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Neuraxial anaesthetic techniques in children: Using the evidence to make it safer

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Introduction

Persistent postsurgical pain (PPSP) is a recognised complication following a surgical insult in children, with a prevalence of 20% at one year postop.[1]

As anaesthetists caring for children, the question posed to us is simply: How can this child be guided through this traumatic event safely, while at the same time minimising his/her pain and suffering? We tend to prioritise safety, while largely neglecting pain control. This results in significant moderate-severe postsurgical pain, with all the deleterious consequences thereof.

In the South African context, where postoperative pain management is a largely neglected priority and concerns around nursing care in wards are prevalent, neuraxial techniques remain an important method of providing good postoperative analgesia for painful procedures.

Anatomical considerations in children in comparison to adults

- Short skin-epidural space distance. Calculating epidural depth using the formula 1 mm/kg is a useful guide in children aged 6 months to 10 years.[2]
- The intercristal line bisects the 5th lumbar vertebra (L5). This contrasts with adults, where the intercristal line bisects L3/L4.
- The ligamentum flavum is softer, thus the distinctive 'pop' felt in adults when advancing the needle through the ligament may not be felt in younger children.
- Narrow epidural space. This may render dural puncture more likely, and contribute to difficulty in threading a catheter.
- The conus medullaris is more caudad and is usually around L3. It reaches adult level (L1) at around 1 year.
- The dural sac is more caudad in neonates, which may predispose to dural puncture when performing a caudal neuraxial technique.
- The sacral plate is not completely ossified and continues to fuse until 8 years of age. This may facilitate the passage of a needle at an insertion point more rostrally, possibly making dural puncture more likely.

→ Some of these anatomical differences contribute to making neuraxial techniques in children more technically challenging for the anaesthetist, and narrow the margin of safety.

- In the thoracic spine, vertebral bodies are less angulated, necessitating a perpendicular approach to the skin.
- Higher CSF volume (ml/kg). Thus, higher volumes (in ml/kg) are required to achieve same level of anaesthesia/analgesia.
- Quicker 'turnover' of CSF, resulting in a shorter duration of spinal anaesthesia.
- Loose epidural fat can contribute to more even spread of Local Anaesthetic (LA), and may enable easier advancement of catheters.

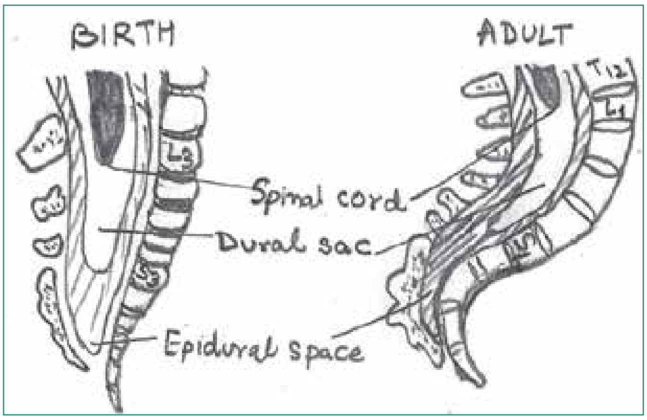

Figure 1. Differences in spinal anatomy between adults and children

Pharmacokinetic considerations in Neonates/Infants in comparison to adults

- LA has lower clearance due to immature liver
  - Bupivacaine metabolism reaches maturity by 1 year.[3] Plasma bupivacaine concentration accumulates in neonates after 48 hours.
  - Ropivacaine metabolism reaches maturity by 4–7 years.[3]
- Higher unbound free fraction of drug due to $\downarrow$ α_1 acid glycoprotein

→ Could render child more susceptible to LA toxicity.

- LA has higher volume of distribution, possibly countering the previously mentioned points.

Pharmacodynamic considerations in Neonates/ Infants in comparison to adults

→ Thinner, smaller nerve fibres

- Myelin sheath not properly formed
- Nodes of Ranvier closer together
- Lower doses/concentrations are required to achieve same effect.

