Review Article

Recent trends in paediatric regional anaesthesia

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ABSTRACT

Paediatric regional anaesthesia today is one of the fastest growing and exciting aspects of paediatric anaesthesia, which requires an ongoing fervour to learn. Application of paediatric regional anaesthesia in neonates, infants, toddlers and children is undertaken to treat perioperative pain without disturbing the physiological milieu with additional advantages elaborated in the review. The available choices, traditional methods and the most recently described methods are discussed with emphasis on their advantages and disadvantages. Clear pointers for selection of the blocks are also discussed. To present a holistic overview of this rapidly growing subject, a comprehensive literature search was performed in May 2019 in MEDLINE, PubMed and Google Scholar to retrieve articles pertaining to all the above topics. The keywords used in various combinations included 'Central neuraxial, blocks, Paediatric(s)', 'Peripheral Nerve blocks', 'Safety, controversies, regional, anaesthesia'.

Key words: Abdominal wall blocks, central neuraxial blocks, paediatric regional anaesthesia, peripheral blocks

INTRODUCTION

Paediatric regional anaesthesia (PRA) is one of the most valuable and safe tools to treat perioperative pain and is an essential part of modern anaesthetic practice. It offers many advantages to both the patient and the hospital.[1] It provides excellent pain relief and allows caregivers to use multimodal analgesic techniques and decrease the use of opioids. Considerable progress has been made in the practice of PRA over the past few years including availability of information on safety and incorporation of ultrasound guidance. We see a general shift away from neuraxial blocks, and yet they continue to have a definite place in certain scenarios such as supra-major cavity invading surgery. Novel regional anaesthesia (RA) techniques, especially the anterolateral and the posterolateral trunk blocks, show promise. Adjuvant medications and ambulatory catheters increase the duration of RA and facilitate cost-effectiveness and early hospital discharge. Our understanding of the local anaesthetic systemic toxicity (LAST) reinforces new safety guidelines.[2]

There are major anatomical differences between adults and paediatric subjects with regard to the spine and its contents. Physiologically too, there are a number of differences found in the developing paediatric nervous system when compared with adults. There is incomplete myelination at birth, which can take 12 years to complete. This allows utilisation of lower concentrations of local anaesthetics (LAs) in the paediatric population, thereby reducing the risk of toxicity. Although the nociceptive pathways are fundamentally the same in both children and adults, there are differences with children experiencing greater pain than adults. In children, the descending inhibitory pathways are immature which may allow unmodulated nociceptive inputs to the ascending spinal pain pathways leading to poor pain localisation. The physiologically immature neonatal liver in association with a relatively high cardiac output produces pharmacological differences that potentiate the risk of LA toxicity in neonates.

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In view of the above factors, this review aims to provide an overview regarding various aspects of PRA with the objective of making pain relief in this most vulnerable population practical and safe.[3]

GENERAL ASPECTS OF PRA

Benefits of PRA

The most tangible advantage of RA is the profound and prolonged pain relief. Alternatively, pain relief can be given by opioids which are known to cause nausea, vomiting, respiratory depression, decrease in gut motility and increase apnoeic spells in the population vulnerable for the same. Nonsteroidal anti-inflammatory drugs can affect the immature renal system adversely. RA offers pain relief without changing the physiological milieu. The subtle benefits of RA are observed in its positive influence on the stress response, cellular, metabolic, immunological, hormonal and haemostatic aspects. Stress hormones release (epinephrine, norepinephrine, adrenocorticotropic hormone, cortisol, prolactin) is lower following RA than after general anaesthesia.[4]

Clinical experience suggests that general anaesthesia supplemented with RA produces better operating conditions and a reduction in surgical blood loss in children compared with general anaesthesia alone.[4] RA results in earlier return of gut function with improved peristalsis, unlike opiates which increase intestinal muscle tone and slow down the peristalsis.[4]

As regards pharmacology, LAs have a greater volume of distribution, a lower clearance and a higher free non-protein-bound fraction in infants. The larger volume of distribution counteracts the increased potential for toxicity caused by the larger free non-protein-bound fraction. This means that the amount used for single-shot procedures in terms of mL/kg can be the same in children as for adults.[5]

