Review Article

Recent developments in paediatric neuraxial blocks

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ABSTRACT

Paediatric anaesthesia and paediatric regional anaesthesia are intertwined. Almost all surgeries unless contradicted could be and should be supplemented with a regional block. The main objective of this review is to elaborate on the recent advances of the central neuraxial blocks, such as application of ultrasound guidance and electrical stimulation in the pursuit of safety and an objective end point. This review also takes account of the traditional technique and understand the benefits as well the risk of each as compared with the recent technique. The recent trends in choosing the most appropriate peripheral block for a given surgery thereby sparing the central neuroaxis is considered. A penile block for circumcision or a sciatic block for unilateral foot surgery, rather than caudal epidural would have a better risk benefit equation. Readers will find a special mention on the recent thoughts on continuous epidural analgesia in paediatrics, especially its rise and fall, yet its unique importance. Lastly, the issue of block placements under sedation or general anaesthesia with its implication in this special population is dealt with. We conducted searches in MEDLINE (PubMed) and assessed the relevance of the abstracts of citations identified from literature searches. The search was carried out in English, for last 10 years, with the following key words: Recent advances in paediatric regional anaesthesia; ultrasound guidance for central neuraxial blocks in children; role of electrical stimulation in neuraxial blocks in children; complications in neuraxial block. Full-text articles of potentially relevant abstracts were retrieved for further review.

Key words: Electrostimulation, paediatric central neuraxial blocks, recent developments, ultrasound

INTRODUCTION

Paediatric regional anaesthesia consists of a spectrum of blocks which may or may not be mastered by all anaesthesiologists, for example, for a unilateral foot surgery, a sciatic block can be safer and beneficial then a central neuroaxis block.[1] Although this remains a proven fact, central neuroaxis block is something that can fit in various situations.

Apart from the relief of surgical pain, the subsequent improvement in autonomic, hormonal, metabolic, immunological/inflammatory and neurobehavioural consequences[2] is now unveiled. This explains the significance of this review. We intend to present all the newer concepts and thoughts on paediatric central neuraxial blocks, along with a swift mention of what has been practised traditionally, and highlighted the advantage and disadvantages of both.

We conducted searches in MEDLINE (PubMed) and assessed the relevance of the abstracts of citations identified from literature searches. The search was carried out in English with the following key words:

- recent advances in paediatric regional anaesthesia;
- ultrasound guidance for central neuraxial blocks in children;
- role of electrical stimulation in neuraxial blocks in children; and
- complications in neuraxial block.

Full-text articles of potentially relevant abstracts were retrieved for further review.

Recent advances have brought a lot of objectivity to central neuraxial blocks, making them safer and effective. Technically, central neuraxial blocks have various approaches. These blocks can be given as single shot or as continuous techniques depending on

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the nature and severity of the surgical procedure.

- Caudal epidural
- Lumbar epidural
- Thoracic epidural
- Spinal anaesthesia

One query that always hits is whether regional techniques, peripheral or central, continuous or single, should be performed in an awake or asleep child. It is practically impossible to pin down a wriggling, resisting infant or a child on an operation table and perform a block. This sounds ethically inhuman, and a moving, resisting child will always increase the chances of undesirable complications and trauma due to unintended needle movement. Epidural space in small infants may be as superficial as 1-1.5 cm and calls for precise controlled needle advancement, whereas in a preterm, very low birth weight neonate who is prone to apnoeic spells, an awake caudal epidural or a spinal block along with a sugar pacifier might be more beneficial for minor surgeries in experienced hands. To perform continuous catheter insertion is again safer and more human in an asleep child. Years of practise has proved this to us.

CAUDAL EPIDURAL

This is a simple and safe technique[3] which fits most of the surgeries below the umbilicus. Analgesic level above the umbilicus can also be achieved. This is directly proportionate to the volume of local anaesthetic solution used and inversely proportionate to the age of the child.[4]

The five sacral vertebrae form the convex dorsal roof of the space. Floor is formed by the base of sacrum. Anatomically the space is approached via the sacral hiatus, which is formed by the sacral cornua on either side. The sacrococcygeal membrane covers the sacral hiatus. The sacral nerves, filum terminale, venous plexus and fat are contained in this enclosed space. It is imperative to note that dura and the spinal cord reach lower levels in the spinal canal in infants (spinal cord L3 at birth, L1/L2 at 1 year and dura S4 at birth, S2 at 1 year). In small infants, the end of the dural sac can be at a distance of only a few millimetres from the puncture site.[5] Recent applications of ultrasound make the anaesthesiologist revisit anatomy. Figure 1 identifies most of the structures relevant to caudal block for basic understanding.

