

Neuraxial anaesthesia in paediatrics

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Abstract

Neuraxial anaesthesia is a valuable aid in the practice of paediatric anaesthesia. Spinal and epidural blockade are used as either the sole anaesthetic or as an adjunct to general anaesthesia, and often confer significant postoperative analgesia. Caudal epidural anaesthesia is used extensively for lower abdominal, urological and orthopaedic procedures in the setting of outpatient surgery. Lumbar and thoracic epidural infusions via a catheter can provide analgesia for chest and upper abdominal procedures. Major complications related to neuraxial catheter placement are uncommon in paediatric anaesthesia, even though block placement is typically after the patient is anesthetized. The use of the ultrasound for real-time visualization during paediatric neuraxial blocks provides an opportunity for observing final catheter position or confirming successful injection into the epidural space.

Keywords Caudal blockade; neuraxial blockade; paediatric thoracic epidural anaesthesia; postoperative analgesia; spinal anaesthesia; ultrasound guided paediatric regional anaesthesia

Royal College of Anaesthetists CPD Matrix: 2G02; 2D05

Introduction

Central neuraxial blockade remains an integral part of both perioperative management and postoperative pain control in children. These techniques include spinal, caudal epidural, lumbar epidural and thoracic epidural analgesia, which are often used as an adjunct to general anaesthesia. However, there is renewed interest in the avoidance of sedation or general anaesthesia altogether in light of growing concerns in popular media regarding neurotoxicity of anaesthetics. Neuraxial techniques may provide the ability to avoid neurotoxicity, but these studies are still ongoing.¹

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Learning objectives

After reading this article, you should know:

- the anatomy and techniques of caudal, epidural, and spinal anaesthesia in children
- the use and complications of neuraxial blocks in children
- the indications and contraindications for caudal and epidural blocks in children
- the sonoanatomy and ultrasound landmarks for neuraxial blocks in children

Indications and contraindications

The benefits of neuraxial anaesthesia must be weighed against risks and also against those of alternative analgesic methods. Relative contraindications to neuraxial blockade are listed in [Box 1](#). Neuraxial blockade is commonly indicated to improve postoperative analgesia and reduce the need for opioid intravenous analgesic medications. Use of central neuraxial blockade in addition to general anaesthesia has the potential advantages of decreasing general anaesthetic requirements and opioid use that in turn allows for a more rapid recovery as well as providing postoperative pain control.²

Spinal anaesthesia

Indications and safety

Spinal anaesthesia is a safe and effective way to provide anaesthesia for lower abdominal, urological and lower extremity procedures.³ It is commonly used as a sole anaesthetic in infants in the interest of avoiding general anaesthesia and opioid medications. A recent study has found that spinal, compared with general anaesthesia, reduces the risk of early postoperative apnoea, but not the overall incidence of apnoea in infants less than 60 weeks postmenstrual age.⁴

Performance

In neonates, the spinal cord terminates at the vertebral level as low as L3 while, in adults, the spinal cord terminates at L1.⁵ As a result, spinal anaesthetics should only be performed at or below the L4/L5 interspace level in neonates and infants. Ultrasound imaging may be used to assist with correct identification of the spinal block level, to determine the depth of the subarachnoid space, and to guide needle placement.⁶ Neonates and infants rarely exhibit haemodynamic changes after spinal blockade even without prior fluid administration. It has also been reported that former premature infants have an almost absent autonomic response to spinal anaesthetics. High sympathetic blockade has little effect in infants because of the parasympathetic dominance in this age group. Bupivacaine 0.5% 0.8 mg/kg (range 0.5–1 mg/kg) is commonly injected, with the dose decreasing on a mg/kg basis as the age of the patient increases. The dose of local anaesthetic, on a per kilogram basis, may be larger because of the relatively large spinal canal and larger volume of cerebrospinal fluid on a per kilogram basis.⁷

Performance of spinal blockade in paediatrics, especially infants and neonates, is made easier by:

Relative contraindications to neuraxial blockade

- Lack of parental consent
- Lack of patient assent (for children >12 years old)
- Anatomical variants
- Infection at the site of injection
- Coagulopathy
- Generalized sepsis
- Increased intracranial pressure
- Urinary retention

Box 1

- Increased flexibility of the spine, which allows improved access to the interspace.
- Short skin-to-subarachnoid space distance.
- Wide spinal canal, which is 70% of the adult size at birth. The spinal column is flat in young children, which allows drugs injected in the subarachnoid space to spread evenly.

