Paediatric regional anaesthesia: *new developments and improving accuracy*

Bösenberg AT
Department of Anaesthesia, University of Cape Town and Red Cross Children's War Memorial Hospital, South Africa

Correspondence to: Prof A Bosenberg, e-mail: Adrian.Bosenberg@uct.ac.za

SAJAA 2007;13(1): 37-41

ABSTRACT

Regional anaesthesia can provide absolute pain relief without the risks of opiate-induced respiratory depression. The purpose of this paper is to (i) provide insight into some new techniques that may improve the success and accuracy of peripheral nerve blocks, with particular reference to the role of nerve mapping, nerve stimulators and portable ultrasound; (ii) introduce methods to reduce the risk of intraneural injection; (iii) suggest methods to prolong the analgesia provided by peripheral nerve blocks, i.e. continuous peripheral nerve catheters appropriate for use in children; and (iv) propose methods to manage local anaesthetic toxicity, with particular reference to the use of intralipid solutions.

Introduction

Peripheral nerve blocks in children are challenging for a number of reasons. Firstly, 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.

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 we at least can expect a stationary child. Although hotly debated in medico-legal circles, there is little or no evidence that the placement of nerve blocks in anaesthetised children is dangerous. Many consider placement of blocks under anaesthesia as 'best practice'. Those who extrapolate from adults and refuse to perform regional blocks in anaesthetised 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.

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 beneficial if regional blocks could be performed with the smallest effective dose of local anaesthetic. Although the incidence of complications from peripheral nerve blocks is low, anecdotal reports demonstrate that the proximity of nerves to other vital structures potentially places the child at considerable risk.

Anaesthesiologists have therefore sought aids to improve the success of the regional blocks that they perform. Eliciting paraesthesia, considered a cornerstone of success by the pioneers of regional anaesthesia, is both inaccurate and clearly impractical in anaesthetised children. Besides, a recent study in adults comparing paraesthesia, nerve stimulation and ultrasound-guided nerve blocks showed that paraesthesia, defined as "pins and needles" or an "electric shock", had a sensitivity of only 38% for successful block.

Although nerve blocks may be achieved with non-insulated needles,[1] peripheral nerve stimulators[2,3] and insulated needles have been a major advance, both as a teaching aid and as a means to improve the success of peripheral nerve blocks. Surface nerve mapping, a technique whereby the motor component of a peripheral nerve may be stimulated transcutaneously, also has its value.[4,5] Sensory nerve mapping is also possible, but requires more sophisticated equipment and a cooperative and discerning patient. Unfortunately, both are 'blind' techniques and the practitioner is unable to determine the exact location of the needle tip in relation to the nerves and their neighbouring structures. It is not surprising that inadvertent puncture of adjacent structures and unpredictable failures still occur.

Ultrasound imaging may provide the answer for anaesthesiologists to improve the accuracy of local anaesthetic placement in both adults and children.[6]

Techniques

Nerve stimulator

There are a number of basic principles that need to be emphasised when using a nerve stimulator. In order to locate a peripheral nerve or plexus, neuromuscular blocking agents must be withheld or given after completion of the nerve block.[1,2] The proper functioning of the nerve stimulator and the needle should be understood prior to use.[1,2] With the flood of peripheral nerve stimulators currently on the market, it is best to "familiarize oneself with the nuances of a particular device and to stick with it".[1] A nerve stimulator that delivers a constant current should preferably be used.

The ***n***egative electrode should be attached to the ***n***eedle and the ***p***ositive electrode is attached to the ***p***atient using a standard

