Review article

Ultrasonographic guidance in pediatric regional anesthesia. Part 2: techniques

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Summary
The benefits of regional anesthesia are well documented. The downsides of such techniques have been a significant failure rate and a potential for serious complications. Nearly, all regional blocks were first described as essentially 'blind' techniques. The development of high-resolution portable ultrasound (US) has made the use of US for regional anesthesia possible. Improved understanding of sonographic anatomy should lessen both the failure rate and the possibility of incurring serious complications. Natural caution has dictated that only a selection of blocks used in adults has been commonly used in pediatric practice, but with the aid of US, the repertoire of blocks for infants and children may be widened. The second part of this review will concentrate on the practice of both peripheral and central blocks.

Keywords: children: regional anesthesia; ultrasound

Introduction
The benefits of regional anesthesia are well documented and include: attenuation of the stress response, improved postoperative analgesia, avoidance of opioid side effects, and earlier extubation. Therefore, a local technique should be used for all operations unless contraindicated.

However, as all these blocks are performed using blind techniques there is a significant failure rate and serious complications are possible. Although all the blocks used in adult practice are possible in children many blocks are underused or avoided. This is largely from fear of complications and failure, and limited experience with complicated techniques. Thus only the safest of upper limb blocks – the axillary approach to the brachial plexus has been used with any frequency in children and the caudal block has held sway for lower limb surgery because it is seen as easy to learn, safe and reliable.

At present the methods of nerve localization have been blind, whether it be by landmark, and/or electrical stimulation. Imaging for regional anesthesia has principally been for research purposes; however, the development of high-resolution portable ultrasound (US) and the improved understanding of sonographic anatomy have made this imaging modality feasible for regional anesthesia.

This article will discuss US approaches to a variety of peripheral and central blocks; indications and contraindications of these techniques will not be discussed. It is assumed for all the blocks described that standard monitoring; intravenous access, and appropriate equipment are used. US machine settings should be optimized as discussed in part 1. When developing these skills, it is recommended
that after receiving basic training the simple blocks (Table 1) are initially performed and perfected in older patients. Thereafter, the complexity can be increased and eventually the age limit lowered. Until the US technique is mastered muscle relaxants should be avoided to allow the use of a peripheral nerve stimulator (PNS).

### The nonanesthetized child

In children, most regional techniques are performed under general anesthesia; however, in some circumstances light sedation or an awake patient may be preferred, e.g. full stomach, difficult airway, risk of postoperative apnea, malignant hyperthermia and patient preference.

This is an uncommon scenario and as such can create stress in anesthetist, surgeon, theater staff, patient and parents. It therefore has to be planned carefully (including plan B, should the block fail) and involve all the above parties. Failure to convince all parties will end in disaster.

Prior to theater, a sedative may be useful and local anesthetic (LA) gel can be applied to the proposed needle puncture site. In the induction room, the parent and play therapist can provide useful distraction. Entonox can also be helpful during block insertion. Older mature children may find the US images themselves interesting in their own right. A cross-sectional needle to probe orientation is recommended because of the shorter depth of needle insertion required.

Once the block is working and the patient is in theater there should be some means of continued distraction, e.g. play therapist, personal stereo.

### Peripheral techniques

#### Upper limb blocks

**Supraclavicular block**

This approach has a high risk of pneumothorax and should only be performed by experienced pediatric regional anesthetists. The plexus is superficial lying between the anterior and middle scalene muscles; it is at this level that the trunks turn into divisions. To aid probe and needle access, the patient’s head is turned slightly to the contralateral side and placed on a head ring, and a small roll is placed between the scapulae. For a right-sided block, a right-handed operator stands at the head of the patient with the US machine at the patient’s ipsilateral side, when performing a left-sided block the positions of operator and machine are reversed. A linear probe of 10 MHz plus is placed parallel and against the clavicle (coronal oblique plane), for most subjects the hockey stick probe is more suitable due to its smaller footprint. The initial mapping scan should identify the subclavian artery lying on the first rib; beneath the rib the cervical pleura and lung are imaged (1). The brachial plexus is found sandwiched between the anterior and middle scalene muscles, lateral and superficial to the artery (Figure 1). An in-line needle

![Figure 1](ultrasonographic_appearance_of_brachial_plexus_supraclavicular_region.png)

**Figure 1**

Ultrasonographic appearance of the brachial plexus in the supraclavicular region.
approach (lateral–medial direction) is preferred thus keeping the needle under complete control at all times. Whilst performing the block the pleura must be kept in view. An initial test injection should be made to ensure a good tip position before finally injecting $0.2–0.5\, \text{ml} \cdot \text{kg}^{-1}$ of LA.

