Comprehensive Guide to Paediatric Spinal Blocks

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KEY POINTS

- Spinal anaesthesia (SA) may have advantages over general anaesthesia (GA) in certain patients.
- The short action duration of spinal anaesthesia limits its use for lengthy surgeries.
- The dosage of local anaesthetics for spinal anaesthesia should be calculated based on age-specific formulas.
- Using ultrasound for spinal anaesthesia improves needle placement by accurately measuring the depth to the dura mater, identifying the optimal interspinous space, and determining the best angle for insertion, thus reducing the risk of neural damage.

INTRODUCTION

Spinal anaesthesia (SA) in paediatric patients was first described by August Bier in 1898. It fell out of favour for decades, overshadowed by the advent of safer general anaesthesia (GA) techniques and drugs.[1] However, in 1984, SA experienced a resurgence thanks to Abajian, who reintroduced it as a safer alternative to GA for high-risk preterm neonates. This was due to its associated lower incidence of postoperative apnoea and bradycardia compared to GA.[2] SA offers significant advantages over GA,[3] as illustrated in Figure 1.

WHY SPINAL ANAESTHESIA?

Interest in SA has increased due to concerns about the effects of GA on the developing brain in young individuals. Animal studies show that GA is associated with neuronal damage and accelerated apoptosis, affecting behaviour and cognition, albeit at supratherapeutic doses.[4,5] These changes are linked to the anaesthesia dose, frequency, duration, and patient comorbidities.[6-8] SA is more effective than GA at reducing the neuroendocrine stress response from surgery, which may contribute to the neurotoxicity associated with GA.[9] Additionally, the use of bisulfite-free local anaesthetics (LA) like chloroprocaine, ropivacaine, and levobupivacaine has made LA safer for intrathecal use, enhancing its preference for certain surgeries. As well, the

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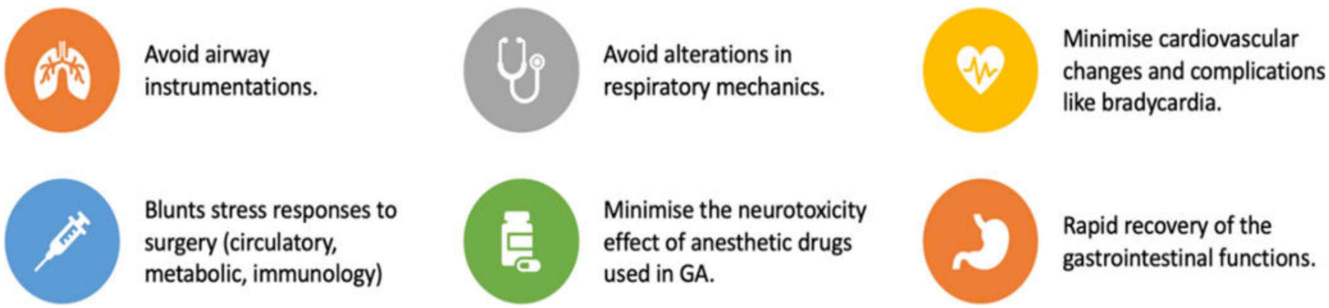

Figure 1. Illustrates the advantages of SA over GA.

haemodynamic response to SA is less pronounced in neonates and infants as the sympathetic system is underdeveloped and there is parasympathetic overdominance.[10]

SCOPE AND LIMITATIONS

SA can be safely used in children of all ages ranging from preterm neonates to adolescents and may be advantageous to GA when certain comorbidities are present (Table 1). It can be utilized in abdominal and lower limb surgeries, but there are potential contraindications to consider (Tables 2 and 3).

AWAKE OR SEDATED?

SA is seldom performed in awake children. However, in preterm infants, term neonates, and infants up to 6 months of age, awake blocks help preserve respiratory function and avoid airway instrumentation. Despite this, awake procedures can be challenging as movement may result in multiple attempts, trauma, failed blocks, and potential cerebrospinal fluid (CSF) leakage. When performing SA on awake patients (Table 4), using age-appropriate distraction techniques such as sucrose pacifiers, swaddling, virtual reality devices, tablets, toys, and reassurance by a friendly operating room team member can soothe the patient. Fortunately, SA naturally sedates children by reducing afferent signalling to brain pathways. Therefore, if the SA is performed with the child awake, they will becomev sedated shortly after administration of the SA.

