprague-Dawley rats, 20% Intralipid® reversed a radio-labelled L bupivacaine-substitute, particularly in the presence of cardiovascular collapse.46

The dose required for resuscitation of humans, and children in particular, is not clearly defined. 100ml 20% Intralipid® has been used successfully in adults.39,40 Weinberg suggests that, in addition to usual resuscitation for cardiac arrest as per the ACLS guidelines, Intralipid® should be given at 1ml.kg over one minute, repeated at 3-5minute intervals (i.e. a total dose of 3ml.kg), converting at that point, (or earlier with evidence of recovery), to 0.25ml.kg.hr, once cardiovascular stability has been restored.39,46 Propofol, is formulated in 10% lipid emulsion, should not be used as a substitute, particularly in the presence of cardiovascular collapse.47

New drugs

An exciting new drug that only works on pain sensing nociceptors is being developed. The TRPV1 ion channel is only present in pain sensing nociceptors. A new drug, QX314,47 a derivative of lignocaine, works from within the cell. In order to gain entry of impermeant sodium channel blockers. Nature, 2007; 449: 607-10.

References
1. Goldman LJ. Compilations of regional anaesthesia. Paediatr Anaesth 1995; 5: 3-9.
2. Giaufre E, Dalens B, Gombert A. Epidemiology and morbidity of regional anaesthesia in children: a one year prospective study of the French-language Society of Pediatric anaesthesiologists. Anaesth Analg 1996; 83:934-12.
3. Gunter J. Caudal anesthesia in children: a survey. Anesthesiology 1991; 75:936.
4. Solar O, Nava S, Tognetti M et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001; 11: 603-6.
5. Theroux MC, Dixit D, Brittin R et al. Axillary catheter for brachial plexus anaesthesia in children: a prospective evaluation of plasma bupivacaine concentrations, pain scores, and side effects. Anaesth Analg 2001;92:1680-4.
6. Johnson CM. Continuous femoral nerve blockade for analgesia in children with femoral fractures. Anaesth Intens Care 1999;24:281-3.
7. Diwan R, Lalchimy V, Shah T, et al. Continuous tibial nerve block for femoral nerve blockade in children after hip fractures. Anesthesiology 2005;102:374-9.
8. Green A, Rose JW, Wells L, et al. Continuous peripheral nerve blockade for inpatient and outpatient postoperative analgesia in children. Anaesthesiol 2007;105:1244-42.
9. Berde CB. Toxicity of local anesthetics in infants and children. J Pediatr 1993; 123: Pt 2:S14-20.
10. McDonnell JG, O’Donnell B, Farrell T, et al. Transversus abdominis plane block: a cadaveric and radiological evaluation. Reg Anesth Pain Med 2007;32:399-404.
11. Diwan R, Lalchimy V, Shah T, et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001;11: 603-6.
12. Diwan R, Lalchimy V, Shah T, et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001;11: 603-6.
13. Jöhr M, Sossai R. Colonic puncture during ilioinguinal nerve block in a child. Anesth Analg. 1999 May;88 :1051-2.
14. Williams S, Hofer CK, Robson MC et al. Sacral osteoemyelitis after single-shot epidural anaesthesia via the caudal approach in a child. Anaesthesiology 2003; 99:5015.
15. Rochette A, Dadure P, Raux O, et al A review of pediatric regional anaesthesia practice during a 17-year period in a single institution. Paediatr Anaesth. 2008;17: 874-80.
16. Rosenbren AT. Lower limb blocks in children using unshielded needles and a nerve stimulator. Anaesth Analg. 1995; 5: 30-206-0.
17. Sarda A. Periperal nerve block: a review of the code – one at a time. Reg Anesth Pain Med 2004; 29: 3-185-8.
18. De Andres J, Alonso-Frigo IM, Sala-Blasco X, Reina MA. Nerve stimulation in regional anesthesia: theory and practice. Best Practice Research Clin Anaesthesiol 2003; 17: 153-74.
19. Rosenbren AT, Raw R, Rozea AT. Surface mapping of peripheral nerves in children with a nerve stimulator. Paediatr Anaesth 2002; 12: 398-403.
20. Urney WE, Gross P. Percutaneous electrode guidance: a non invasive technique for location of peripheral nerves to facilitate peripheral plexus and nerve blocks. Reg Anesth Pain Med 2002; 27: 261-10.
21. Albert DH, Dudaevitch D, Bloom K, Rosenbren AG. Surface stimulation to determine needle direction and angle when performing an infracavicular plexus block. Pain Pract 2006;10:14-6.
22. Marhofer P, Greher M, Kapral S. Ultrasonic guidance in regional anaesthesia. Br J Anaesth 2005; 94:7-17.
23. Eichenberger U, Greher M, Kirchner L et al Ultrasonic-guided blocks of ilioinguinal and iliohypogastric nerves: accuracy of a selective new technique performed by anatomical dissection. Br J Anaesth. 2008; 97:263-64.
24. Willschke H, Marhofer P, Rosenbren A, et al. Ultrasonography for ilioinguinal/iliohypogastric nerve blocks in children. Br J Anaesth. 2005;95:226-30.
25. Willschke H, Rosenbren A, Marhofer P, Rosenbren et al. Ultrasonic-guided ilioinguinal/iliohypogastric nerve blocks for pediatric anaesthesia; what is the optimum volume? Anaesth Analg 2006; 102:1680-4.
26. Willschke H, Rosenbren A, Marhofer P, Johnston et al. Ultrasonography for sciatric and femoral nerve blocks in children Br J Anaesth. 2007; 98:797-801.
27. Casati A, Baciarello M, Di Gianni et al Effects of ultrasonic guidance on the minimum effective anaesthetic volume required for femoral nerve block. Br J Anaesth. 2007;98(6):823-7.
28. Willschke H, Marhofer P, Rosenbren A, et al. Ultrasound catheter for sciatric and femoral nerve blocks in children Br J Anaesth. 2007;98(6):823-7.
29. Casati A, Baciarello M, Di Gianni et al Effects of ultrasonic guidance on the minimum effective anaesthetic volume required for femoral nerve block. Br J Anaesth. 2007;98(6):823-7.
30. Sarda A, Matsuura M, Gebhard et al. Continuous posterior lumbar plexus block for acute postoperative pain control in young children. Anaesthesiol 2003; 95, 1521-3.
31. Paut O, Sallaberry M, Schreiber-Deturmeny E, et al. Continuous fascia iliaca compartment block in children: a prospective evaluation of plasma bupivacaine concentrations, pain scores, and side effects. Anaesth Analg 2001;92:1680-4.
32. Diwan R, Lalchimy V, Shah T, et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001;11: 603-6.
33. Diwan R, Lalchimy V, Shah T, et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001;11: 603-6.
34. Dadure C, Bringuier S, Nicolas F, Bromilow L. Continuous epidural block for femoral nerve blockade in children with femoral fractures. Anaesth Intens Care 1999;24:281-3.
35. Paut O, Sallaberry M, Schreiber-Deturmeny E, et al. Continuous axillary block for upper limb surgery in a patient with epidermolysis bullosa simplex. Paed Anaesth 2001;11: 603-6.