Block technique

The child is placed in the lateral position with the spine and the knees flexed.

Note: Flexing helps to palpate the sacral cornua better and shifts the end of the dural sac cranially.[6] Alternatively, prone position can be used. We prefer lateral position in our practice.

Block procedure

The region is cleaned by any antiseptic solution in a cranio-caudal direction. Chlorhexidine solution has been demonstrated superior for skin preparation before epidural insertion in children.[7] Use of gown, mask, cap and sterile gloves is standard for all regional anaesthesia procedures. This cannot be underestimated as a case of sacral osteomyelitis has been reported.[8,9]

The sacral hiatus is identified by palpating the

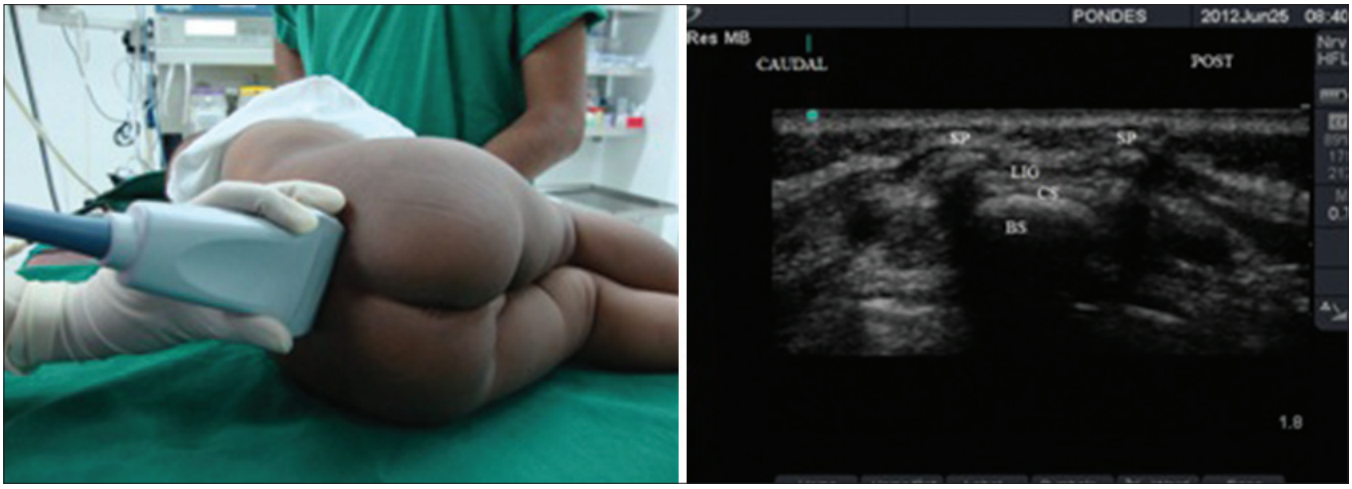

Figure 1: Probe placement in transverse axis and the respective ultrasound scan. SP - Sacral cornua; LIG - Sacrococcygeal ligament; BS - Base of the sacrum; CS - Caudal epidural space

posterior superior iliac spine and the sacral hiatus form the edges of an equilateral triangle. The middle finger and the thumb rest on the two posterior superior iliac spines, which form the base on the triangle described above; the index finger is then placed to complete the equilateral triangle. The tip of the triangle so formed is now palpated by the distal phalanx of the thumb as it has a bigger surface area to feel both the cornua together. With the palpating finger on the S4 spinous process, needle puncture is achieved in the most proximal region of the sacral hiatus with the needle inclined 45-60° to the skin. The needle is then advanced further to "feel" the "give" or "pop-up" experienced due to perforation of the sacrococcygeal ligament.

Note: After entering into the caudal space, the needle should only be minimally advanced, not more than 1-3 mm.[10,11] The reason being firstly, the distance between the dural sac and the puncture site can be very short[11] and chances of accidental intrathecal injections with total spinal anaesthesia increase.[12] Secondly, our clinical experience does show that undue advancement of the needle in the caudal space leads to bloody taps. The 22-G BD needles are used for single-shot caudal blocks.