COMPARING ADULT AND PAEDIATRIC SPINES

The paediatric spine differs anatomically from the adult spine due to ongoing skeletal and neuronal development. The paediatric spine matures to attain an adult configuration by 8 years of age. In neonates, the spinal cord extends to the level of L3, compared to L1 in adults. The dural sac, which encloses the subarachnoid space, extends to S3 in infants and S1 in adults (Figure 2). Hence, the spinal needle should be inserted at L4-L5 in neonates, rather than L3-L4 level typically used in adults, to avoid damaging the spinal cord and breaching dura mater.

NEEDLE DESIGN

When performing SA in children, it is important to select the appropriate needle for the procedure (Figure 3):

Clinical Comorbidities
Risk of apnoea of prematurity
Bronchopulmonary dysplasia
Hyaline membrane disease
Anticipated difficult airway
Risk for malignant hyperthermia
Congenital heart disease posted for non-cardiac surgery
Obstructive sleep apnoea
Day care surgeries where rapid recovery is desired
History of postoperative nausea and/or vomiting

Table 1. Comorbidities or Characteristics Where, When Present, SA Could Be Advantageous to GA

Types of Surgery	Specific Procedures
General surgical procedures	**Supraumbilical:** Umbilical hernia, gastrostomy, closure of gastroschisis, and omphalocele **Infraumbilical:** Inguinal herniotomy, exploratory laparotomy, colostomy, ileostomy, appendicectomy, rectal biopsy, perineoplasty
Urological procedures	Urethroplasties, circumcision, cystoscopy, orchidopexy, fulguration of posterior urethral valve, vesicostomy, pyeloplasty, ureteric reimplantation
Orthopaedics and lower limb surgery	Closed hip reduction, open reduction and internal fixation of hip, excision of tumours, club foot repair, muscle biopsy

Table 2. Surgical Procedures That Can Be Performed Under SA in Paediatric Patients

Absolute	Relative
• Parent refusal • Infection at puncture site • LA allergy • Severely raised Intracranial pressure • Major deformity of the spinal column (ex - uncorrected spina bifida) • Ongoing degenerative axonal disease • Coagulopathies	• Procedure lasting for >90 mins • Severe hypovolemia

Table 3. Contraindications to SA in Paediatric Patients

- **Size of the needle:** A 25-27 G needle is recommended. Smaller diameter needles used in infants makes the recognition of intravascular and subarachnoid placement difficult.
- **Design of the needle tip:** Both dura cutting and dura splitting needles can be used safely in infants and neonates, with no significant difference in the rates of transient neurological symptoms or post-dural puncture headaches (PDPH) between the two types.[11] Although PDPH is less of a concern in this age group compared to adults, transient neurological symptoms remain a potential issue. In children, identifying the subarachnoid space can be more challenging with a dura splitting needle than with a dura cutting needle. To reduce trauma, a dura cutting needle should be inserted parallel to the ligaments and fibres.
- **Bevel characteristics:** A short-bevelled needle is preferred because it offers better tactile feedback for tissue resistance and allows for more precise drug placement into the intrathecal space.
- **Length of the needle:** In infants and children, a shorter needle is advantageous as it allows more precise movement, better stability while injecting drugs, and minimal dead space. A longer length needle will increase technical difficulty, especially in maintaining needle stability and may result in needle displacement while administering the drug. Also, the dead space will increase, resulting in wastage of drug and lower dosing. In older children (>8 years old), a standard adult size needle can be used with the same success rate.
- **Stylet:** A spinal needle should have a stylet as well as transparent plastic hub. The stylet ensures patency of the needle. It avoids introduction of skin/interspinous ligament into the intrathecal space which may result in development of epidermoid tumour.

LOCAL ANAESTHETICS AND ADJUVANTS

Selection of the appropriate local anaesthetic (LA) and dose for SA is essential. Table 5 tabulates the most common LA used in SA. It is notable that the dead space of the spinal needle is around 0.02-0.04 mL and results in a reduced delivered volume of drug if not taken into consideration.

Using LA with different baricities can affect the distribution of the block. Isobaric solutions match the specific gravity of CSF and allow for a predictable spread influenced mainly by patient position. Conversely, hyperbaric solution's spread is influenced

Former preterm infants with limited respiratory reserve, bronchopulmonary dysplasia, apnea of prematurity.
At risk for malignant hyperthermia where inhaled anaesthetics should be avoided.
Cooperative children who wish to be awake.
In children with sleep disorders like obstructive sleep apnoea where avoiding GA might be beneficial.