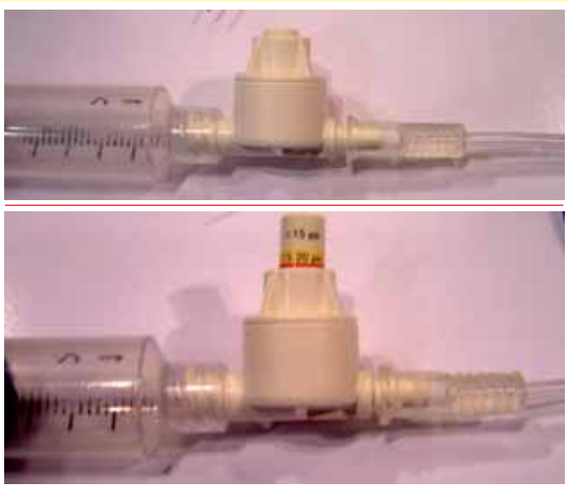
ECG electrode. Once the appropriate landmarks have been determined or 'surface-mapped', the peripheral nerve stimulator should be set to provide a constant 'square wave' current output of 1 -1.5 mA for 1 msec at a frequency of 1-2 Hz. The short-duration stimulus allows selective motor nerve stimulation without sensory or painful effects in patients that are awake. Whilst advancing the needle toward the nerve through the skin and underlying tissue planes, distal muscle contractions should be elicited as the needle approaches the nerve. The contractions should be in the muscle(s) supplied by the particular nerve, root, trunk, cord or branch to be blocked. The output should then be decreased until maximum motor response is elicited with the least amount of current, i.e. a visible twitch with approximately 0.3 to 0.5 mA. In a recent animal study, a motor response in an exposed sciatic nerve was elicited when the needle was 1 to 2 mm from the nerve. The position of the needle-tip can be adjusted to achieve this, but adjustment of the current output and needle position should not be done simultaneously.

An appropriate dose of local anaesthetic can be injected at this point. The muscle stimulation will immediately cease, indicating that a successful block is likely. Failure to elicit this response requires the needle to be repositioned before repeating the process. It has recently been suggested that this initial test should be done with 5% dextrose so that twitch is maintained. The local anaesthetic should not be injected if intense muscle contraction is elicited at <0.2 mA, or if there is resistance to injection. Both suggest that the tip of the needle may be intraneural and that the nerve may be damaged by further injection. But this is another area of debate!

Safety: Undetected intraneural injection of local anaesthetic can result in permanent damage to the nerve. This remains a potential risk with any 'blind technique', particularly when blocks are performed under anaesthesia. Increased pressure during injection is an indicator of intraneural injection or other needle misplacement. This surrogate marker of intraneural injection is a subjective feeling, and varies according to the size of the syringe used. A recent study performed on the sciatic nerve of anaesthetised pigs has offered some guidelines. Pressures greater that 20 psi generated during intraneural injection (rate of injection 15 ml.min) resulted in delayed nerve recovery. No evidence of nerve injury was detectable when lower pressures were generated. In practice, the rate at which local anaesthetic is injected varies from individual to individual. Whether these findings can be extrapolated to clinical practice remains to be seen. However, a new pressure detection device, placed between the syringe and needle, is being marketed to monitor the pressure generated during injection, based on these findings. *(See Figure 1)*

To minimise the risk of intraneural injection when a nerve stimulator is used, some advocate withdrawing the needle slightly before injecting the local anaesthetic. Others caution that injecting against resistance, or when the stimulating current is <0.3 mA, may indicate that the needle is intra-neural.[7] The minimum stimulating current for safe injection is open to debate. Many

Figure 1: Pressure manometer (B-Smart)



Pressure manometry is used to monitor the pressure generated during the injection of local anaesthetic agent. Pressures exceeding 20psi warns the anaesthesiologist that the pressure generated is potentially damaging to the nerve.

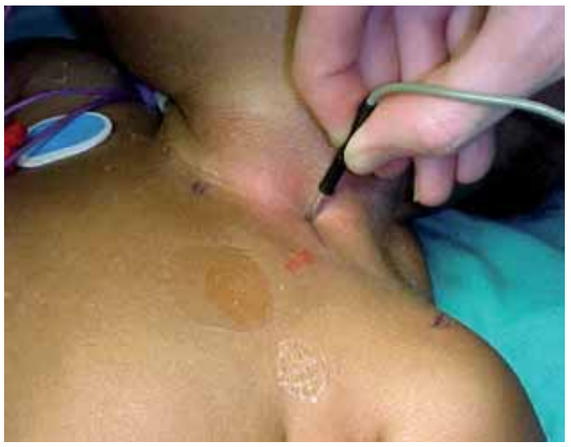
factors are involved and the current output is dependent on the nerve stimulator used,[1,2] the shape and duration of the impulse, the fascicular pattern of the nerve and location of the motor fibres within the nerve, the electrolyte milieu within and around the nerve, the size of the needle and the length of the non-insulated distal tip. In a recent case report, where a stimulus of 0.05 mA and 3 ms duration elicited a brisk motor stimulus that disappeared at 0.02 mA, the stimulating catheter was shown, using fluoroscopy, to lie outside the nerve plexus.[8] But studies in animals (pigs, dogs) have demonstrated that intraneural injection may occur with a range of currents, i.e. from 0.1 to 1 mA.[8,9,10,11] Extraneural positioning of the needle had a similar range. It therefore seems that simply relying on a number is inappropriate and that other factors must be taken into account.

