Ultrasound-guided central neuraxial blocks and peripheral nerve blocks in children

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Key points
- Use of ultrasound in paediatric regional anaesthesia may have specific advantages.
- Aspects relating to ergonomics, sterility, and probe choice should be given due consideration, as in the adult population.
- Direct visualization of a test bolus of saline ('visual swoosh test') in the caudal space before injection of local anaesthetic provides an additional safety feature.
- Visualization of the entire needle length is essential when performing truncal blocks in children, as the peritoneal cavity is easily entered if the needle is advanced without due care.
- Ilioinguinal and iliohypogastric nerve blocks may fail because of anatomical variation and difficulty in identifying the correct plane for injection; probability of a successful block is greatly enhanced by using ultrasound guidance.

The safe performance of central neuraxial and peripheral nerve blocks are essential skills for the paediatric anaesthetist. The use of ultrasound to assist in these blocks in this population subset may have specific advantages. A correctly deposited volume of local anaesthetic (LA) may allow a relatively opioid free general anaesthetic, with added advantages of reducing postoperative nausea and vomiting, preventing respiratory depression, enabling earlier mobilization, and discharge home. Secondly, in children the anatomical structures of interest (i.e. nerves and vessels) are more closely related, with lesser margins of error using a landmark technique compared with adults. Ultrasound can also help to improve the precision of the block, as the volumes that can be safely used are more tightly weight restricted in children, and the safe practice of dissecting the tissue planes with saline ('hydro dissection') before injecting the LA may be limited in its scope for fear of dilution of the LA.

This review will consider the most commonly performed regional anaesthetic techniques in the paediatric population: caudal epidural, transversus abdominis plane (TAP) block, rectus sheath block, ilioinguinal iliohypogastric nerve block, and block of the dorsal nerve of the penis.

General considerations
Regional blocks in children are usually performed after general anaesthesia has been administered. The choice of probe will depend on the size of the area to be scanned, and operator familiarity. The detailed physics of ultrasound¹ are beyond the scope of this article: briefly, ultrasound comprises high energy waves travelling in a longitudinal direction; their frequency range far exceeds the audible range of human hearing (20–20 000 Hz). Medical ultrasound commonly uses frequencies ranging from 2 to 15 MHz and may even be as high as 50 MHz.

Some points to be considered in obtaining the best scan image in the paediatric population are:

(i) The higher the frequency, the better the resolution of detail in the scan, but at the expense of tissue penetration. As the structures of interest in the paediatric patient are relatively...
superficial, a higher frequency probe will be more suitable, as the better resolution provided by such a probe (at the cost of poorer penetration) will be desirable in this population. Typically, a 10 MHz high-frequency probe will give good resolution up to a depth of 2–3 cm, which will be sufficient in the paediatric patient.

(ii) The choice of probe will usually be between a linear (frequency range 5–18 MHz) and a hockey stick probe (Fig. 1). Both operate at higher frequencies; the hockey stick probe has a smaller ‘footprint’ (width) of 25 mm and a frequency range of 5–10 MHz, and may be suitable for the ‘small’ paediatric patient. The linear probes are available in different widths, ranging from 20 to 40 mm, with corresponding variation in ‘footprint’ size. These are the most widely available probes.

Choice of the needle type depends on operator preference and local availability. We use a 22G wingless cannula for caudal blocks and a 50 or 100 mm insulated needle for peripheral blocks. Other options for peripheral blocks may include cannulae, spinal needles, or echogenic block needles. The entire needle needs to be visualized at all times, and LA spread observed in the correct planes.

Our preferred LA is levobupivacaine, the pure S(−) enantiomer of bupivacaine, in view of its superior safety profile. Sug- gested doses for caudal epidural and truncal blocks are summarized in Tables 1 and 2, respectively.2 3

For truncal blocks, the calculated volume is split equally between both sides, if bilateral injections are planned. For the TAP blocks and rectus sheath blocks, a larger volume of more dilute LA would be acceptable, provided the mass of LA administered is less than the calculated maximum allowable dose based on the patient’s ideal body weight (IBW). Estimating the IBW has particular relevance to the obese child, and may be estimated from the following formula relating IBW to body mass index (BMI):

\[
IBW = \left(8\text{MI at the 50th percentile for the child’s age}\right) \times \text{(height (m))}^2.
\]