Table 4. Indications Where Awake SA May Be Preferred

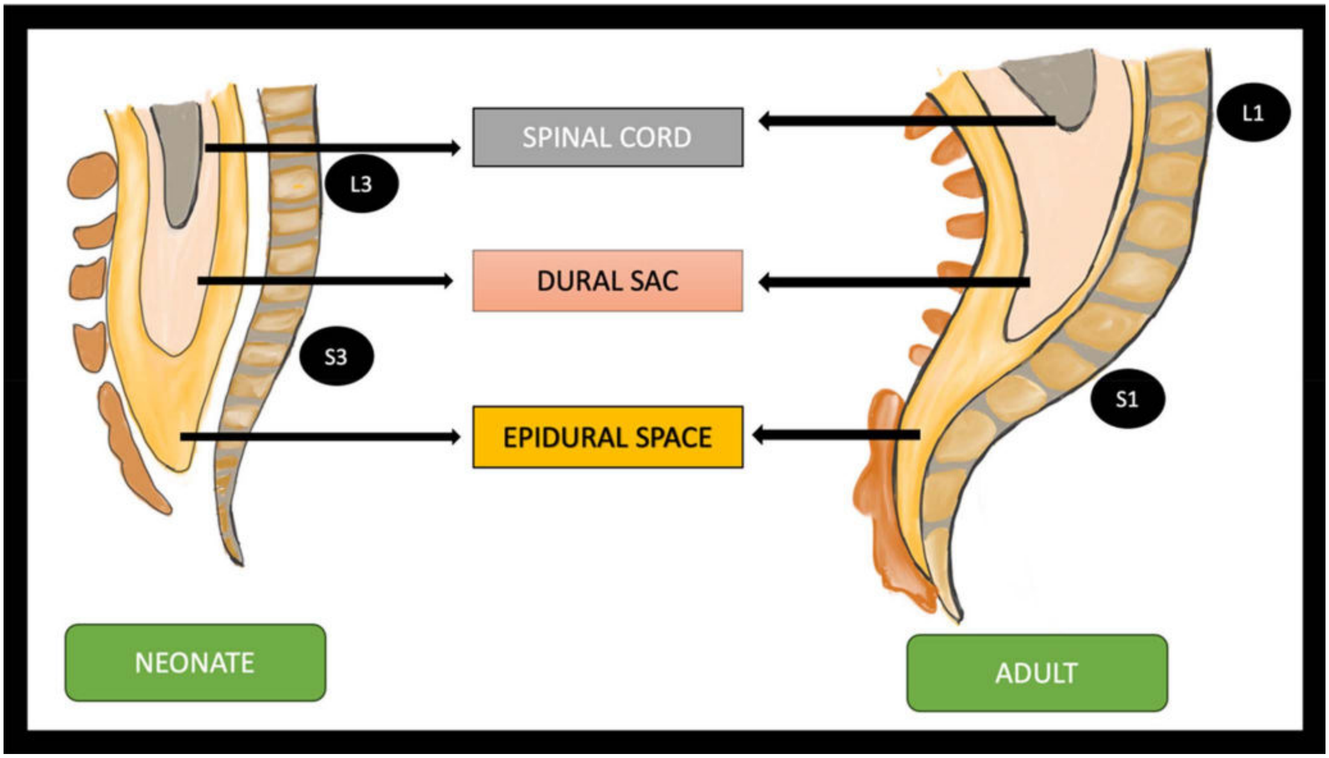

Figure 2. Paediatric neuraxial anatomy compared to the adult. In small children, the termination of the spinal cord and dural sac are at a lower level compared to adults.

by both gravity and patient positioning. Furthermore, hyperbaric solutions allow for a rapid, denser motor block onset with shorter duration of action.

Adjuvants can be used in for SA in paediatric patients, however one should be cautious in neonates and infants due to the risk of potential side effects like hypotension and bradycardia. The adjuvant of choice is clonidine at 1mcg/kg; higher doses may be associated with hypotension and sedation.[12,13] Morphine can be given at a dose of 10-30 mcg/kg, whereas fentanyl is given at a dose of 1 mcg/kg for lower abdominal surgery and 0.2 mcg/kg for hernia repair. When opiate adjuvants are administered, there is a potential for delayed respiratory depression, especially in neonates, so patients must be monitored post-operatively high dependency unit. Ketamine is directly neurotoxic to the developing spinal cord and contraindicated as an adjuvant. It should be noted that SA provides very short duration postoperative analgesia, so this should be considered during post-operative care.

LANDMARK BASED APPROACH TO PAEDIATRIC SA

SA can be performed with a landmark-based technique in the operating theatre. Prior to beginning, the surgical plan and anticipated duration of the surgery should be discussed with the surgical team. Consent for SA should be obtained from the parent after explaining the risks and the benefits. An experienced paediatric anaesthesiologist should be available to preform or supervise the procedure.