Surface nerve mapping[4]

This is a modification of the standard nerve stimulator technique and is particularly useful in children. The path of a superficial peripheral nerve or plexus can be traced prior to skin penetration by stimulating the motor component of the nerve transcutaneously. The nerve stimulator output is set at 3-5 mA at 1-2 Hz and the negative electrode is used as the mapping electrode. The current required varies and is dependent on the depth of the nerve, the moistness of the overlying skin, the size of the mapping electrode and the pressure exerted. The point at which the motor response elicited in the muscles supplied by that nerve is maximal is marked and used as the landmark for that specific nerve block. *(See Figure 2)*

Direct muscle stimulation is finer and more localised and should be recognised as a 'false positive' response. Excessive pressure applied over the nerve may inhibit the response. The 'nerve mapping technique' may be used for various approaches to the brachial plexus, as well as the axillary, musculo-cutaneous, ulnar,

Figure 2: Nerve mapping



Landmarks are identified and the nerve is stimulated transcutaneously to seek a motor response. At the point of maximal response the skin can be marked and serves as the point of needle entry.

median and radial nerve blocks of the upper limb; and to the femoral, sciatic and popliteal nerve blocks in the lower limb. Surface nerve mapping is particularly useful when classic anatomical landmarks are absent or difficult to define, for example in children with contractures (arthrogryposis multiplex congenital; burns) or with major congenital limb defects.

Ultrasound-guided nerve blocks

Experience with the use of ultrasound as an aid in paediatric regional anaesthesia is still relatively limited and confined to a few centres. This method is fast becoming an important adjunct in regional anaesthesia and may soon become standard practice in the USA.[6] Ultrasonography is non-invasive, relatively expensive (in the South African context), and is being used to improve the accuracy of local anaesthetic placement. The technique is easily taught and the learning curve is steep. Technological advancements have allowed the development of small portable ultrasound equipment that can be taken into the operating room (SonoSite 180+® or the Micromax® unit, SonoSite™, Bothell, WA, USA). Image resolution is dependent on the frequency of the ultrasound, and the size and depth of the nerve. Higher frequency probes (10 to 15 MHz), which produce a 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. Deeper structures require lower frequencies and the resulting images have a lower resolution. Frequencies of 10 to 15 MHz can provide good resolution of nerves as small as 1 mm, but the tissue depth at which small nerves can be identified easily is limited to approximately 2 to 3 cm.

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 neuraxial 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 lie within range of portable ultrasound probes and good definition is obtained.[12,13,14,15,16] A 5-10 MHz linear hockey stick probe provides high resolution and is the most popular for use in children.

A further advantage of ultrasound is that, in neonates, and particularly in premature neonates, the vertebral column is poorly ossified, allowing ultrasound waves to reach the spinal cord. Ultrasound examination of the spinal cord may provide useful information prior to placing a caudal, spinal or epidural in neonates. The conus medullaris, dural sac and any abnormal anatomy within or around the vertebral column can be identified. Identification of the epidural space, confirmation of local anaesthesia spread and catheter placement within the epidural space are possible.[16]

Proponents of ultrasound-guided regional anaesthesia claim earlier onset times,[13,14] improved quality[13,14,15] and duration of block with smaller volumes of local anaesthetic, [15] and fewer complications in children.

Continuous peripheral nerve blocks[17,18,19,20,21]

Continuous peripheral nerve catheters have not been available for use in children until recently. Previously, continuous peripheral neural blockade required improvisation. A variety of methods, some subsequently forming the basis for the development of the modern 'designer' catheters, were used. As the appropriate equipment has become available, an increasing number of reports of their use for continuous postoperative pain management or therapeutic care have been published.

The main indications for continuous peripheral nerve blocks have been for children undergoing procedures, or having conditions that are associated with significant or prolonged postoperative pain, to improve peripheral perfusion following micro-vascular surgery or in managing vasospastic disorders, and to allow physical therapy in chronic regional pain syndromes. In selected cases, patient-controlled analgesia is feasible. Blood levels reached during continuous brachial plexus infusions are lower than those found during continuous epidural analgesia.