There is an argument against it that this practice could be unsafe because of the risk of spreading epidermal cells into the spinal canal.[13,14] Specially designed caudal needles are available with a short bevel and stylet; they might reduce the risk of vascular puncture.[15] Plastic IV cannulas or lumbar puncture needles are also used.

As mentioned earlier, we use a 22-G needle routinely because a relatively bigger gauge has a better chance of demonstrating a bloody tap. Some authors do claim that bigger than 25 G should not be with a justification that a finer needle causes less trauma. The caudal needle from Braun with extension tubing allows an immobile needle technique. Certain needles (SPROTTE cannula 24, 25 27 G × 35 mm, SPROTTE®, Crawford cannula 23 G × 25 mm) from Pjunk are specifically designed for caudal use.

Drug and dosages and rate of drug injection

Sacral level: 0.25 ml/kg of 0.5% bupivacaine; T10: 0.75 ml/kg of 0.25% of bupivacaine; T6: 1 ml/kg of 0.125% bupivacaine. Alternatively, ropivacaine 0.2% is well suited as it has a better safety profile as compared to bupivacaine. It provides less motor blockage than bupivacaine and lesser toxicity in case of accidental intravascular injection. Drug should be given slowly at a rate from 0.25 to 0.5 ml/min, in aliquots and with intermittent aspiration to rule out intravascular injection. Triffterer *et al.*[16] demonstrated with ultrasound guidance that the speed of injection does not determine the cranial spread of the drug.

Complications of caudal block

With the above-mentioned traditional techniques:[17-19] *Subcutaneous injection,* Infections, *Intrathecal injections (total spinal,* Local anaesthetic systemic toxicity due to intravascular injection, Urinary retention, Self-limiting back pain, Sacral osteomyelitis and others are known to occur.

Recent advances in caudal blocks

Safety and efficacy of any regional block would increase if in some ways we could confirm the exact needle placement and spread of the injected drug. Caudal block, notwithstanding its simplicity, is no exception to this. Complications such as intrathecal injections and improper needle placement damaging the surrounding bony structure can be avoided if this does not remain a blinded procedure. The traditional methods indicated it by the change in resistance that the anaesthesiologist experienced while inserting needle. The main drawback is its subjective end point. The following techniques added objectivity to it by demonstrating a reliable real-time objective end point.

Recent advances in caudal block

Application of electrostimulation and application of ultrasound

The above-mentioned recent advances have made us overcome most of the complications, especially the most dreaded total spinal following a caudal block.

Application of electrostimulation

Stimulating the caudal and epidural spaces and eliciting an appropriate end motor response at an appropriate current strength helps in improving the safety profiles and efficacy of these blocks.

A 22-G insulated needle is placed in the caudal canal, instead of a 22-G hypodermic needle until a "pop" is felt. An electrical stimulation of 1-10 mA is applied. The correct needle placement elicits anal sphincter contractions (S2 to S4).[20] Motor response at a threshold current of <1 mA has been suggested to be sufficient

to produce a motor response to electrical stimulation if the needle tip is in the intrathecal space.[21]

Application of ultrasound

The grandest advancement in modern paediatric regional anaesthesia is the application of ultrasonography. It has been shown that application of ultrasound guidance increases the safety and efficacy of the block in children.[22] In central neuroaxis blocks, ultrasonography has its own limitations as the age of the child advances. With age, the ossification of the spine continues and does not allow the neural conduit to be visualised as well as it would be in neonates and infants (below 6 months).[23] Ultrasound-guided caudal epidural block remains an exception to this. It is a reliable technique as compared with lumbar thoracic epidural blocks irrespective of the age of the child.

Caudal epidural sonoanatomy

The caudal space can be visualised in two views, transverse and longitudinal.

Transverse scan

The position of the probe is as shown in Figure 1.

The scan shows two hyperechoic sacral cornua and dark acoustic shadows posterior to each of them. The hyperechoic fibrous structure intervening between them is the sacrococcygeal membrane or ligament. Posterior to the sacrococcygeal membrane is the base of the sacrum [Figure 1].

Longitudinal scan

Position of the probe is as shown in Figure 2. The sacral vertebrae, the filum terminale and termination of the dural sac (conus medullaris) can be identified in the longitudinal axis [Figure 2]. The filum terminale is a cordlike hyperechoic structure and is surrounded by hyperechoic nerve roots of the cauda equina. It is difficult to differentiate filum terminale from the nerve roots due to their identical appearance (both appear like hyperechoic strands).