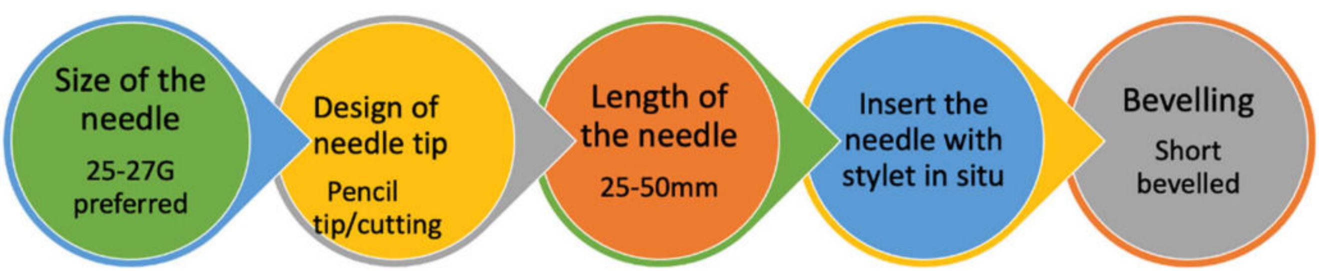

Figure 3. Preferred characteristics of the needled used for SA in children.

Drugs	Body Weight (kg)	Dose (mg/kg)	Anticipated Duration of Action (mins)
Esters			
Tetracaine 0.5% (hyperbaric)	<5	0.2-0.6	85-105
	6-10	0.4-0.5	75
	11-20	0.3-0.4	80
	>20	0.2-0.3	85-90
Amides			
Levobupivacaine or bupivacaine 0.5% (hyperbaric)	<5	0.3-1	65-90
	6-10	0.4-0.5	75
	11-20	0.3-0.4	80
	>20	0.2-0.3	85-90
Ropivacaine 0.5% (isobaric)	<5	0.5-1	45-80
	6-10	0.5	90
	11-20	0.5	90
	>20	0.5	105

Table 5. Dosage of Commonly Used LA in Paediatric SA

Temperature management is paramount, especially in small children. Ensure the operating theatre is warm before entering, and the patient should be covered with warm blankets, or forced air or radiant warmers can be employed. Standard American Society of Anesthesiology (ASA) monitors should be applied and an intravenous (IV) cannula secured. If this child will be sedated prior to SA, positioning can be accomplished afterwards, usually in the lateral position with knees and hips flexed (Figure 4). Further information on sedation in paediatric patients can be found in ATOTWs 105 and 293. If no sedation is used, the child is usually seated for the SA. Avoid over-flexion of the neck as this can result in airway obstruction.

When performing the SA, aseptic technique must always be observed with proper hand hygiene and gloves. The area should be cleaned with antiseptic solution, chlorhexidine or 5% betadine, starting in a circular manner from centre to periphery. Prior to inserting the spinal needle, the dose of the LA should be calculated and placed in an insulin/tuberculin syringe using sterile precautions (Figure 5a and 5b).

To identify the appropriate space to insert the spinal needle, find the line connecting the two anterior superior iliac spines, also known as the inter-cristal line. This line intersects the spinal column at different levels depending on the age of the patient. It crosses at the L5-S1, L4-L5, and L3-L4 interspace in neonates, infants, and older children, respectively.

Once the appropriate space has been identified, a 25-27 G stylleted spinal needle should be introduced in the midline and gradually advanced until a loss of resistance (LOR) is felt (Figure 6). The LOR is felt as the needle traverses the ligamentum flavum. This sensation can be subtle in younger children when compared to adults and older children. After ensuring a free flow of CSF and negative aspiration for blood, the desired drug is injected slowly over 20 seconds. Barbotage should be avoided.[14] Gently withdraw the spinal needle, applying pressure at the puncture site with a sterile gauze pad.

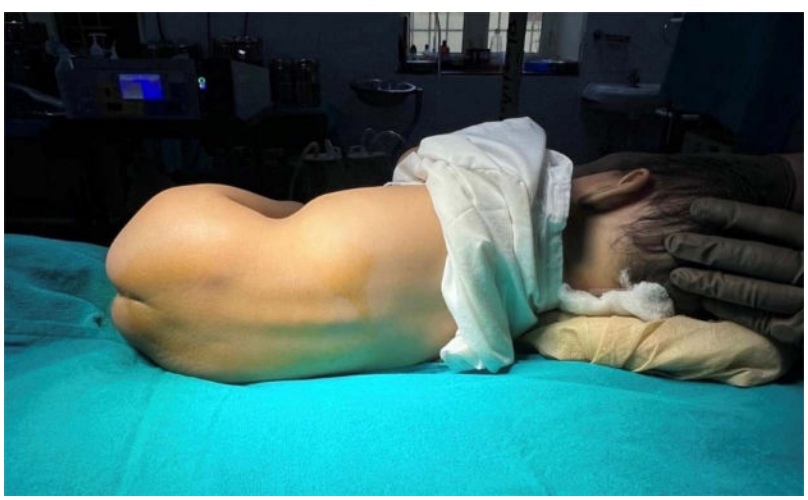

Figure 4. The patient position for SA if the patient is sedated for the procedure.