Complications

A list of common and uncommon complications of spinal anaesthesia can be found in [Box 2](#). Overall, failure rates are reported to be low, 1–5% depending on the study reported.^{3,8} Furthermore, use of the ultrasound in real-time reduces the number of failures and improves the ease of the procedure in obese patients.⁹ Post-dural puncture headache in neonates and infants is thought to be very low, but the exact incidence is unknown following spinal blockade. However, the incidence in children 2–15 years of age is probably similar to adult populations, less than 5% overall.⁷ The incidence of backache, like other complications, has been difficult to quantify in young nonverbal infants, but spinal anaesthesia may not be associated with an increased risk of backache compared to general anaesthesia.⁷ Although total spinal anaesthesia rarely occurs, it must be identified quickly. Treatment includes airway support, sedation, and hemodynamic monitoring until spinal blockade subsides.

Caudal epidural anaesthesia

Indications and safety

Caudal anaesthesia is a popular regional anaesthetic technique to provide analgesia for paediatric patients. Single-shot caudal epidural blockade can be completed for most urological, lower extremity and lower abdominal procedures.¹⁰ Placement of a caudal catheter *and advancement to the thoracic spine* can extend its use to upper abdominal and thoracic surgical procedures with

Complications of spinal blockade

- Post-dural puncture headache
- Backache
- Total spinal anaesthetic
- Subcutaneous infection
- Meningitis
- Epidural hematoma
- Failed block

Box 2

the added utility of continuous analgesia in the postoperative period.¹¹ Caudal epidural catheter threaded to the thoracic space has been recently shown to improve pain scores as part of a multimodal strategy in renal transplant patients.¹²

Caudal blockade is normally performed in conjunction with general anaesthesia, which allows for a lighter plane of anaesthetic to be used. This reduces the time of recovery from anaesthesia and time to discharge from the hospital for outpatient procedures.

It is possible to use caudal blockade as the sole anaesthetic for many cases. The duration and anatomic location of the surgical procedure as well as the need for prolonged postoperative analgesia may guide the decision to choose single shot versus catheter placement for caudal anaesthesia. Single-shot caudal blocks are an incredibly safe technique when used for postoperative pain control, as confirmed in a prospective collection of data on over 18,000 single-shot caudal blocks in the Pediatric Regional Anesthesia Network.¹³ However, care must be taken to not exceed potentially toxic dose thresholds for local anaesthetics.

Performance

The caudal epidural space is reached through the sacrococcygeal membrane at the sacral hiatus. Sacral anatomy in young children and infants is unique in that the sacral fat pad is usually absent in this age group and ossification of the sacrum does not completely occur until 8 years of age. Thus, one is more readily able to identify landmarks such as the sacral cornua in paediatric as opposed to adult patients.¹⁴ Techniques in performing caudal blockade start by placing the patient in the lateral decubitus or prone position. Knee, leg and neck flexion in the lateral position shifts the termination of the dural sac cephalad, which may improve the safety margin in young children. A useful check is to flex the upper leg in the lateral position to 90 degrees at the hip. Then, a line through the midline of the lateral aspect of the thigh and the tip of the greater trochanter of the femur will usually pass through the sacrum at the level of the sacral hiatus. The most common error for the novice is to aim too low on the sacrum and coccyx.

Identification of the sacral cornua should be followed by sterile preparation with a 70% alcohol solution with chlorhexidine or iodine. Though epidural abscess is extremely rare, using alcoholic chlorhexidine solution rather than povidone iodine for site preparation decreases colonization of epidural catheters in children.¹⁵ Use of alcohol-containing solutions is extremely variable across neonatal intensive care units due to safety concerns, one should follow the local policies regarding appropriate skin preparation.