Needle placement

The needle is inserted at an angle of 20-30° to the skin from the caudal space in an "in-plane" approach. After piercing the skin and subcutaneous tissue, it pierces the sacrococcygeal membrane to lie in the caudal space [Figure 3].

Note: A needle placed well before (distal) the demarcation of conus medullaris confirms the extradural placement of the needle [Figure 3]. The subsequent complication such as a total spinal (due to injection of the drug in the CSF) is avoided.

Local anaesthetic injection and its spread in the caudal space as seen under ultrasound guidance

The observation of real-time drug spread in the caudal epidural space has unveiled a lot of facts pertaining to its cranial spread.[16,24,25] Posterior dural sag [Figure 4] as the drug displaces posterior dura anteriorly while making its way in the cehaplic direction is taken as a surrogate marker for correct drug placement.[6] The effect of different drug volumes on the cranial spread was also studied; although the spread correlated with the volume, the correlation between injected volumes of local anaesthetic and the cranial spread of caudally administered local anaesthetics was numerically small.[25] While studying the secondary spread of the drug injected in the caudal block, two separate patterns were observed: the horizontal intrasegmental redistribution from the dorsal to the ventral

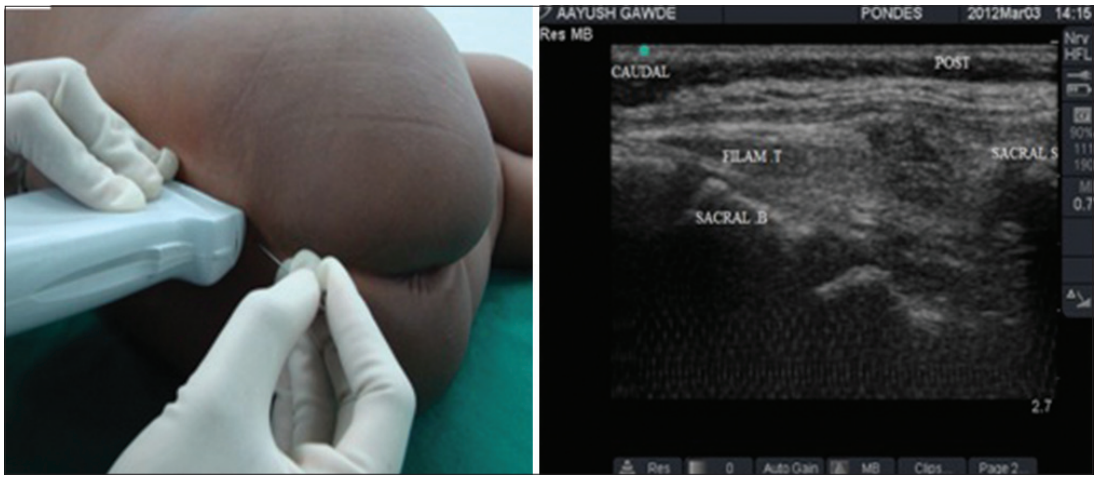

Figure 2: Probe placement in longitudinal axis and the respective ultrasound scan. Filum T - Filum terminale; sacral P - Sacral spinous process; sacral B - Sacral vertebral body