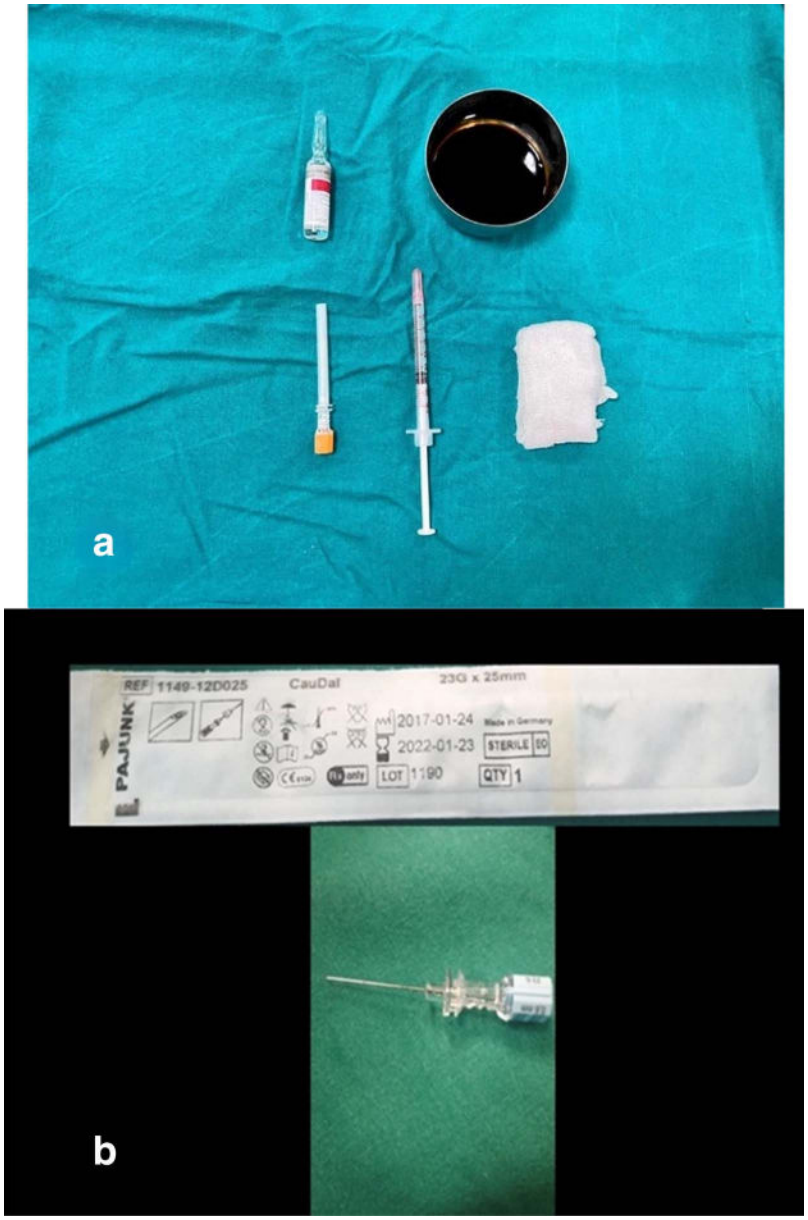

Figure 5. Equipment needed to perform SA; (a) Aseptic tray with cleaning solution and gauze for application, local anaesthetic vial and appropriate does drawn up in a tuberculin syringe, and protected spinal needle; (b) The bevelled spinal needle, unprotected, and packaging for reference.

After administrating the drug, avoid elevating the legs (e.g., placing a cautery pad on the back) to prevent excessive cephalad spread of the drug and a resultant high spinal block. The modified Bromage scale can be used for motor blockade assessment in children older than 2 years (Table 6).[15] Complete inability to raise leg, flex knee, and move feet or toes (Bromage grade 3) implies the spinal anaesthetic block has reached the high lumbar segments and any surgery on the leg below the groin should be able to proceed. Pinpricks should be avoided for sensory assessment of block adequacy as it can cause pain and discomfort, which can be distressing for children. This can lead to anxiety and fear, making the procedure more traumatic for the young patient. An alcohol swab or ice can be used to assess for the adequacy of sensory blockade. A reduction in temperature sensation is often the initial clinical sign of a spinal block preceding the onset of sensory blockade.