For a continuous infusion the situation in the developing child is much more complex; CYP1A2 which metabolises ropivacaine is immature before 4–7 years of age, whereas CYP3A4/7, which metabolises levobupivacaine, has full enzymatic capacity by the age of 1 year, although there are no well-designed studies comparing the two anaesthetics.[5]

Disadvantages of PRA

A good technique requires knowledge, skill and the right equipment.[6] Potential complications of regional block include failure and possible permanent damage to nerve or other structures.[6] The majority of complications (e.g., intravascular injection, convulsions, dural puncture) occur at the 'end of the needle' when the anaesthesiologist is still present and would be successfully managed without long-term sequelae.[4]

Safety of PRA

Increasing amounts of data attest to the efficacy and safety of paediatric RA. The safety profile is not affected by the standard practice of performing the blocks in anaesthetised children. Walker *et al*.[3] analysed more than 100,000 blocks from the Pediatric Regional Anesthesia Network but did not identify any permanent motor neurologic deficits. Few case reports[6] confirm the risk of permanent neurologic injury, primarily with epidural analgesia, but the analysis by Walker *et al*.[3] did not show any difference between complication rates following peripheral and central blocks.

Controversies in PRA

RA in sedated/anaesthetised children

Based on the available literature and expert opinion, it is recommended that anaesthesia or heavy sedation be used when regional block is given in children.[5,7] A frightened child cannot be expected to cooperate nor report any signs of systemic toxicity during a block procedure. Any inappropriate movement during the procedure can be detrimental and hazardous. Awake RA could be possible in a mature child for minor procedure. Although there is a potential risk of the child being unable to warn regarding any nerve injury due to needle when performing regional block under general anaesthesia, PRA has been found to be safe in a large series of patients, as discussed in the previous section on safety.

Loss of resistance technique to air or saline

Loss of resistance (LOR) to saline is commonly used for identification of epidural space, but it can be mistaken for cerebrospinal fluid (CSF). Use of air for LOR may result in air embolism, root compression, pneumocephalus and incomplete analgesia.[4,5] Saline is therefore preferred in LOR technique in our practice.

Test dose

Aspiration test to elicit blood or CSF reflux is not very sensitive, particularly in infants. A test dose of epinephrine 0.5 μg/kg (administered as 0.1 mL/kg of lignocaine with epinephrine 1 in 200,000) allows

detection of intravenous injection with changes in T-wave amplitude occurring first, followed by changes in heart rate and systolic blood pressure.[5] The anaesthetic agents can mask these electrocardiogram (ECG) changes with intravenous agents such as propofol having less effect than volatile agents.[5] The use of the 'fractional test dose' or slow injection of the whole LA dose under haemodynamic and ECG monitoring remains essential for patient safety.

Compartment syndrome

Compartment syndrome is a pathological condition characterised by an increased pressure in a closed muscle compartment. Untreated compartment syndrome leads to loss of muscle tissue, hyperkalaemia, metabolic acidosis, renal insufficiency, amputation of extremities and outright mortality.[8] A very dense regional block can mask pain due to compartment syndrome. Thus, the least concentration of LA that provides adequate regional block should be chosen. The anaesthesiologist should NOT step up analgesic or LA boluses if there is evidence of an increase in pain but evaluate the compartment pressure. In today's literature there seems to be no evidence to suggest that RA increases the risk of compartment syndrome.

