

Session:

PHARMACOLOGICAL APPROACHES TO PAIN MANAGEMENT IN CHILDREN:

Lecture:

REGIONAL ANAESTHESIA: NEW DEVELOPMENTS AND IMPROVING ACCURACY

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Objectives: *Regional anaesthesia can provide absolute pain relief without the risks of opiate induced respiratory depression. The purpose of this lecture is to provide an insight into some new techniques that (i) 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) methods to prolong the analgesia provided by peripheral nerve blocks i.e. continuous peripheral nerve catheters appropriate for use in children; and (iii) 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-weightbearing 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 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. 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.

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. Although the incidence of complications for 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. Although nerve blocks may be achieved with non-insulated needles,⁽¹⁾ peripheral nerve stimulators^(2,3) and insulated needles were a major advance, both as a teaching aid and as a

means to improve the success rate of peripheral nerve blocks Surface nerve mapping^(4,5), 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

Ultrasound imaging may provide the 'ray of hope' for which anaesthesiologists have been searching to improve the accuracy of local anaesthetic placement in both adults and children.⁽⁶⁾

Nerve stimulator There are a number of basic principles that need to be emphasized when using a nerve stimulator. In order to locate a peripheral nerve or plexus, neuromuscular blocking agents must be withheld until 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⁾

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 EKG 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 -1.5mA for 1msec at a frequency of 1-2 Hz. The short duration stimulus allows selective motor nerve stimulation without sensory or painful effects in awake patients. When 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 0.3-0.5mA. 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 anesthetic 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 dose should be performed with 5% dextrose so that twitch is maintained. The local anesthetic should not be injected if intense muscle contraction is elicited at <0.2 mA, or if there 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: To minimize the risk of intraneural injection some recommend withdrawing the needle slightly before injecting the local anesthetic. Others caution that injecting against resistance,⁽⁷⁾ or when the stimulating current is <0.3 mA, may indicate that the needle is intra-neural. The minimum stimulating current for safe injection is open to debate. Many factors are involved and the current output is dependant 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 fibers 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. Studies in animals (pigs, dogs)⁽⁸⁻¹¹⁾ have demonstrated that intraneural injection may occur with a range of currents from 0.1-1mA. Extraneural positioning of the needle had a similar range. In a case report where a stimulus of 0.05mA and 3ms duration elicited a brisk motor stimulus that disappeared at 0.02mA, the stimulating catheter was shown to lie outside the nerve plexus using fluoroscopy.⁽⁸⁾

Surface nerve mapping⁽⁴⁾ is a modification of the standard nerve stimulator technique. 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 3-5mA at 1-2Hz 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.

Direct muscle stimulation is finer and more localized and should be recognized 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, median and radial nerve blocks of the upper limb; and the femoral, sciatic and popliteal nerve blocks in the lower limb. Surface nerve mapping is particularly useful where 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 but it is fast becoming an important adjunct in regional anaesthesia.⁽⁶⁾ Ultrasonography is non-invasive, relatively inexpensive, and is being used to improve the accuracy of local anaesthetic placement. The technique is easily taught but 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 Micromax[®] unit, SonoSite[™], Bothell, WA, USA). Image resolution is dependant on the frequency of the ultrasound and the size and depth of the nerve. Higher frequency probes (10 -15MHz) that produce much higher image resolution are preferred. But 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 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 be easily 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 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.⁽¹³⁻¹⁶⁾ A 5-10 MHz linear hockey stick probe provides high resolution and is the most popular in children.

A further advantage of ultrasound is that in neonates, particularly premature neonates, the vertebral column is less 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 can be easily identified. Identification of the epidural space, confirmation of local anaesthesia and catheter placement within the epidural is possible.⁽¹⁶⁾

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

Continuous peripheral nerve blocks⁽¹⁷⁻²¹⁾ 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 have associated conditions, that are associated with significant or prolonged postoperative pain; or to improve peripheral perfusion following micro-vascular surgery or in managing vasospastic disorders. In selected cases patient controlled analgesia is also feasible. Continuous infusions have also been used to allow physical therapy in chronic regional pain syndromes. 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 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 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 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.

Alternatively one could improvise with a modification of the Seldinger technique whereby the nerve to be blocked is stimulated via a guidewire passed either through a needle or IV cannula; followed by needle removal and placement of a catheter over the wire or threading the catheter 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 <6 months and 0.4 mg.kg⁻¹.hr⁻¹ in children >6 months.⁽²²⁾ Disposable infusion pumps, which may be programmed to deliver local anesthetic based on a child's weight, are currently available and may offer an option for outpatient pediatric pain control in the future. To date the reported complications have been low but include catheter-induced infection particularly in immuno-compromised patients; hematoma formation, catheter breakage or knot formation on removal.

Management of local anaesthetic toxicity: Salvaging a patient from local anaesthetic toxicity may be difficult. A wide range of agents, including anti-arrhythmics (phenytoin, bretyllium),

positive inotropes (epinephrine, isoproterenol, amrinone, insulin) and vasopressors (vasopressin, epinephrine), and even extracorporeal circulation, have been used with varying success. Recent reports of successful management of local anaesthetic toxicity – one of immediate onset following a combination of bupivacaine and mepivacaine⁽²³⁾ and another of delayed onset following ropivacaine⁽²⁴⁾ - using 20% Intralipid solution, after initial resuscitation attempts failed, has stimulated renewed interest in this method of resuscitation.^(24,25)

Lipid emulsion has been shown to increase the survival rates of both rats and dogs after local anaesthetic intoxication.⁽²⁶⁻²⁸⁾ 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 overwhelm the inhibition by bupivacaine of the carnitine-dependant fatty acid transport into the myocardial mitochondria.⁽²⁴⁻²⁷⁾ 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 who were given Krebs solution; the myocardial function returned more rapidly and the concentration of bupivacaine in the myocardial tissue after resuscitation was less.⁽²⁸⁾

The dose required for resuscitation of humans, and children in particular, has not been clearly defined. 100ml 20% Intralipid® has been used successfully in adults.^(23,24) 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 3-5minutes 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.^(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⁾

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