APPLICATION OF ULTRASOUND IN PAEDIATRIC SA

The nonossification of the infant bones allows better ultrasound (US) imaging for the purposes of SA. US guidance can be used to determine the skin to dura distance, to identify the best interspinous space, angle of needle insertion and to

Figure 6. Landmark-guided needle placement.

prevent damage to adjacent neural tissue and vertebral bodies. It also helps in identifying anatomical anomalies like a low lying cord, tethered cord, or lipoma of the cord. US-guided techniques have been used successfully in children with obesity, scoliotic spines, and a history of difficult neuraxial blocks. However, fluoroscopy guidance can be used as an adjunct.

ULTRASOUND-AIDED SA

To perform an US-guided SA, the US machine is usually positioned across from the operator for optimal ergonomics. In small children and infants, a high frequency (7-13 MHz) small footprint linear probe is used. For older children, a curvilinear probe is used. Sterile technique is strictly adhered to including use of sterile probe covers and saline/sterile gel. The transverse view is preferred for identifying the interspinous space and performing measurements, serving as an essential preparatory step. However, for real-time needle insertion under ultrasound guidance, the parasagittal oblique view is generally favoured.

Transverse view: The US probe is kept transversely over the lumbar spine at L3-L4/L4-L5 level to identify the spinous processes and interspinous spaces (Figure 7). The image is optimised by cephalo-caudal angulation of the probe to visualise the anterior and posterior dural complex (comprising of the ligamentum flavum and posterior dura). Probe angulation is done to ensure the symmetry of transverse processes on both sides (Figure 8). Once this image is optimised, the depth of the posterior dural complex from the skin is measured and the angulation of the probe is noted. This aids in determining the needle insertion point and trajectory. Furthermore, the needle insertion point can be demarcated. The midpoint of the probe on the lateral side and in the cephalocaudal axis are marked. The corresponding points are joined

Score	Intensity of Motor Block
0	Full motor function: can flex hip, knee, and ankle
1	Can't flex hip (unable to perform straight-leg lift)
2	Can't flex hip or knee
3	Can't flex hip, knee, or ankle

Table 6. Modified Bromage Score to Assess for Motor Blockade in Children Age 2 and Older

Figure 7. Probe position in transverse orientation.

to form 2 lines. The point of transection of the lines is the needle entry point during the US assisted SA technique (Figure 9).

Parasagittal oblique view: The probe is placed in a parasagittal orientation over the sacrum (Figure 10). With this probe orientation, the sacrum is identified by a longitudinal hyperechoic continuous line without any interspaces. Moving the probe cranially, the first interspace indicates the S1 and L5 interspace. The probe is tilted inwards to identify anterior and posterior hyperechoic dura through the interlaminar window. Scanning further cranially will bring in the conus medullaris into view (Figure 11). Once the view is optimised, the depth of the posterior dural complex from the skin is measured and the optimal interlaminar space is identified. A real-time needle insertion is also possible.

REAL-TIME US-GUIDED SA

With real-time guidance, the needle puncture is done while obtaining the above views. The needle can be approached in plane as well as out of plane depending on the operator preference. The injection of the drug into the intrathecal space can be visualized by the expansion of the intrathecal space in real time.

Saline or gel can be used as the conducting medium for the transducer. Saline has theoretical advantages, though. It is sterile and easily available, while ultrasound gel can introduce pathogens and increase the risk of infection if inadvertently introduced into the needle insertion site. Sterile saline potentially minimizes this risk.