Risk

Complications seem to occur in theatre with the anaesthetist present, and not in the ward, as is often our concern. It is worth noting that the nurse to patient ratio, as well as the quality of nursing care may differ significantly from the institutions where these complications were reported. Paediatric-appropriate equipment and ultrasound have been key contributors to improved safety of neuraxial anaesthesia in children.

For an excellent and comprehensive review of complications associated with neuraxial anaesthesia, please refer to Dr Dean Nolte's 'Managing the complications of neuraxial anaesthesia: the big short of it all' (FCA Part 2 Refresher 2016). From the extensive paediatric literature on this topic, it is important to mention that:

- Institutions at which ≥ 200 paediatric epidurals are performed annually have been found to have lower complication rates (minor and serious).
- Neonates are at higher risk of complications, but these have been found to be minor and self-limiting, and largely due to drug errors and local anaesthetic toxicity, rather than insertion.[4]
- Thoracic epidurals in children under 1 year were associated with the highest complication rates.
- Post-dural puncture headache (PDPH) is rare in children. This may be due to a lower CSF pressure and lower hydrostatic pressure when upright. It is, however, difficult to diagnose PDPH in younger children.
- In the UK, the national paediatric audit on opiate infusions revealed a similar incidence of complications as the national paediatric epidural audit.[4,5] Severe complications with persistent deficit occurred in 1:10 000 patients.

Contraindications

Table 1. Contraindications to Neuraxial Anaesthesia in Children

ABSOLUTE
Coagulopathy
Raised intracranial pressure
Haemodynamic instability
Infection at the insertion site
Cardiac disease with fixed output state
Refusal by patient/parent
RELATIVE
Neuromuscular disease, e.g. Central Core Disease*
Poorly controlled seizures
Cutaneous anomalies, e.g. dimples, hairy naevi, angiomas
Anorectal anomalies
Ventriculoperitoneal shunt in-situ
Anatomical deformities of the spine

*Due to concerns around possibly worsening pre-existing neurological deficits

Neuraxial anaesthesia may be safely performed in the presence of cutaneous and anorectal anomalies, provided that the patient has had an ultrasound/MRI of the spinal cord to exclude abnormalities.

Spinal Anaesthesia

While there are few indications for spinal anaesthesia in children owing to the short duration of analgesia provided, this technique has re-emerged as a sole technique for sick neonates and infants requiring short procedures. Duration of anaesthesia is 30–60 minutes. Clonidine can be used to prolong duration by up to 90 minutes, but is associated with apnoea in neonates. Spinal anaesthesia has found a place in ex-premature neonates who are at risk of apnoea. The landmark GAS study, conducted in ex-premature neonates requiring inguinal herniorrhaphy, showed a decrease in incidence of early apnoea (within 30 minutes postop) and a decrease in severity of apnoea, requiring less intervention.[6] This technique is potentially useful in resource-poor areas.

Intrathecal morphine has been used successfully in children, but is limited by significant nausea and vomiting, pruritis and urinary retention.[7] If used in low doses (see below), the risk of respiratory depression is low.

- Neonates/Infants: 0.2 ml/kg of 0.5% isobaric bupivacaine (minimum volume 0.5ml)
- Older children (> 1 year): 0.5 mg/kg isobaric bupivacaine

Table 2. Indications for spinal anaesthesia in children

General Surgery	Herniorrhaphy – umbilical + inguinal, appendicectomy colostomy, perineoplasty, rectal biopsy I+D rectal abscess, gastrostomy, exploratory laparotomy
Urology	Orchidopexy, hydrocoelectomy, cystoscopy ablation posterior urethral valves, suprapubic catheter placement, vesicostomy, hypospadias, ureteral re-implant
Orthopaedic & lower limb	I+D abscess, amputation, ORIF hip bilateral adductor myotomy, closed reduction of hip spica cast placement, club foot repair, arthrogram muscle biopsy, tumour excision, tendon lengthening
Miscellaneous	Meningomyelocele, radiation oncology chronic pain management, cardiothoracic

Epidural Anaesthesia

While the benefits of single-shot caudal anaesthesia are without question, there still exists some debate on whether catheter-based neuraxial techniques should be adopted more widely, particularly in neonates and young infants, or whether they should remain a technique used in specialist tertiary centres, by specialist paediatric anaesthetists.