A variety of needles may be used for performance of the caudal epidural injection. Some centres prefer the use of styletted caudal needles to decrease the theoretical risk of epidermoid tumour development after caudal injection, but it is more a theoretical concern rather than practical concern with this injection.¹⁶ Blunt-tipped rather than sharp-bevelled needles may increase tactile sensation of ‘popping’ or puncturing the sacrococcygeal membrane. A 22 g needle is a commonly used size for a single-shot caudal blockade. A larger 18 g needle can be utilized to place a catheter.

The needle is inserted in the midline at the level of sacral cornua at an angle of 45–60 degrees. After puncturing the skin,

advancement through the sacrococcygeal membrane is felt. The angle of the needle or cannula is then decreased and advanced slightly into the caudal space, allowing the needle bevel to enter the space. In a neonate, care is required, lest the dura is punctured. When using a needle with a cannula, such as an intravenous access cannula, gentle feeding of the cannula off the needle is needed to avoid crimping or folding of the plastic material. Ease of cannula advancement suggests successful entry into the sacral canal. Aspiration from the needle or cannula should then be completed and a lack of CSF and blood should be noted prior to injection of a test dose. Use of a test dose may confer additional safety and its use is supported in the literature.¹⁷ A negative test dose should be followed by easy injection of local anaesthetic in divided doses. High tactile injection pressure should alert the practitioner to incorrect needle positioning. The use of ECG to predict intravenous placement should be routinely used to aid in identification of intravascular injection.

Caudal epidural catheter placement may be achieved in a similar manner. After placement of the needle into the caudal space, the distance between the needle and the desired level on the back should be measured. The catheter can then be advanced the appropriate distance. Ultrasound may be helpful in placing the catheter and confirming the tip's location within the epidural space at the correct level.

Ultrasound guidance of the caudal block allows for identity of the sacral cornua, hiatus and sacrococcygeal membrane in children with presacral fat tissue, obesity or uncertain landmarks. Ultrasound guidance can be used to visualize the caudal space to avoid inadvertent injection into the intrathecal space or subcutaneous tissue. Cannula-tip visualization and advancement may be seen under real-time ultrasound placement; although, it is unnecessary as long as spread of local anaesthetic in the caudal epidural space or displacement of the posterior dura mater in an anterior direction is seen (Figure 1).

When using ultrasound for this block, pre-scanning with a short, linear, high-frequency (6–13 MHz) probe in transverse plane should be done before localization of the caudal needle entry point (Figure 2). Rotation of the probe in longitudinal or paramedian plane (older children) is recommended for optimal viewing during insertion of the needle or catheter advancement (Figure 3). With placement of a catheter in the epidural space, a transverse view and colour Doppler can be used to confirm local anaesthetic spread or to estimate the level of catheter placement.

Although many local anaesthetics can be used, 0.2% ropivacaine or 0.125%–0.25% bupivacaine, or levobupivacaine, are commonly used for postoperative analgesia. Ropivacaine has the benefit of an increased margin of safety and less motor blockade than bupivacaine. For single-shot caudal blockade, a volume of 1 ml/kg can be used to consistently achieve a T10 level.¹⁸ A volume of 0.6 ml/kg has been shown to be effective for inguinal surgeries. Epinephrine is most commonly added to serve as a marker for intravascular injection.