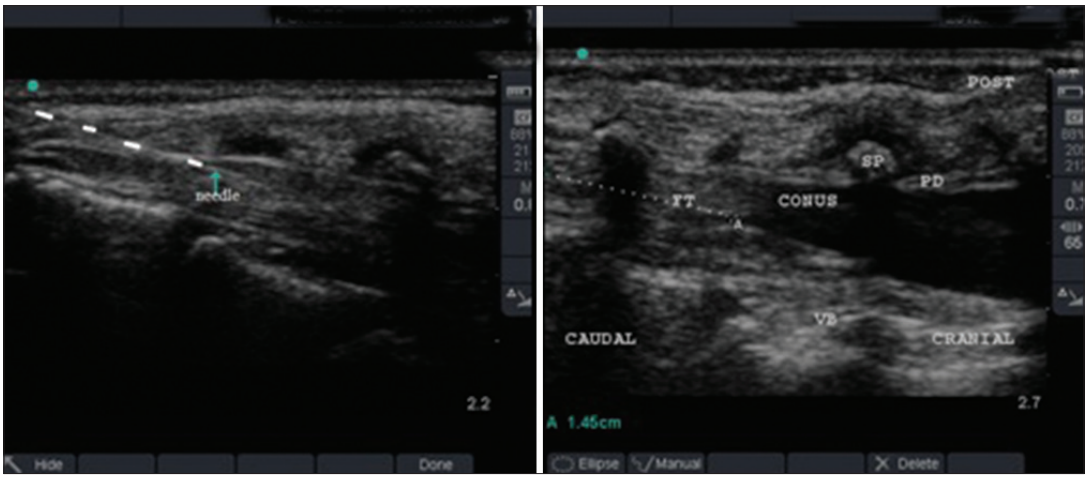

Figure 3: The needle placed amongst the filum terminale and well demarcated the conus medullaris. SP - Sacral spinous process; PD - Posterior dura; Conus - Conus medullaris

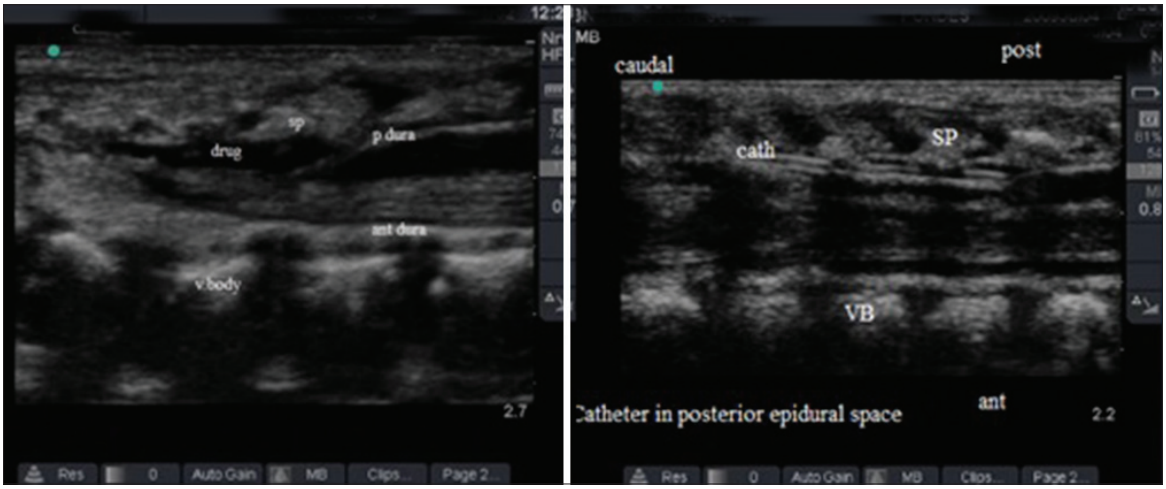

Figure 4: Drug deposition on the posterior aspect of the posterior dural resulting a "dural sag" and illustrates a catheter placed in the posterior epidural space. P. dura - Posterior dura; a. dura - Anterior dura; SP - Spinous process; VB - Vertebral body; v body - Vertebral body

compartment of the epidural space and longitudinal caudal to cranial spread.[24]

CONTINUOUS CAUDAL EPIDURAL BLOCKS (CAUDO-LUMBAR-THORACIC ANAESTHESIA)

A single-shot caudal can be converted into a continuous technique depending upon the invasiveness of the surgery. It is useful for intraoperative and postoperative pain relief. These catheters can be safety kept for 3-4 days in the postoperative period. A catheter can be threaded up cranially through the sacral hiatus via simple plastic cannula, Tuohy needles, or specifically designed stimulating catheter sets with appropriate gauge needles (19 G, Pjunk). This technique carries a smaller risk of dural puncture or spinal cord trauma than a direct thoracic or lumbar epidural approach. In small kids, insertion of catheters from caudal to thoracic level is possible.[26] Although malpositionings are known,[27] they can be reduced by the use of large bore catheters (18 G) and catheters with a stylet (the stimulating catheters).[28] The catheter tip position can be confirmed by radiography,[29] ultrasound,[30] ECG tracing[31] or electrostimulation.[32] Direct visualisation of the neural conduit is possible below 6 months of age because vertebral column remains largely cartilaginous in neonates and infants till 6 months. In this age group, it is possible to see the real time of the catheter and its movement towards the desired level [Figure 4]. In older children, stimulating catheters would be a better alternative. Exact placement of the epidural catheter tip is indicated by a motor response elicited with a current between 1 and 10 mA. A motor response observed with a significantly lower threshold current (<1 mA) suggests that the catheter is in the subarachnoid or subdural space as the CSF is more conductive.