In children, median BMI varies with the child’s age and sex, and values may be obtained from gender-specific curves of reference according to age.4

Appropriate aseptic precautions should be taken: a suitable sterile cover, well coupled with sterile gel, should cover the probe head. Ergonomics of ultrasound machine placement with respect to operator and patient position should be optimized to obtain the best view of the screen. At the same time, the anaesthetist should ensure that he or she is able to appropriately monitor the anaesthetized patient by ensuring an uninterrupted view of the monitor screen. Suitable skin disinfectant solution should be used. Our practice is to use 0.5% chlorhexidine for central neuraxial blocks and 2% chlorhexidine for truncal blocks.

**Caudal**

Lack of ossification of the sacral structures renders the paediatric sacrum suitable for ultrasound visualization. In neonates and infants, the sacrum comprises mainly soft bone tissue and cartilage. In infants, the dura ends at the level of S3–4, and reaches adult level by the ages of 8–9 yr. The distance between the sacral hiatus and the dural sac may be <1 cm in neonates; hence, there is a significant risk of dural puncture. Pre-scanning with ultrasound can delineate the sacral structures and also provide information about anatomical abnormalities such as sacral agenesis or dysgenesis. This has been shown to be useful where a sacral dimple or pit is present.

The scanning can be performed in both the transverse axial and longitudinal paramedian or midline positions (Fig. 2). A linear probe may be positioned over the median sacral crest longitudinally. As the probe is moved caudally over the sacral crest up to the most caudal spine, the bony profile of the sacral cornua should become visible. The space between the cornua is the

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**Table 1** Suggested doses for caudal epidural block using levobupivacaine. *Use IBW in obese children

<table>
<thead>
<tr>
<th>Age</th>
<th>Dermatomal spread</th>
<th>LA agent</th>
<th>Concentration (mg ml⁻¹)</th>
<th>Volume (ml kg⁻¹)</th>
<th>Dose (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–3 months</td>
<td>Sacral</td>
<td>Levobupivacaine</td>
<td>2.5</td>
<td>0.4</td>
<td>1</td>
</tr>
<tr>
<td>3 months+</td>
<td>Sacral</td>
<td>Levobupivacaine</td>
<td>2.5</td>
<td>0.5</td>
<td>1.25</td>
</tr>
<tr>
<td>0–3 months</td>
<td>Lumbosacral</td>
<td>Levobupivacaine</td>
<td>1.25</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td>3 months+</td>
<td>Lumbosacral</td>
<td>Levobupivacaine</td>
<td>2.5</td>
<td>1</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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**Table 2** Suggested doses for truncal and peripheral blocks in infants aged 3 months+ and children. *Use half the concentration but the same volume in neonates and infants aged 0–3 months; †use IBW in obese children

<table>
<thead>
<tr>
<th>Block</th>
<th>LA agent</th>
<th>Concentration* (mg ml⁻¹)</th>
<th>Volume† (ml kg⁻¹)</th>
<th>Dose‡ (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAP</td>
<td>Levobupivacaine</td>
<td>2.5</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Rectus sheath</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ilioinguinal–iliohypogastric</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penile</td>
<td>Levobupivacaine</td>
<td>5</td>
<td>0.2 (0.1 per side)</td>
<td>1</td>
</tr>
</tbody>
</table>
sacral hiatus. At this stage, rotate the probe through 90° to obtain the transverse view of the sacral cornua. A ‘saw tooth’ appearance can be seen representing the spinous processes. The dura mater will be visible as hyperechogenic shadows between the spinous processes.

We use a 22G wingless cannula inserted by palpating anatomical landmarks to inject a test bolus of saline before injecting LA. Direct visualization of a test bolus of 1–2 ml saline in the caudal space using the ultrasound probe positioned approximately one patient hands-width cephalad to the injection site longitudinally enables one to observe distension of the epidural space because of anterior movement of the posterior aspect of the dura. This ‘visual swoosh’ test during the scanning helps to avoid intravascular injection and provides an additional safety check, before injection of the LA. In the authors’ experience, we do not feel that the dilution of the LA resulting from the test saline injection is significant to produce a lessening of the desired analgesic effect clinically; at the same time, the additional safety benefit provided is considerable. Ultrasound confirmation of the test bolus of saline, in the caudal space, also helps to ensure that the injection has not been made into the subcutaneous space. The upper limit of the spread of the LA can also be observed by ultrasound scanning (Fig. 2).