Several additives have been utilized to strengthen caudal blockade. Opioids may be added to prolong the duration of the block but may cause respiratory depression, itching, and nausea or vomiting. Clonidine has been shown to improve pain scores but may cause hypotension and sedation. In recent years, dexmedetomidine has been added to caudal blocks and has resulted in improved pain control, but there is concern for sedation, bradycardia, and urinary retention. Though ketamine increases the duration and density of the block, concerns related to neurotoxicity have decreased the use of this additive.¹⁹

Complications

Complications resulting from caudal blockade are listed in Box 3. The most recent Pediatric Regional Anesthesia Network (PRAN) study analyzed more than 100,000 blocks and demonstrated the safety of regional anaesthesia in paediatrics, including caudal blocks. There were a total of three cases of local anaesthetic systemic toxicity (LAST) attributed to caudal nerve block. LAST is not more common in caudal blocks compared to other nerve blocks, but is more common in patients less than 6 months old. Careful attention to local anaesthetic dose and use of a test dose can minimize the risk of local anaesthetic toxicity. If suspected, treatment of bupivacaine-induced toxicity can be treated with lipid rescue therapy to improve resuscitation outcomes.

For caudal epidural catheters, local cutaneous infection is rare and is not more common than in lumbar or thoracic epidural catheters, despite longstanding anecdotal concern for the risk of infection in the caudal area. Infection risk increases with longer durations of catheter placement.

Dural puncture is less common with caudal blocks compared to lumbar and thoracic approaches. Delayed micturition and urinary retention can occur but the exact incidence is not known. The potential devastating risk of neurological injury from

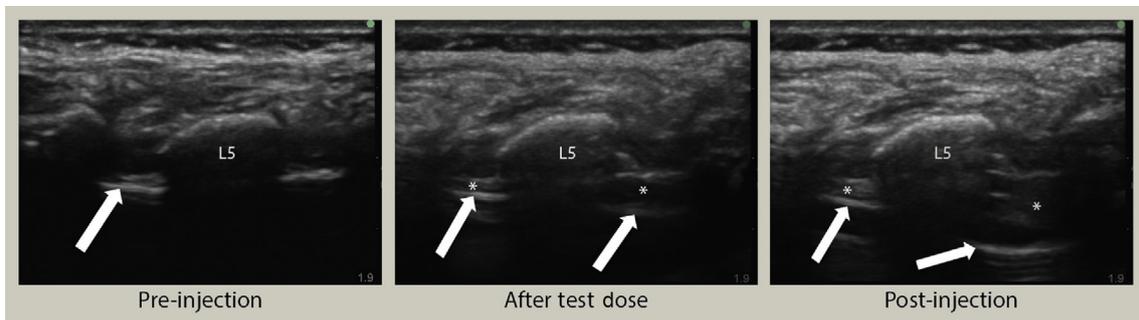


Figure 1 Longitudinal paramedian view of the lumbar epidural space during caudal epidural injection. In the pre-injection image, L5 is visualized in the center with an arrow pointing out the dura mater, close in proximity to the ligamentum flavum. After injection of the test dose, it is possible to see the epidural space (denoted by an asterisk) expanding slightly, pushing the dura mater ventrally. Post-injection the epidural space is thoroughly expanded by local anaesthetic. Arrows denote the dura mater in each image and the asterisk is within the epidural space.