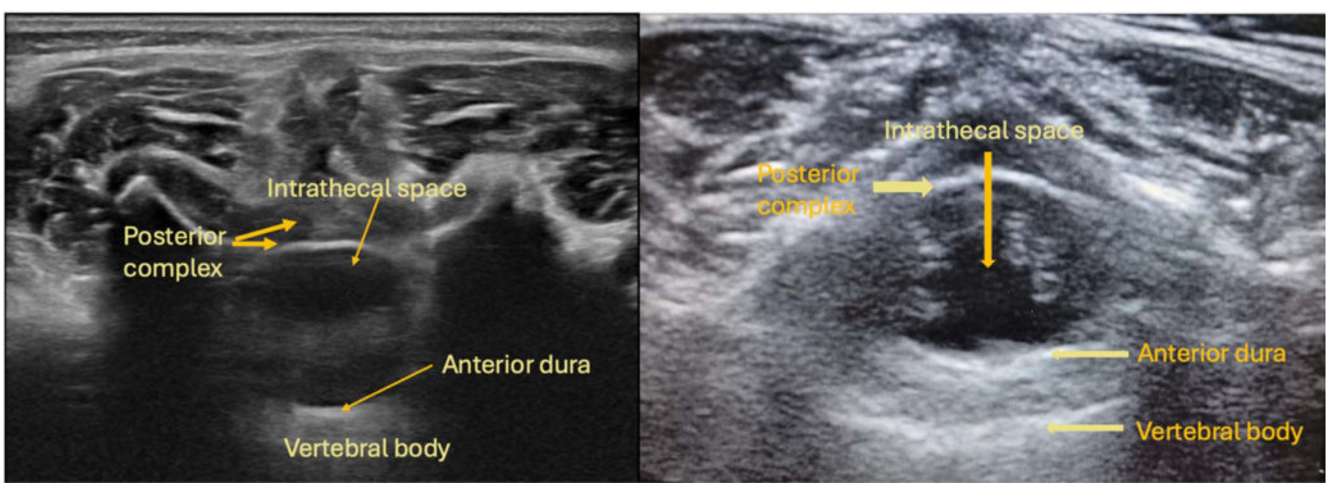

Figure 8. Sonographic image in transverse orientation. Left side image is taken in a 6-year-old child at the level of L2-L3 level. Right side image is taken in a 2-month-old child at the level of L4-L5.

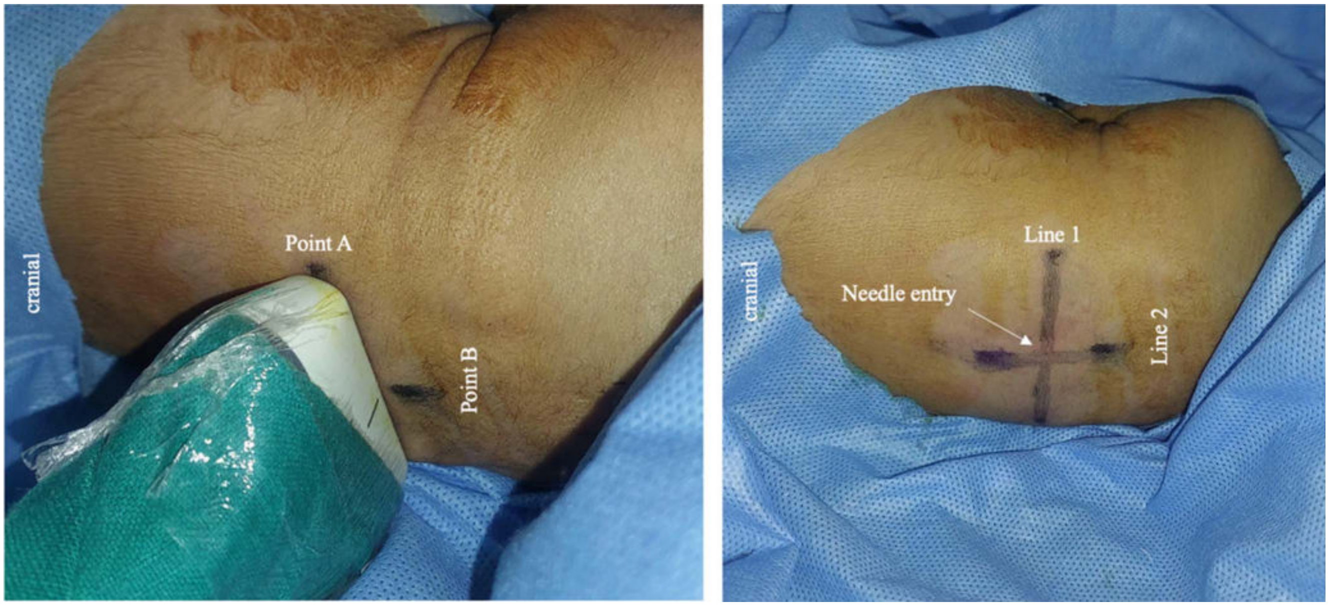

Figure 9. The left image shows a linear ultrasound probe placed transversely at the L3-L4 interspace in an 8-month-old child, with markings indicating Points A and B. The right image illustrates the intersection of Line 1 and Line 2, formed by connecting Points A and B to their respective corresponding points on the same plane, denoting the needle entry site.