Practical aspects of PRA

LAs, dosages and additives in PRA

The choice and dosages of LAs and additives matter the most in every day practice. Among the LA, 0.2% ropivacaine, 0.25% bupivacaine and 2% lignocaine with adrenaline are commonly used. Clonidine in a dose of 1 μg/kg is routinely used as an adjuvant to prolong the duration of analgesia. For the sake of brevity, the list of options is shown in Tables 1 and 2.[9]

LAST in PRA

Strict adherence to the allowable dosing guidelines and use of ultrasound when possible are recommended.[10] Consider test dosing and slow and incremental injections in aliquots. The LAST affects the central nervous system and the cardiovascular systems, leading to seizures, tachyarrhythmias and ultimately death from apnoea and cardiovascular collapse.[11] The initial line of treatment is prompt airway control and oxygenation. Control of seizures with midazolam and thiopentone, maintenance of good intravenous (IV) access, arterial blood gases and, if possible, drug level sampling are required. Lipid therapy forms the cornerstone of cardiovascular treatment. It consists of 1.5 mL/kg of 20% lipid emulsion bolus intravenously over 1 min. The bolus can be repeated once or twice if cardiovascular collapse persists, followed by continuous infusion of 0.25 mL/kg/min (upper limit approximately 10 mL/kg lipid emulsion over the first 30 min). Shenoy *et al.* have reported features of ventilation/perfusion mismatch in children following lipid emulsion therapy.[12]

Equipment

Ultrasound improves the success rate, prolongs block duration, reduces time of block performance and the number of needle passes.[13] A high-frequency linear probe is required for superficial blocks, and for deeper blocks a low-frequency curvilinear probe is necessary.

Table 1: Commonly used LA with their respective dosages

Local anaesthetics	Maximum allowable dose (mg/kg)	Bolus for peripheral and truncal blocks		Infusion for continuous block	
		Concentration (%)	Volume (mL/kg)	Concentration (%)	Rate* (mg/kg/h)
Bupivacaine	2.5	0.25	0.5	0.125	0.4
Ropivacaine	2.5	0.2	0.5	0.2 or 0.1	0.4
Levobupivacaine	2.5	0.25	0.5	0.125	0.4
Lignocaine with adrenaline	7	2	0.25	-	-

*The infusion rate should be halved in children below 1 year of age

Table 2: Commonly used adjuvants

Drug	Dose	Common indication	Mechanism of action	Side effects
Morphine	0.05 mg/kg	Neuraxial blocks	Local action on the spinal cord	Nausea vomiting respiratory depression
Fentanyl	0.5-1 μg/kg	Neuraxial blocks	Local action on the spinal cord	Nausea vomiting respiratory depression
Clonidine	0.5-2 μg/kg	Neuraxial and peripheral blocks	Alpha 2 agonist	Sedation bradycardia, hypotension
Dexmeditomidine (approved for IV use only)	1-2 μg/kg	Neuraxial and peripheral blocks	Specific Alpha 2 agonist	Sedation bradycardia, hypotension
Ketamine (preservative-free)	0.5 mg/kg	Predominantly neuraxial	NMDA antagonist	Sedation, odd behaviour, agitation or restlessness

IV – Intravenous

Although in infants and small children, because most of the structures are superficial, high frequency linear is more useful. A nerve stimulator with insulated needles can also be used. The various needles used for the blocks are 25-G 50-mm short-bevel needles, hypodermic needles, 25- and 29-G spinal needles with a length of 25–30 mm for infants and 50 mm for small children, IV catheters and hypodermic needles. For continuous infusions, 19-G epidural needle, with 23-G catheter, and 18-G needle with 21-G catheter are available.

SPECIFIC REGIONAL BLOCKS

Several commonly used regional blocks, their current trends, indications and complications will be reviewed in this section.

Single-shot caudal epidural neuraxial block

The caudal epidural is commonly indicated for circumcision, orchidopexy, herniotomy, hypospadias repair, infraumbilical surgery and lower limb surgery [Table 3]. This is the simplest block to learn.[14] This block involves placing the child in the lateral position with flexion of the spine and hip which creates a cephalad dural sac shifts adding safety.[15] The needle is inserted through the sacral hiatus to deliver the LA into the caudal–lumbar–lower thoracic (in neonates) epidural space. The two posterior superior iliac spines and sacral hiatus make an equiangular triangle. The use of equiangular triangle concept to identify the sacral hiatus is common, but may be inappropriate because the actual triangle formed by the sacral hiatus and the posterior superior iliac spine is not equiangular.[16] Park *et al*.[13] demonstrated using ultrasound imaging that the optimal angle for needle insertion is 20° to the skin to avoid puncture of the bone and potential intraosseous injection. Lee *et al.* demonstrated the distance between the depth of the caudal epidural space to prevent dural sac puncture during the caudal block in children.[17] This matters the most in neonates as the distance between the dural sac and the sacral hiatus is very small.[18]