**Sheath block**

This block provides good-quality analgesia for many operations that require a midline incision, including midline hernias, laparoscopic procedures, and laparotomies.

After coursing within the ‘transversus abdominis’ plane (lying between the internal oblique and transversus abdominis muscles), the six lower thoracic and upper two lumbar nerves give a lateral cutaneous branch, and continue to reach the rectus abdominis muscle, which is then perforated by the anterior cutaneous branches which innervate the skin overlying the linea alba. The rectus muscle has three tendinous insertions, continuous anteriorly with the anterior rectus sheath but discontinuous posteriorly. This anatomical feature is the basis for the rectus sheath block.

The linea alba can be seen in the midline. On moving the probe laterally, the main body of the rectus muscle can be clearly seen. Just behind the rectus muscle, the closely adherent posterior rectus sheath and the transversalis fascia can be seen as a pair of bright hyper echoic parallel lines. The aim is to deposit the LA between the muscle belly and the posterior sheath using an in plane approach. The LA should be seen to separate the muscle from its sheath. Visualization of the needle tip at all times is critical, as the distance from the posterior sheath to the peritoneal cavity is very small, and the peritoneal cavity is easily entered if the needle is advanced too far (Fig. 3).

**TAP block**

The TAP block or more accurately the posterior TAP block is useful for postoperative analgesia after lower abdominal incisions for laparotomies, appendicectomy, pyloromyotomy, and stoma formation and reversals.

The lower six thoracic nerves and the upper two lumbar nerves innervate the anterior abdominal wall. These fan out on the anterior abdominal wall as the anterior branches of the intercostal nerves. These nerves run in a neurovascular plane known as the TAP located between the internal oblique and transversus abdominis muscles.
abdominis muscles; there is extensive branching and communication between the nerves in this plane.

There is continued debate about the fate of the LA once injected in this plane, with contrasting results from cadaver studies about the degree of spread. Magnetic resonance imaging and computed tomography imaging has shown the spread to be as far posterior as the quadratus lumborum muscles and up to the paravertebral regions.6

A ‘hockey stick’ probe or a linear probe (Fig. 1) is placed in a transverse plane between the lower costal margin and the iliac crest on the lateral abdominal wall in the midaxillary line, as far lateral as possible (Fig. 4). Alternatively, the probe may be

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**Fig 3** (1) Rectus sheath block with probe at the level of the umbilicus and needle entry position depicted; (2) posterior rectus sheath (marked by arrows); (3) needle seen approaching posterior rectus sheath; (4) needle seen just above posterior rectus sheath; (5) needle piercing the sheath, small volume of LA splitting the sheath; (6) continued injection of LA; (7) entire volume of LA within sheath; (8) needle well seen (reverberations of needle also seen); and (9) LA seen in correct plane.

**Fig 4** (1) TAP block with position of the probe and needle entry point; (2) the external oblique (EOM), internal oblique muscle (IOM), and transversus abdominis muscle (TAM); (3) needle approaching TAP plane; (4) needle in TAP plane; (5) splitting of the fascia seen with LA spread; and (6) and (7) LA spread seen.
placed just lateral to the umbilicus, and the image will show the rectus abdominis muscle and the posterior rectus sheath. On moving the probe laterally and on reaching the nipple line, the three distinct layers of the abdominal wall, the external oblique, the internal oblique, and the transversus abdominis muscle layers may be clearly seen. The probe may be moved further lateral, and using an in plane approach, the needle tip should be placed between the internal oblique and the transversus abdominis muscle. Correct placement is indicated by the injectate producing an oval hypoechoic image as the layers are dissected. Where there are critical limits on LA volumes (e.g. neonates) then saline can be used in the first instance to confirm correct placement (Fig. 4).

**Ilioinguinal iliohypogastric block**

This block has been traditionally performed using a variety of landmark techniques, with variable rates of failure because of the injectate reaching the muscle belly, subcutaneous planes, and even into the peritoneum.\(^7\) Inadvertent femoral nerve block may cause delayed discharge home.