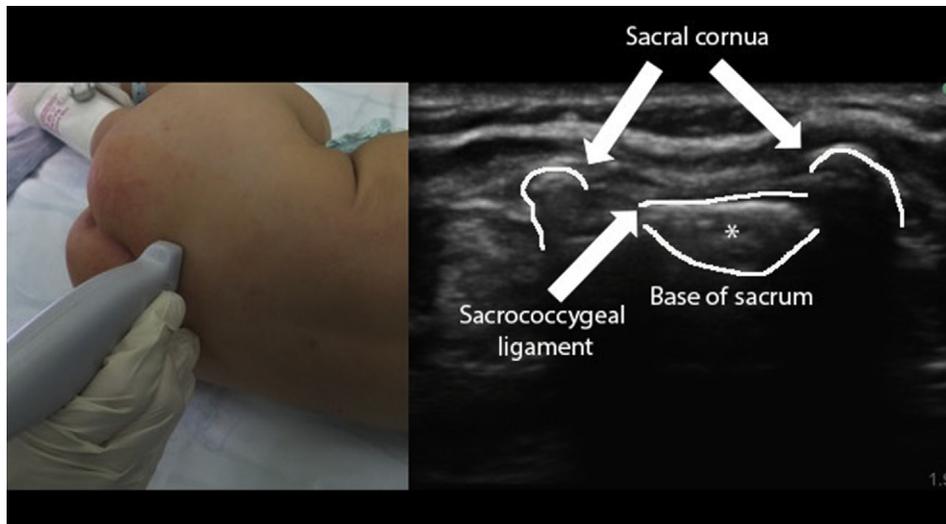


Figure 2 Caudal epidural ultrasound imaging in the transverse plane. The sacral cornua, base (pelvic surface) of the sacrum and the sacrococcygeal ligament are outlined. The sacral canal is marked with an asterisk.

epidural abscess, epidural hematoma, or direct neurologic injury is rare, but possible. In addition to the aforementioned PRAN study, an earlier PRAN study focused on and confirmed the safety of caudal epidural injection as a technique in the paediatric population.¹³

Lumbar and thoracic epidural anaesthesia

Lumbar and thoracic epidural anaesthesia is an effective method to provide analgesia for thoracic, abdominal, and orthopaedic procedures. Placement of epidural catheters is similar to that in the adult patient with the two exceptions:

- There is a shallow depth to the epidural space, which can be visualized and estimated under ultrasound guidance.
- The ligamentum flavum may not elicit the same tactile feel when encountered by the Touhy needle as in the adult patient, due to less ossification in paediatric patients.

Complications of caudal blockade

- Dural puncture
- Post-dural puncture headache
- Total spinal anaesthetic
- Delayed micturition/urinary retention
- Local anaesthetic systemic toxicity
- Backache
- Cutaneous bleeding
- Cutaneous infection
- Epidural hematoma
- Epidural abscess
- Motor block
- Puncture of the viscera
- Implantation dermoid tumour
- Failed block

Box 3

The loss-of-resistance technique is commonly used but ultrasound guidance during lumbar and thoracic epidural block can also be used. Pre-procedure scanning with ultrasound may help, especially in infants and younger children, with appropriate localization of the block level. Assessment of the depth to the ligamentum flavum and dura mater may become more difficult as the patient ages.²⁰ Ultrasound is also used for identification of spinous process and the midline in obese patients.

Neonates and infants have a largely cartilaginous posterior vertebral column, which makes it possible to direct and advance the Touhy needle or catheter under ultrasound during the real-time procedure due to improved penetration of the ultrasound beam. In older children, visibility of the structures in spinal canal may be decreased, due to ossification of the vertebral column. The paramedian longitudinal view, performed with 6–13 MHz linear array transducer, can be used to obtain the largest ultrasound window during the procedure. Extradural local anaesthetic spread confirms successful neuraxial block and the level of the epidural catheter placement. Though the catheter itself is difficult to image, extradural local anaesthetic spread indirectly confirms correct level of catheter placement. Lumbar epidural catheters may be advanced to thoracic levels but with more difficulty than with the caudal technique due to the variable distribution of epidural fat as well as lordotic changes in the lumbosacral spine.

Thoracic epidural catheters can be placed safely in the awake or asleep patient. While this debate has been ongoing for years, it is probably safe to place these catheters in the anaesthetized patient, especially if the patient is unlikely to be cooperative in the awake or sedated state.²¹ The concern for neurological injury during placement due to lack of feedback from the patient may be alleviated by the use of ultrasound imaging to guide placement and/or confirm extradural spread of a test solution. Young patients may not be able to provide useful feedback on paraesthesia or cooperate sufficiently to make the procedure safe; therefore, lack of patient movement may allow for improved