In the lower extremities, the main indication has been for the management of femur fractures or major trauma involving the lower limb. Catheters have also been placed in the lumbar plexus (psoas compartment) or fascia iliaca compartments to provide unilateral analgesia of the hip or thigh, and in the popliteal fossa for foot surgery. 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 iliacus compartment block).

Ideally, a commercially available kit should be used to identify the nerve sheath prior to placement of the catheter. Several manufacturers now provide insulated Tuohy needles of 'child

friendly' length through which an appropriately-sized stimulating 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.

Alternatively, one could improvise with a modification of the Seldinger technique, whereby the nerve to be blocked is stimulated via a guidewire passed through a needle. The needle can then be removed and the catheter or cannula thread over the guidewire. A catheter can subsequently be fed through the cannula. These improvised methods are not conducive to accurate catheter placement and radiographic confirmation may be required.

After an initial bolus dose, the dosage recommended for continuous infusions is 0.1 to 0.2 $mL.kg^{-1}.hr^{-1}$ 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 recommended infusion rate of 0.2 $mg.kg^{-1}.hr^{-1}$ for infants younger than six months and 0.4 $mg.kg^{-1}hr^{-1}$ in children older than six months.[22]

Disposable infusion pumps, which may be programmed to deliver local anaesthetic based on a child's weight, are currently available and may offer an option for outpatient paediatric pain control in the future. To date, the reported complications have been low, but include catheter-induced infection, particularly in immunocompromised patients, haematoma formation, catheter breakage or knot formation on removal.

Management of local anaesthetic toxicity

Salvaging a patient from local anaesthetic cardiotoxicity may be difficult. A wide range of agents, including anti-arrhythmics (phenytoin, bretyllium), positive inotropes (epinephrine, isoproterenol, amrinone, insulin), vasopressors (vasopressin, epinephrine), and even extracorporeal circulation has been used with varying success. Recent reports of successful management of suspected local anaesthetic cardiotoxicity using 20% intralipid solution, after initial resuscitation attempts failed, have stimulated renewed interest in this method of resuscitation.[23,24] These reports include one of immediate onset following a combination of bupivacaine and mepivacaine toxicity,[25] and another of delayed onset following ropivacaine administration.[23]

Lipid emulsion has been shown to increase the survival rates of both rats and dogs after local anaesthetic-induced cardiac arrest.[26,27,28] 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 carnitine-dependent fatty acid transport into the myocardial mitochondria.[23,24,26,27] In a recent study using the isolated heart of Sprague-Dawley rats, 20% Intralipid® reversed a radio-labelled L bupivacaine-induced cardiac arrest more rapidly than controls that were given Krebs solution. The myocardial function returned more rapidly and the concentration of bupivacaine in the myocardial tissue after resuscitation was lower.[28]

The dose required for resuscitation of humans, and children in particular, has not been defined clearly. In adults, 100 ml of 20% Intralipid® has been used successfully.[23,24] Weinberg suggests that, in addition to the usual resuscitation for cardiac arrest as per the ACLS guidelines, Intralipid® should be given at 1 ml.kg over one minute, repeated at three to five-minute intervals (i.e. a total dose of 3 ml.kg), converting at that point, or earlier with evidence of recovery, to 0.25 ml.kg.hr as an infusion once cardiovascular stability has been restored.[27,29] Propofol, which is formulated in 10% lipid emulsion, should not be used as a substitute, particularly in the presence of cardiovascular collapse.[30] **SAJAA**