Table 3: Caudal epidural blocks: common surgeries and respective volumes

Site of surgery	Volume	Concentration of LA
Lower limb/penile	0.5 mL/kg	0.25% bupivacaine or 0.2% ropivacaine
Hernia/orchidopexy	1-1.25 mL/kg	0.125% bupivacaine or 0.1% ropivacaine
Lower thoracic surgeries	1.25 mL/kg	0.125% bupivacaine or 0.1% ropivacaine

Objectivity to caudal epidural block can be added by nerve stimulation[19] or ultrasonography (USG) [Figure 1]. With the nerve stimulation, the end point is the anal muscle contractions at high currents (3-5mA). The end motor response at very low currents is a tell-tale sign of contact between needle tip and CSF.[19] USG demonstrates the entire neuraxial conduit. The visualisation is better till infancy due to incomplete ossification of the vertebral column and can demonstrate real-time LA ascent. The reach of high-volume blocks was found to be inversely related to age. Interestingly, the speed of injection does not change or augment the cranial ascent of the drug into the epidural space. Recently, median epidural space volume was measured to be 1.30, 1.57 and 1.78 mL/kg at the L1, T10 and T6 levels, respectively.[20] Suresh *et al*.[21] reported that the USG was used only in 2.4% of 18,650 total cases of the caudal block. However, USG is strongly recommended if variations are noticed in the sacral hiatus and sacral cornua.[22]

Rare but known complications are total spinal leading to apnoea, osteomyelitis of the sacrum, damage to the rectum and LAST.

Continuous caudal epidurals

The sacral hiatus is also a portal for continuous catheters which can be passed into the lumbar or thoracic vertebral level for continuous infusion in the postoperative period. Ponde *et al*.[23] reported accurate advancement of the epidural catheter to the expected lumbar or thoracic level under USG guidance when compared with the traditional technique.

Lumbar and thoracic continuous epidurals

These are indicated for major orthopaedic, abdominal and thoracic surgeries and have their own firm place in

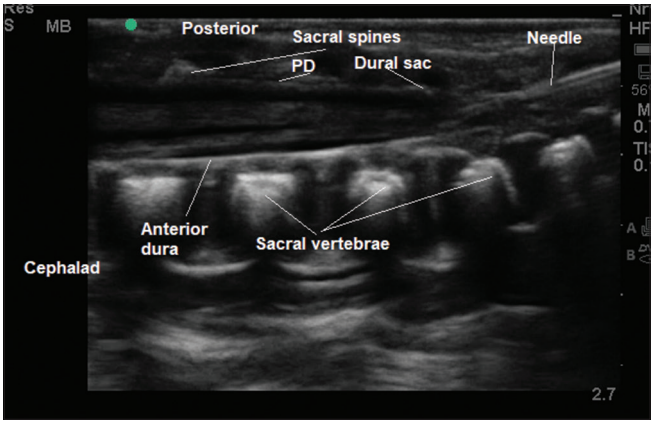

Figure 1: Midline longitudinal ultrasound scan at the sacral level showing caudal needle. PD = Posterior dura

PRA.[24] LOR technique is commonly used to detect the epidural space. Alternative methods described to locate the tip of the catheter are use of electrocardiograph signals or nerve stimulation guidance.[25,26] Reported complications include spinal cord injury, paraplegia, total spinal and LAST.[27]

Spinal anaesthesia

This is mostly indicated in the sick neonate or preterm babies and may be used in an awake child. General anaesthesia or sedation is avoided in these neonates to decrease the risk of postoperative apnoea associated with anaesthetic drugs. Spinal anaesthesia in infants and young children is devoid of cardiorespiratory disturbances and has a fast onset of action.[5] The dural sac ends at S3 and spinal cord at L3 vertebral levels in neonates. The Tuffier's line passes through L4–5/L5–S1 and forms the landmark for needle introduction. Hyperbaric or isobaric bupivacaine in the dose of 0.5 mg/kg is the most common choice.[28] Spinal blockade in infants has a shorter duration of analgesia and less dense blockade compared with adults. It also has a measurable failure rate and can lead to high spinal block requiring resuscitation.