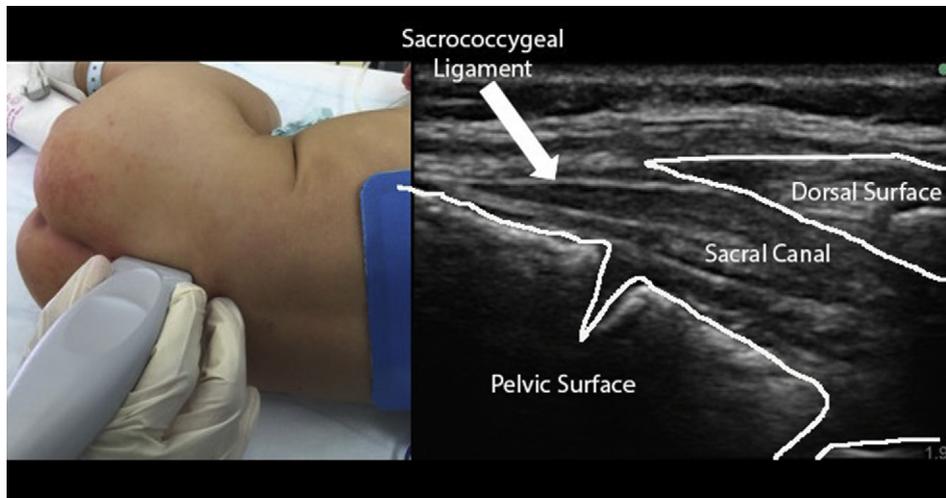


Figure 3 Caudal epidural ultrasound imaging in the longitudinal plane. The dorsal and pelvic surfaces of the sacrum are outlined. The sacrococcygeal ligament is denoted by the arrow and needle placement is generally in the direction of the arrow. In this patient, the dural sac does not extend caudally into the view obtained here.

conditions while placing an epidural catheter in younger patients.

Once an epidural catheter is in place, it can be used intraoperatively to provide analgesia and reduce general anaesthetic requirements. Epidural analgesia is of extraordinary value in providing postoperative analgesia. Prior to epidural discontinuation, care should be given to transition to oral pain medications, which is most consistently achieved through the guidance of an organized acute pain service. Establishment of an organized paediatric acute pain service may be considered standard of care.²²

Complications

Complications of thoracic and lumbar epidural blockade in the paediatric population are similar to those in adults and to those of caudal epidural blockade. Overall, there is a very low incidence of complications following neuraxial blockade. The national paediatric epidural audit found only a single patient out of 10,000 cases with sequelae 12 months following a serious incident after epidural anaesthesia.²³ Similarly, a Pediatric Regional Anesthesia Network (PRAN) study identified only two cases out of 7,617 neuraxial catheters placed, with a major complication (one each of local anaesthetic toxicity and seizure) even though most catheters in young children were placed in anaesthetized patients.²¹

Additional considerations

Central neuraxial blockade remains an essential component of the goal to provide a pain-free perioperative experience for children. Advancements in ultrasound-guided techniques have the opportunity to ensure safety and improve block success. The most common problem with neuraxial anaesthesia is block failure or failure to maintain the block. While systemic opioids have long remained the standard of care, neuraxial techniques may have the opportunity to reduce morbidity in certain situations. There is a vast experience in the use of neuraxial techniques and their application in even the youngest patients should be

considered to be safe, whether applied in the awake or asleep patient. Central neuraxial blockade is a valuable tool in achieving individualized analgesia in the practice of paediatric anaesthesia. ◆