LIMITATIONS OF SA

The major limitation of SA is the short duration of actions (< 80-90 mins) due to the high volume of CSF (4 ml/kg in small children versus 2 mL/kg in adults) and its faster turnover compared to adults. The addition of adjuvants as mentioned above can prolonged the duration by 30% (∼110 mins). SA provides very short duration postoperative analgesia as well.

SPINAL AND CAUDAL COMBINED TECHNIQUES: CONCEPT AND RATIONALE

The main limitation of SA in paediatric patients is its short duration. Combining spinal with caudal anaesthesia can effectively render quick operable conditions and prolonged anaesthesia and analgesia duration, which is particularly beneficial for surgeries like bilateral hernia in preterm infants.[16-18] This approach reduces the need for opioids and inhalational anaesthetics. After SA, 1 mL/kg of 0.1% plain ropivacaine is typically injected into the caudal space after ensuring no blood or CSF aspiration. It's essential to accurately calculate the total LA dose to avoid systemic toxicity. More information about performing caudal anaesthesia can be found in ATOTOW 439.

Figure 10. Probe position in parasagittal orientation.

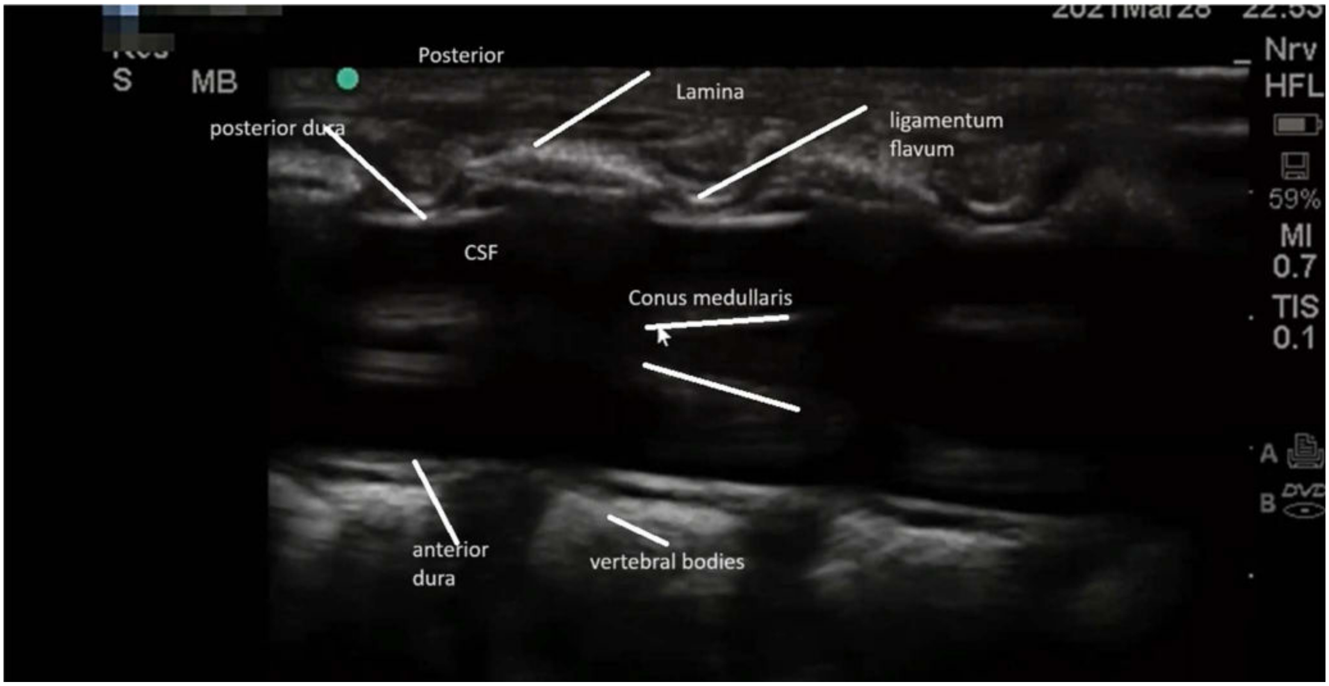

Figure 11. Sonographic image in parasagittal oblique orientation showing the conus medurallis.

SUMMARY

Performing SA in paediatric patients demands careful attention due to their unique anatomy and physiology. Prioritizing the child's comfort, safety, and emotional well-being is essential. Effective communication with the child and their guardian, supported by a skilled and attentive team, is critical. Approaches must be pragmatic and tailored, as no single method suits all situations. Flexibility to adapt to each patient's needs and staying informed about the latest paediatric spinal procedure guidelines are key to maintaining high standards of care.

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