Epidural catheters remain an excellent method of providing long-lasting analgesia and have transformed the perioperative care of children. They promote good respiratory function and decrease the need for postop ventilation and possibly ICU, which is an important consideration in resource-constrained settings. Other benefits are numerous, and include modification of the neuroendocrine stress response, improved haemodynamic stability, decreased ICU and high care stay, and possibly shorter hospital stay. While some are difficult to prove, they must be borne in mind when choosing a postoperative pain management strategy. In many patients it can be argued that the benefits outweigh the risk.

Caudal Anaesthesia

Caudal anaesthesia remains a commonly utilised technique in children and provides good analgesia for common day-case procedures.

Current evidence shows strong correlations between age, height, weight and body surface area (BSA), and the distance between the sacrococcygeal ligament and the dural sac.[8] The formula 25 x BSA (mm) has been suggested as simple method of calculating this distance, to avoid puncture of the dura, particularly in neonates/infants.

Studies indicate that using larger volumes of dilute LA (bupivacaine or ropivacaine) are associated with more effective intraoperative analgesia with no change in the quality of postoperative analgesia.[9,10]

In a small study conducted in infants undergoing caudal anaesthesia, the speed of injection was shown to cause significant reduction in cerebral blood flow velocity and consequently regional cerebral perfusion and oxygenation, despite normal systemic haemodynamic parameters, when large volumes (1.5 ml/kg) were used.[11] The consequences in otherwise healthy children are postulated to be insignificant, but this may be cause for concern in children at risk.

Level of anaesthesia/analgesia required	Volume of local anaesthetic required
Low thoracic level	1.25 – 1.5 ml/kg
High lumbar level	1 – 1.25 ml/kg
Sacral level	0.5 – 1 ml/kg

Figure 2. Recommended volumes for caudal anaesthesia

What about catheters?

Catheters can be utilised to provide prolonged analgesia for major procedures, but their use is associated with higher complication rates.

Rates of skin colonisation at catheter sites have been found to be higher in children and range from 12–35%. Caudal catheters show higher colonisation rates when compared to lumbar catheters, particularly in the age group under 3 years due to no/incomplete toilet training.[12] Despite this, higher colonisation rates have not translated into higher infection rates, and thus remain clinically insignificant. Bacterial colonisation correlates positively with redness at the insertion site, and with time in-situ (of the catheter).[13] Tunnelling catheters has been shown to reduce colonisation rates, and should be considered when pain is expected to be protracted.

Catheter migration is more likely in children under 40 kg.[14] A recent study described migration of thoracic epidural catheters inserted at the thoracic site. Results showed that migration is fairly common in neonates and infants (64%), and suggested postoperative imaging to confirm catheter tip position, to avoid inadequate analgesia and other potentially dangerous outcomes.[15]

Ultrasound guidance

Ultrasound is a useful tool that allows for visualisation of the dura, local anaesthetic spread in the epidural space, and helps guide advancement and placement of epidural catheters.[16] This has the potential to improve safety as well as efficacy of neuraxial techniques in children. Available evidence shows that ultrasound decreases time to siting epidurals,[16] decreases the number of punctures required, and improves success rate on first attempt. The National Institute of Clinical Excellence (NICE) in the UK has recommended routine use of ultrasound for insertion of epidural catheters.

Paramedian longitudinal scans using linear probes are the suggested technique for visualisation of the thoracic and lumbar neuraxial anatomy in infants and young children. Best visualisation is obtained in infants up to three months of age, thereafter visualisation decreases in an age-dependent manner.[17]

Table 3. Safe additives for neuraxial anaesthesia in children

Additive	Dose	Effect	Comments
Clonidine	1–2 mcg/kg	Improved quality + duration of analgesia (+/- 4 hours)	Systemic absorption causes some sedation. Can cause post-op apnoea in neonates.
Dexmedetomidine	1 mcg/kg	Improved quality + duration of analgesia (+/- 4 hours)	Marked post-op sedation can occur
Ketamine*	1 mcg/kg	Improved quality + duration of analgesia for single shot caudals only	Not for use if < 1 year
Fentanyl	1 mcg/kg	Improved quality of epidural/intrathecal analgesia in some studies	Inferior to α-agonists in quality and duration of analgesia, and less favourable side-effect profile
Morphine**	4–5 mcg/kg	Improved quality of epidural/intrathecal analgesia	Side effects include nausea, urinary retention, respiratory depression, pruritis
Dexamethasone	0.5 mg/kg **IV**	Prolongs duration of analgesia (+/- 1 hour), less additional analgesia needed up to 48 hours.	Dexamethasone given **IV**