References

1. 1 Bosenberg AT. Lower limb blocks in children using unsheathed needles and a nerve stimulator. Anaesthesia 1995;50(3):206–10.
2. Hadzic A. Peripheral nerve stimulators: cracking the code – one at a time. Reg Anesth Pain Med 2004;29(3):185–8.
3. De Andres J, Alonso-Inigo JM, Sala-Blanch X, Reina MA. Nerve stimulation in regional anesthesia: theory and practice. Best Practice Research Clin Anesth 2005;19:153–74.
4. Bosenberg AT, Raw R, Boezaart AP. Surface mapping of peripheral nerves in children with a nerve stimulator. Paediatr Anaesth 2002;12:398–403.
5. Urmey WF, Grossi 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;27:261–7.
6. Marhofer P, Greher M, Kapral S. Ultrasound guidance in regional anaesthesia. Br J Anaesth 2005;94:7–17.
7. Kapur E, Voljevica A, Divanovic K, Vuckovic I. Intraneural injections result in high injection pressure and delayed neurologic recovery after sciatic nerve block in pigs. Reg Anesth Pain Med 2005;30(3):A4 (abstract).
8. Wehling MJ, Koorn R, Leddell C, Boezaart AP. Nerve stimulation using a stimulating catheter: what is the lower limit? Reg Anesth Pain Med 2004;29:230–3.
9. Brull R, Chan V, Shannon P. Intraneural electrical stimulation and ultrasound detection of intraneural injection. Reg Anesth Pain Med 2005;30(3):A1 (abstract).
10. Tsai T, Vuckovic I, Eldan K, Kucuk-Alija D. Intensity of the stimulating current is not a reliable indicator of intraneural needle placement. Reg Anesth Pain Med 2005;30(3):A2 (abstract).
11. Sinha S, Abrams J, Weller R. Ultrasound guided interscalene needle placement produces successful anaesthesia regardless of motor stimulation above or below 0.5mA. Reg Anesth Pain Med 2005;30:A3 (abstract).
12. Carlos B, William U, Luis V, Fernando C. Experimental neural stimulation and abolition of motor response after extra and intra neural local anesthetic injection Reg Anesth Pain Med 2005;30(3):A4.
13. Willschke H, Marhofer P, Bosenberg A, Johnston S, *et al.* Ultrasonography for ilioinguinal/iliohypogastric nerve blocks in children. Br J Anaesth 2005;95:226–30.
14. Willschke H, Bosenberg A, Marhofer P, Johnston S, *et al.* Ultrasound-guided ilioinguinal/iliohypogastric nerve blocks in pediatric anesthesia; what is the optimum volume? Anesth Analg 2006;102:1680–4.
15. Willschke H, Bosenberg A Marhofer P, Johnston S, *et al.* Ultrasound-guided rectus sheath blocks in pediatric anesthesia; a new approach to an old technique. Br J Anaesth 2006;97:244–9.
16. Willschke H, Marhofer P, Bosenberg A, Johnston S, *et al.* Epidural catheter placement in children: comparing a novel approach using ultrasound with the standard loss of resistance technique. Br J Anaesth 2006;97:200–7.
17. Sciard D, Matuszczak M, Gebhard R, *et al.* Continuous posterior lumbar plexus block for acute postoperative pain control in young children. Anesthesiology 2001;95:1521–3.
18. Paut O, Sallabery 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. Anesth Analg 2001;92:1159.
19. Eichenberger U, Greher M, Kirchmeir L, *et al.* Ultrasound-guided blocks of ilioinguinal and iliohypogastric nerves: accuracy of a selective new technique confirmed by anatomical dissection. Br J Anaesth 2006;97:238–43.
20. Johnson CM. Continuous femoral nerve blockade for analgesia in children with femoral fractures. Anaesth Intens Care 1994;22:281–3.
21. Diwan R, Lakshmi 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.
22. Berde CB. Toxicity of local anesthetics in infants and children. J.Pediatr 1993:122(2):S14–20.
23. Litz RJ, Popp M, Stehr SN. Koch T. Successful resuscitation of a patient with ropivacaine-induced asystole after axillary plexus block using lipid infusion. Anaesthesia 2006;61:800–1.
24. Groban L, Butterworth J. Lipid reversal of bupivacaine toxicity: has the silver bullet been identified? Reg Anesth Pain Med 2003;28:167–9.
25. Rosenblatt MA, Abel M, Fischer GW, *et al.* Successful use of a 20% lipid solution to resuscitate a patient after a presumed bupivacaine-related cardiac arrest. Anesthesiology 2006;105:217–8.
26. Weinberg G. Lipid infusion resuscitation for local anesthetic toxicity. Anesthesiology 2006;105:7–8.
27. Picard J, Meek T. Lipid emulsion to treat overdose of local anaesthetic: the gift of the glob. Anaesthesia 2006;61:107–9.
28. Weinberg GL, Ripper R, Murphy P, *et al.* Lipid infusion accelerates removal of bupivacaine and recovery from bupivacaine toxicity in the isolated rat heart. Reg Anesth Pain Med 2006;31:296–303.
29. Weinberg G. Lipid rescue: caveats and recommendations for the "silver bullet" (letter). Reg Anesth Pain Med 2004;29:74.
30. Weinberg GL Lipid not propofol treats bupivacaine overdose Reg Anesth Pain Med 2006;31:296–303.