REFERENCES

- Davidson AJ, Disma N, de Graaff JC, et al. Neurodevelopmental outcome at 2 years of age after general anaesthesia and awake-regional anaesthesia in infancy (GAS): an international multicentre, randomised controlled trial. *Lancet* 2015; **387**: 239–50.
- Pullerits J, Holzman RS. Pediatric neuraxial blockade. *J Clin Anesth* 1993; **5**: 342–54.
- Williams RK, Adams DC, Aladjem EV, et al. The safety and efficacy of spinal anesthesia for surgery in infants: the Vermont Infant Spinal Registry. *Anesth Analg* 2006; **102**: 67–71.
- Davidson AJ, Morton NS, Amup SJ, et al. Apnea after awake regional and general Anesthesia in infants: the general Anesthesia compared to spinal Anesthesia study-comparing apnea and neurodevelopmental outcomes, a randomized controlled trial. *Anesthesiology* 2015.
- Van Schoor AN, Bosman MC, Bosenberg AT. Descriptive study of the differences in the level of the conus medullaris in four different age groups. *Clin Anat* 2015; **28**: 638–44.
- Oulego-Eroz I, Mora-Matilla M, Alonso-Quintela P, et al. Ultrasound evaluation of lumbar spine anatomy in newborn infants: implications for optimal performance of lumbar puncture. *J Pediatr* 2014; **165**: 862–8651.
- Kokki H. Spinal blocks. *Paediatr Anaesth* 2012; **22**: 56–64.
- Puncuh F, Lampugnani E, Kokki H. Use of spinal anaesthesia in paediatric patients: a single centre experience with 1132 cases. *Paediatr Anaesth* 2004; **14**: 564–7.
- Nomura JT, Leech SJ, Shenbagamurthi S, et al. A randomized controlled trial of ultrasound-assisted lumbar puncture. *J Ultrasound Med* 2007; **26**: 1341–8.
- Johr M, Berger TM. Caudal blocks. *Paediatr Anaesth* 2012; **22**: 44–50.

- 11 Bosenberg AT, Bland BA, Schulte-Steinberg O, Downing JW. Thoracic epidural anesthesia via caudal route in infants. *Anesthesiology* 1988; **69**: 265–9.
- 12 Soaida SM, ElSheemy MS, Shouman A, et al. Caudal extradural catheterization in pediatric renal transplant and its effect on perioperative hemodynamics and pain scoring: a prospective randomized study. *J Anesth* 2016; **30**: 47–54.
- 13 Suresh S, Long S, Birmingham PK, De Oliveira Jr GS. Are caudal blocks for pain control safe in children? an analysis of 18,650 caudal blocks from the Pediatric Regional Anesthesia Network (PRAN) database. *Anesth Analg* 2015; **120**: 151–6.
- 14 Chen CP, Tang SF, Hsu TC, et al. Ultrasound guidance in caudal epidural needle placement. *Anesthesiology* 2004; **101**: 181–4.
- 15 Kinirons B, Mimos O, Lafendi L, et al. Chlorhexidine versus povidone iodine in preventing colonization of continuous epidural catheters in children: a randomized, controlled trial. *Anesthesiology* 2001; **94**: 239–44.
- 16 Guldogus F, Baris YS, Baris S, Karakaya D, Kelsaka E. Comparing tissue coring potentials of hollow needles without stylet and caudal needles with stylet: an experimental study. *Eur J Anaesthesiol* 2008; **25**: 498–501.
- 17 Tobias JD. Caudal epidural block: a review of test dosing and recognition of systemic injection in children. *Anesth Analg* 2001; **93**: 1156–61.
- 18 Chipde S, Banjare M, Arora K, Saraswat M. Prospective randomized controlled comparison of caudal bupivacaine and ropivacaine in pediatric patients. *Ann Med Health Sci Res* 2014; **4**(suppl 2): S115–8.
- 19 Bosenberg A. Adjuvants in pediatric regional anesthesia. *Pain Manag* 2012; **2**: 479–86.
- 20 Tsui BC, Suresh S. Ultrasound imaging for regional anesthesia in infants, children, and adolescents: a review of current literature and its application in the practice of neuraxial blocks. *Anesthesiology* 2010; **112**: 719–28.
- 21 Taenzer AH, Walker BJ, Bosenberg AT, et al. Asleep versus awake: does it matter?: pediatric regional block complications by patient state: a report from the Pediatric Regional Anesthesia Network. *Reg Anesth Pain Med* 2014; **39**: 279–83.
- 22 Lonnqvist PA, Morton NS. Postoperative analgesia in infants and children. *Br J Anaesth* 2005; **95**: 59–68.
- 23 Llewellyn N, Moriarty A. The national pediatric epidural audit. *Paediatr Anaesth* 2007; **17**: 520–33.