Both these nerves are derived from anterior primary ramus of L1, and supply the internal oblique and transversus abdominis muscles and also the skin overlying the inguinal and hypogastric areas, while running in a plane between the internal oblique and transversus abdominis muscles. The probe is placed with one end close to the anterior superior iliac spine and the other end pointing towards the umbilicus. The nerves will be visible as oval, hyperechoic structures between the internal oblique and transversus abdominis muscles (‘TAP plane’). An in-plane approach from medial to lateral with the needle directed towards the anterior superior iliac spine is used to deposit LA in this plane. Weintraud and colleagues\(^8\) have demonstrated that systemic absorption from this area after ultrasound-guided blocks is higher than after the landmark-guided approach, and careful attention needs to be paid to avoid LA toxicity (Fig. 5).

**Penile block**

Penile block performed using the landmark approach has reported failure rates of 4–8%. Ultrasound-guided penile block aims to deposit LA in the subpubic space, a triangular space bounded inferiorly by deep penile fascia (Buck’s fascia), superiorly by the pubic symphysis and anteriorly by the membranous layer of the superficial fascia (Scarpa’s fascia). The fundiform ligament, an extension of the linea alba, lies within this plane, as a fan-shaped structure, dividing the subpubic space into two compartments. Ultrasound allows real-time assessment to ensure bilateral spread of LA either side of the fundiform ligament. Ultrasound guidance provides additional safety to prevent

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**Images:**

1. Iliohypogastric and ilioinguinal nerve block with position of the probe and needle entry point.
2. The iliohypogastric and ilioinguinal nerves seen in between the internal oblique muscle and transversus abdominis muscle.
3. Needle pointing towards the nerves.
4. LA spread.

5. Iliohypogastric and ilioinguinal nerve block with position of the probe and needle entry point; (2) the iliohypogastric and ilioinguinal nerves seen in between the internal oblique muscle and transversus abdominis muscle; (3) needle pointing towards the nerves; and (4) LA spread.

6. Penile block with position of the probe and needle entry points.
7. Normal anatomy of penis with a pair of corpora cavernosum and corpus spongiosum.
8. Corpus longus view.
9. Corpus with LA in subpubic space.
10. Transverse view showing circumferential spread of LA.
accidental injury to corpora cavernosa, urethra, and intravascular injection.

The dorsal nerve of the penis is one of the terminal branches of the pudendal nerve. The terminal branches of the dorsal nerve run deep to the deep fascia of the penis (Buck’s fascia). The ilioinguinal and genitofemoral nerves may variably supply the base of the penis, so subcutaneous infiltration around the base of the penis may be required to complete the block for some procedures.

We use a technique first described by Sandeman and Dilley in 2007. The probe is placed vertically along the shaft of the penis in a sagittal plane. Scanning should reveal the subpubic space, deep to Scarpa’s fascia. The needle is advanced out of plane from either side of the probe into the subpubic space. The LA should be seen as a dark hypoechoic triangular shadow filling the subpubic space. Bilateral spread can be confirmed by rotating the probe through 90° at the injection site. If bilateral spread is ensured, the effect should be satisfactory even if the dorsal penile nerve is not seen (Fig. 6).

Conclusion
We have considered the application of ultrasound for the performance of common regional blocks in children.

Despite many potential advantages with regard to block characteristics, no large-scale prospective studies in this population have so far been published to demonstrate that ultrasound does reduce the incidence of complications after regional blocks. The Pediatric Regional Anesthesia Network database showed that regional anaesthesia in children has a very low rate of complications. This should reassure the paediatric anaesthetist who is competent and comfortable with the landmark technique, and we are not advocating a wholesale change of practice and adoption of what is still a relatively young technology. It is likely that a large-scale study will demonstrate added safety benefits of ultrasound guidance over traditional techniques.

Nevertheless, traditional methods of nerve localization using landmarks or nerve stimulation have varying degrees of success, depending on operator experience and patient body habitus. Block characteristics have been shown to be improved when ultrasound is used, resulting in lesser time to perform the block, higher success rates, shorter onset time, longer block duration, and reduction in volume of LA required, and hence, a reduction in risk of LA toxicity in a population subset wherein LA doses are tightly weight restricted. These points are undoubted advantages, and adopting ultrasound into our clinical practice will translate into benefits for patients.

Declaration of interest
None declared.

References