Issues with continuous caudal technique

1. Its proximity to anal region makes it prone to infections although they are not very common.[33] Subcutaneous tunnelling can decrease colonisation as the catheter is tunnelled inside the subcutaneous tissue
2. Catheter leaks: In practice, we often observe a back leak of local anaesthetic while injecting it through the caudal catheters. This can be reduced by injecting the drug at a slow rate
3. As mentioned earlier, the catheters need not always reach the site that we expect them to by external measurements resulting in inadequate analgesia.

Issues with the modern techniques

1. Ultrasound machines are expensive, but when applied to peripheral nerve blocks and venous cannulations, they will soon become an integral part of the operation theatre
2. Proper sterility protocol has to be maintained with the use of ultrasound probes
3. It has a learning curve. Every technique in that case has a learning curve
4. Stimulating catheter sets are also expensive and the motor response is abolished with the use of muscle relaxant. General anaesthesia technique has to be modified while using them; muscle relaxants are administered after placing these catheters.

LUMBAR EPIDURAL

Lumbar epidural can be practised as a single shot and continuous technique. In children, since caudal epidural is technically much easier and safer to practise for intra-abdominal minor surgeries, the risk benefit ratio is advantageous for continuous technique for intra- and post-operative analgesia for major surgeries. Again, the pursuit of regional techniques today is to be more and more site specific. The catheters are introduced as close to the level of incision as possible. Lesser the distance a catheter is expected to travel in the epidural space, lesser is its chance to migrate, coil or take any unwanted route.

World over, the concept of continuous epidural analgesia is undergoing certain interesting changes. On one side of the spectrum, the benefits of adding epidural analgesia to general anaesthesia have demonstrated a decrease in hospital stay compared with a morphine technique.[34] On the other side, with laparoscopic surgery and the greater use and success of other peripheral local anaesthetic techniques such as paravertebral blocks, transabdominal plexus blocks and rectus sheath blocks, the use of continues lumbar epidural in slightly declining.[35] As mentioned previously in this article, not all anaesthesiologists may have mastered these techniques. Hence, continuous lumbar epidural analgesia remains the most popular modality of intra- and post-operative analgesia in children for: major intra-abdominal surgeries; spinal surgery;[36] and long-term pain management.

Contraindications for lumbar epidural are coagulopathies, inexperience and deformed spines which can be challenging.

Technique for lumbar epidural block

- Epidural space is identified by loss of resistance technique.[37] Loss of resistance can be elicited with either air or saline. Although air is readily available and cannot be confused for another substance, and also may permit easier detection of a dural tap compared to saline in children, loss of resistance is elicited by saline instead of air. Many complications have been reported with the use of air such as venous air embolism, nerve root compression, subcutaneous emphysema, pneumocephalus, a greater incidence of incomplete analgesia and a higher incidence of paresthesia[38,39]
- Needle: 19 G with 21 G catheter and 18 G with 20 G catheters Touhy (B Braun and Portex), stimulating epidural catheters (Pjunk) available with 19 G stimulating Touhy needles and 21 G stimulating catheters (Pjunk).

Recent advances: Visualisation of epidural space

The ligamentum flavum and posterior dural complex is identified on the transverse scan [Figure 5]. The displacement of posterior dura due to drug injection is an indication of its placement in exact location. In this method, real-time placement of the epidural catheter tip may not be possible with a single operator. Confirmation of the epidural catheter tip can be tried after placing the catheter at the decided site.

Risks with continuous lumbar or thoracic catheters

The incidence of complications is low, but they do occur and are serious in nature. The risk of serious complications is shown to be 1:2000 and that of persistent complications is 1:10,000 epidurals.[40] Paraplegia or death secondary to central techniques in patients of all ages was described as 1:100,000. ADARPEF[41] in 2010 have in their repeat audit stated that of all local