*Preservative-free ketamine, reserved for > 1-year olds due to concerns around neuronal apoptosis. Not available in SA.
**Opiates – preservative-free morphine. Most paediatric institutions utilise the α-agonists and avoid opiates. If morphine is used, patients must be nursed in a monitored environment postoperatively. *Opiate administration by any other route to supplement analgesia should be avoided.*

Additives

The following agents can be considered as safe additives to local anaesthetic agents for neuraxial anaesthesia:

Safety Aspects:

- **Patients on anticoagulant therapy**

  There are no paediatric-specific guidelines for patients who are on anticoagulant therapy. It is recommended that anaesthetists follow the guidelines provided by the American Society of Regional Anaesthesia, as recommended by the South African Society of Regional Anaesthesia.[18]

- **Use of protocols**

  Drug errors, particularly in children under 1 year, are a concern and can possibly be prevented by the strict use of comprehensive protocols.

- **Performing neuraxial anaesthesia in children under general anaesthesia**

  Historically it was thought that it is safer to perform regional anaesthesia techniques in awake patients, which is not necessarily possible in most children. There is sufficient evidence to reassure anaesthetists that neuraxial anaesthetic techniques can be safely performed in anaesthetised children.[4, 19]

- **Acute compartment syndrome**

  Traditionally surgeons have expressed concern over the use of regional anaesthesia and the potential to mask signs and symptoms of compartment syndrome. Neuraxial anaesthesia can be safely employed provided lower concentrations of LA are used, and patients who are at risk identified early and monitored closely. Patients should be promptly referred for assessment and investigation should severe breakthrough pain occur.[20]

- **Markers of intravascular injection**
  - The aspiration test for blood has poor sensitivity in children, whose small veins are prone to collapse.[21] Practical tip: aspirate slowly, and open the catheter to air to check for backflow.
  - The quick administration of a single test dose is unreliable at detecting intravascular injection. The general anaesthetic agent, dose, sedative premedication and resting basal heart rate must be borne in mind. Administration of a 'test dose' is at the discretion of the anaesthetist. The suggestion is to administer LA (with or without adrenaline) in fractional volumes (0.1–0.2 ml/kg), observing for ECG changes for 90 seconds, before proceeding with incremental doses.[20,21] ECG changes include changes in T-wave amplitude and ST segments, slowing of the heart rate or development of a nodal rhythm (uncommon, but specific).
  - Where possible, administer the test dose with the patient breathing spontaneously, and monitor for cessation of respiration.

- **LA toxicity**

  Always calculate the toxic dose and adhere to recommended safe doses for LA. Maximum dose for bupivacaine (racaemic/levo isomer) is 2.5 mg/kg and ropivacaine 3–4 mg/kg.[3] The Association of Anaesthetists of Great Britain and Ireland has made available a comprehensive protocol to guide the management of LA Toxicity. Relevant protocols and Intralipid® should be readily available in any environment where these techniques are used.

- **Preprocedural timeout**

  Before performing any regional technique, it is strongly recommended that anaesthetists perform a 'timeout' with the anaesthetic nurse. This is an important safety step where the patient, procedure, neuraxial technique and dosage of LA are checked.

Summary

In recent years, catheter-based neuraxial techniques have been superseded in favour of regionals with a more favourable risk profile. This risk profile can be modified by utilising the extensive evidence available, and amending practice accordingly. Certain institutions still favour the use of these techniques, while others seem to have moved away. Whatever your preference, there is no doubt that expertise in neuraxial anaesthesia in children is a crucial part of the armamentarium of any paediatric anaesthetist.

'Pain is inevitable. Suffering is optional.'

- Haruki Murakami

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