Peripheral RA, single-shot and continuous

Peripheral blocks are preferred for their longer duration of action and less drastic complications when compared with central neuraxial blocks. A single-shot block can be converted into a continuous block, provided indications are appropriate. This section shall deal with the common peripheral blocks.

Upper extremity brachial plexus blocks in children

Various approaches to brachial plexus are available. These blocks can be guided by peripheral nerve stimulation (PNS) and USG. The choice of the block is made depending on the indications. The interscalene block is indicated for surgeries of shoulder or proximal humerus, which are very uncommon in children. The common complications associated are the phrenic nerve palsy, intraarterial injection and epidural injection.

The supraclavicular approach [Figure 2] covers all the surgeries of humerus and below.[29] Before the advent of ultrasonography, this block was not favoured because of the risk of damage to the pleural dome in the root of the neck. This block is back in vogue due to our ability to avoid this damage in real-time USG-guided blocks. Yet, complications such as arterial and pleural puncture are known. The most commonly used block

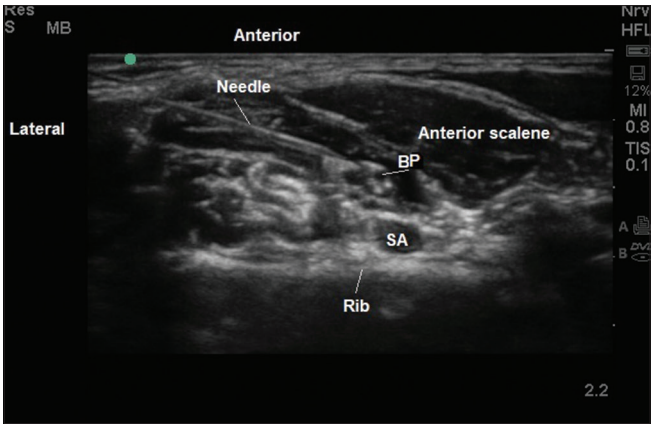

Figure 2: Transverse ultrasound scan for supraclavicular block. SA = Subclavian artery, BP = Brachial plexus

in children is the infraclavicular block [Figure 3]. It is indicated in distal humerus, elbow, forearm and hand surgeries as it combines the advantages of supraclavicular and axillary block.[30] The nerves spared in axillary (musculocutaneous and axillary) approach are covered with this block. Anatomically, it renders itself very well for catheter placements. Complications such as vascular punctures and pneumothorax are possible. Axillary approach [Figure 4] to brachial plexus block is indicated mainly for wrist and finger surgeries. Arterial damage is a common complication with this approach.

Lower extremity blocks

A combination of femoral and sciatic [Figure 5] nerve blocks[31] or fascia iliaca compartment block (FICB)[32] imparts anaesthesia for unilateral lower limb surgeries. Like upper extremity blocks, these can be given with USG and PNS guidance. FICB can be given under ultrasound guidance and LOR technique. Femoral block provides analgesia to the anterior aspect of the thigh and the femur itself. The FICB is well-suited for the anterolateral surgeries of the thigh. Using these blocks, we spare anaesthesia to the contralateral limb which is not operated and urinary retention, a common feature with central neuraxis block. The subgluteal, intragluteal and popliteal sciatic nerve blocks are the most common approach. These are indicated in surgeries below the knee.