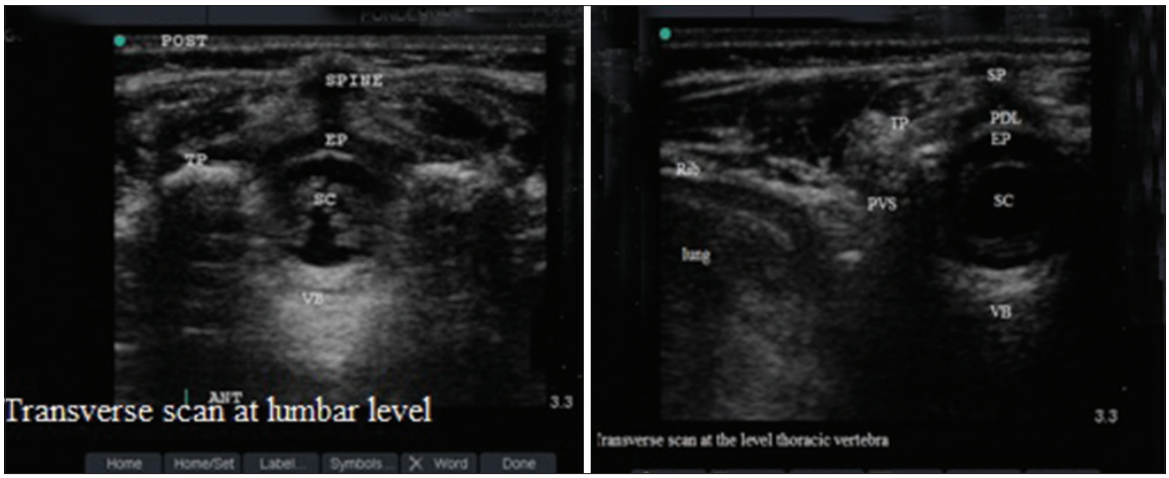

Figure 5: Transverse scans at the level of lumbar and thoracic vertebrae. TP - Transverse process; EP - Epidural space; SC - Spinal cord; PDL - Posterior dura ligamentum flavum complex; PVS - Paravertebral space

anaesthetic techniques, 1500 were cases of continuous epidural anaesthesia. The incidence of complications in them was comfortingly low, but still central techniques have an incidence of complications that is seven times that of peripheral regional techniques. It should also be noted that spinal cord by itself has no sensations and any damage to it caused by the Tuohy needle will not elicit any response.[42] Complications are said to be higher in children below 6 months, where caudo-lumbar-thoracic catheters have a better risk benefit equation. The risks can be minimised by selecting an apt indication, strict asepsis, refraining from repeated attempts, if possible restricting the duration to 72 h, and proper protocols for the staff in the postoperative period.

Spinal blocks in children

Indication: Surgery on the lower part of the body of maximum 60-75 min duration.

In high-risk premature neonates, unsupplemented spinal anaesthesia is used for inguinal hernia repair.

Absolute contraindication

Ventricular shunts

Technique

Needle placement: L4/5 or L5/S1 interspace. At the level of intercristal line as the iliac crest is at the level of the 5th lumbar vertebrae.

Drugs and dosages

Baricity does not appear to be that important for the selection of local anaesthetic as it is in adults.[43] The anatomical configuration of the spinal column is flat in young children, and consequently, drugs injected into the subarachnoid space spread in a mid-thoracic block.[44]

Dose: 0.8 ml/kg of 0.5% bupivacaine or 0.5 mg/kg of ropivacaine.

Needle: Pedi spinal tray 3 cm 26 G needle; alternatively, any spinal needle, preferably small gauge.

Note: The lower limbs should not be raised which often happens in practice, typically to place the cautery pad. This leads to unintentional cranial extension of the spinal block and respiratory compromise. Trendelenburg position should also be avoided for the same reason.[45]

Additives used in central neuraxial blocks

Epinephrine (5 μg/ml) prolongs the duration and allows the detection of intravascular needle placement.[46] Recent practice is to inject 0.5-1 μg/kg epinephrine in 0.1-0.2 mg/kg local anaesthetic solution. Clonidine 1-2 μg/kg prolongs the duration.[47] Infusion analgesia with clonidine has been described. Higher doses, 5 μg/kg, caused sedation, hypotension and bradycardia.[48] Fentanyl,[49] pethidine[50] and ortramadol[51] cause side effects, but do not prolong the duration of analgesia. Although addition of ketamine triples the duration of analgesia after caudal bupivacaine,[52] potential neurotoxicity is a problem,[53,54] and similar to midazolam or neostigmine, *S*-ketamine cannot be recommended for clinical use.[55] Due to recent concerns of direct neurotoxic and apoptotic changes, these drugs are no longer recommended.

CONCLUSION

Site specificity and adding an objective end point to blind techniques would impart safety and make blocks more effective. This is the best tool we have to treat and prevent perioperative pain.

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