Trunk blocks

Several blocks such as posterior rectus sheath block, ilioinguinal and iliohyogastric nerve block, transversus abdominus plane (TAP) block, subcostal TAP block, quadratus lumborum (QL) block, erector spinae block and the chest wall blocks are described recently.[33] The bilaterally performed posterior rectus

sheath blocks provide anaesthesia extending from the central aspect of the anterior abdominal wall to the iliac crest. It is indicated for surgeries around the umbilicus, such as umbilical hernia or an umbilical port. Peritoneal puncture and injury to the bowel are possible complication, hence USG guidance is mandatory.[34] The ilioinguinal and iliohypogastric nerves block render analgesia for surgeries in the inguinal region, for example, inguinal hernia. This can disturb the tissue planes in this area, making it difficult to identify the structures during surgery, especially in delicate and flimsy tissue of small babies. Second, the hernial sac is not anaesthetised by this approach.

Figure 3: A child positioned for infraclavicular block with ultrasound probe in place

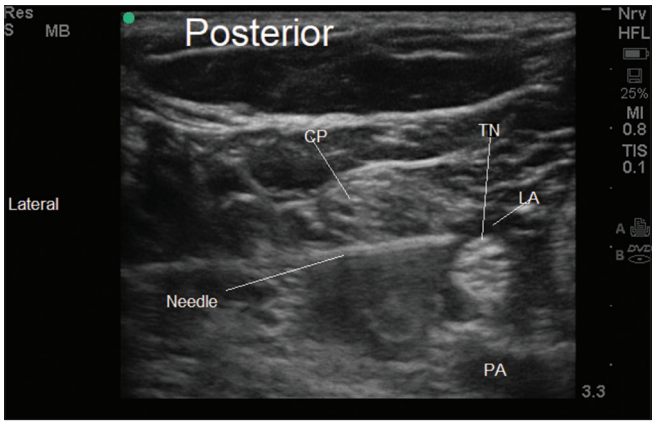

Figure 5: Transverse ultrasound scan above the popliteal crease for popliteal nerve block. TN = Tibial nerve, PA = Popliteal artery, CP = Common peroneal nerve, LA = Local anaesthetic

TAP [Figure 6] block gives analgesia to the ipsilateral anterolateral abdominal wall. It provides somatic analgesia. It forms an integral part of multimodal analgesia especially in minimally invasive surgeries. Subcostal TAP block provides analgesia to the ipsilateral upper quadrant of the abdominal wall. Injury to the intrabdominal organs is a possible complication.

The QL block (QL 1, 2, 3 and 4) has a possibility to offer somatic and visceral analgesia to the ipsilateral side and is commonly indicated in ileostomy [Figure 7], unilateral laparoscopic surgeries, pyeloplasty, herniorrhaphy and unilateral limb surgeries. Injury to the kidney, peritoneum, lingering motor blockage of the ipsilateral limb could be few of the complications.

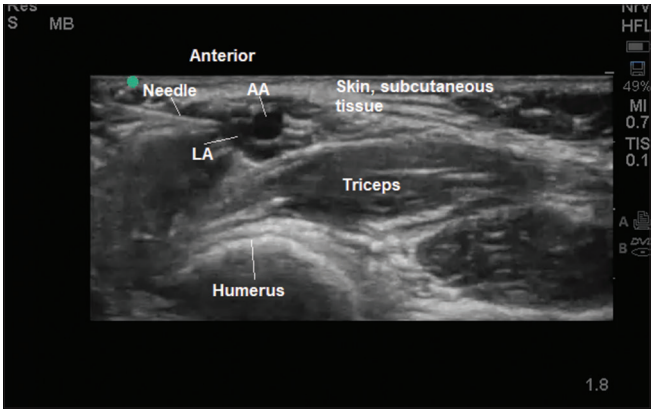

Figure 4: Transverse ultrasound scan for axillary block. AA = Axillary artery, LA = Local anaesthetic

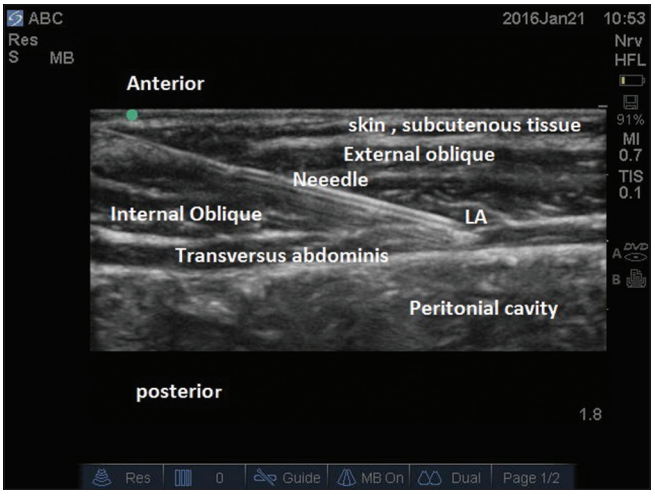

Figure 6: Ultrasound scan for transversus abdominis plane block. LA = local anaesthetic

Figure 7: A child positioned for quadratus lumborum block with ultrasound probe in place

Erector spinae block[35] can be used for unilateral abdominal and thoracic procedures and has a promise of providing visceral analgesia. This is the most recently described block and requires further clinical evaluation.

Paravertebral block provides ipsilateral somatosensory analgesia for unilateral surgeries on thorax and trunk without the risk of epidural-related unintentional spinal cord damage.[36] USG application has made it safer. To make a landmark-based approach safer, formulas have been derived, especially for Indian children.[37] This can be an alternative in cases with deranged coagulation. Analgesia with paravertebral block is denser than epidural. No fatalities have been reported. It should not be used in the presence of infective conditions of lung or pleura. The complications include hypotension, vascular puncture, pleural puncture and pneumothorax.

The pectoralis plane block 1 and 2 and serratus anterior plane blocks[38] are easier options to thoracic epidural, paravertebral, intercostal and intrapleural blocks. All three blocks are required to obtain the required analgesia. In children, these blocks render analgesia for intercostal drain insertion or any surgeries over the hemithorax. Unlike other options, continuous catheters' placement is not possible and major thoracic surgeries usually require profound and continuous analgesia.

Lumbar plexus block is an advanced level block and is suitable for analgesia over the hip and anterolateral thigh procedure with a high success rate. There is a possibility of damage to the kidney, abdominal structures and major vessels.

Penile block

Penile block is a common everyday practice block indicated for circumcision, meatoplasty, hypospadias repair and so on. The dorsal penile nerve is blocked. This can be good alternative to caudal epidural for the above surgeries. Arterial puncture and ischaemia are known complications.

Few miscellaneous blocks such as head face neck and scalp blocks are not considered here, but do form good options to offer pain relief in respective surgeries.

Postoperative care

Postoperative advice pertaining to protecting the anaesthetised area should be given to the family. The family and child should be made aware of occurrence of muscle weakness and diminished sensation. Every institution must have guidelines for monitoring of regional anaesthetic techniques and staff must receive regular education on managing regional blocks postoperatively and care of the anaesthetised extremity. For continuous blocks, the infusions should be set up by the anaesthesia team. The infusion pumps or elastomeric pumps should be labelled with the name and concentration of LA, infusion rate and additive, if any. A warning of 'NO IV' use can also be added in bold letters. Pericatheter leakages, urinary retention, numbness and lingering motor blockage are few of the aspects which need attention. A team work including the anaesthesia team, surgical team and the nursing staff is crucial to manage continuous infusions.

Training

The training of anaesthesiologists in PRA and anatomy is essential for its successful and safe implementation. A structured approach to teaching the common simple blocks, US scanning and needling techniques is essential.

SUMMARY

We have in a nut shell reviewed why and when we should use RA in children. The detailed description of each block is beyond the scope of this review. The choices of blocks, the LA dosages and additives should be considered on case-to-case basis. Invasiveness of the surgical procedure should be balanced with the risks and benefits of the RA to suit a given case with the aim of sufficiently treating perioperative pain with minimum risk. In conclusion, RA plays a major role in postoperative pain relief in children, and the classical techniques have an excellent safety record.

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Conflicts of interest
There are no conflicts of interest.

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