**Infraclavicular block**

Infraclavicular approaches to the brachial plexus are unpopular due to the risk of pneumothorax; and even with the more lateral subcoracoid technique it remains a concern. Its main advantage is increased success blocking the axillary and musculocutaneous nerves.

The block is typically performed with the patient supine with the arms by the sides. As with the supraclavicular block the position of the patient is often optimized by the use of a head ring and a small roll between the scapulae. Interestingly, in adults it has been shown that $110^\circ$ abduction of the arm with external rotation of the shoulder brings the brachial plexus more superficial and thus distant from the pleura (2). When performing a left-sided block, a right-handed operator stands at the head of the patient with the US machine at the ipsilateral side of the patient, the position of operator and US machine are reversed for a right-sided block. A linear probe is held in a parasagittal plane just beneath the coracoid process and is then moved medial and lateral beneath the clavicle to form the initial mapping scan. The operator should first identify the pectoral muscles, and then locate the subclavian artery. The subclavian vein is compressible and positioned caudad to the artery. Finally, before locating the plexus the pleura must be identified and when performing the puncture it should be kept in view at all times. The plexus itself lies cephalad to the artery, as it travels laterally the cords take up their medial (between artery and vein), lateral (cephalad) and posterior positions (Figure 2). The probe should be moved along the clavicle until the best view of the cords, vessels and pleura is obtained. The needle is introduced from the medial aspect of the probe using a cross-sectional technique towards the lateral or medial cord. Extreme care is required with this approach as the needle tip is difficult to image and an infant’s plexus, vessels and pleura can be very close to one another; therefore, the operator should only insert the needle when they are confident of needle tip position. A test injection of saline (this is used in infants where the amount of LA available is limited) or LA is used to ensure the needle has passed through all the appropriate layers, if the injectate begins to encircle the artery the position is held and $0.5\, \text{ml} \cdot \text{kg}^{-1}$ of LA injected. A multiple injection technique targeting individual cords is not always possible or necessary, as it is not easy to image all three cords in the same plane and the LA usually spreads well.

When performed in the nonanesthetized child the US technique has the added advantage of being more comfortable as there are no painful muscle contractions (3).

**Axillary block**

This popular approach is limited by it high failure rate; this can be partly attributed to the exit of the musculocutaneous nerve from the sheath at the level of the coracoid process.

The arm is positioned $80–90^\circ$ abducted with the elbow flexed $90^\circ$. A linear probe is placed transverse across the upper arm in the axilla. The probe should have light contact with the skin, otherwise the veins will be compressed and the nerve structures may be displaced. The initial mapping scan should first identify the axillary artery and veins. The four major nerves (median, musculocutaneous, radial, and ulna) should be identified; at this level they are round or oval in shape. Correct identification of the nerves requires the operator to track the structures
distally. The median nerve is usually located close to the artery on the lateral aspect, the ulna nerve is generally more superficial and medial, and the radial nerve is usually located posterior to the artery. The musculocutaneous nerve may be found close to the median nerve before traveling between the biceps and coracobrachialis; as it travels distally its shape changes through oval to elliptical to triangular (4), and it increases in size distally (Figure 3). Depending on the size of patient and probe footprint, it may be necessary to slide the probe up over the biceps muscle to locate the musculocutaneous nerve. It is important to remember that there is some variability of nerve position (5). Both the in-line and cross-sectional approaches can be used, though the latter is preferred in nonanesthetized children. The radial nerve is blocked first, followed by the ulna, median and finally the musculocutaneous nerve. By working deep to superficial this order ensures that the injected LA does not distort the more superficial image. Multiple injections are usually required to block the median, ulna and radial nerves as LA spread within the sheath is prevented by septae. Axillary hair can trap air thus creating bubbles that interfere with US imaging; it may therefore be necessary to shave the axilla in pubescent patients.

**Forearm nerve blocks**
This area of the body is probably the easiest place to start learning basic scanning and needle/probe techniques. The three major nerves are easily identified and as experience is gained it is possible to track the nerves from the wrist into the axilla. It is possible to block each nerve at any point of its route with as little as 1–2 ml of LA. Although it is possible to block the nerves at the wrist, the nerves are very superficial (requiring the highest frequency probes), there is little space for injection, and it can be hard to differentiate nerve from tendon at this site. It is therefore easiest to block these nerves within the proximal third of the forearm.

The median nerve is located in the antecubital fossa medial to the brachial artery (Figure 4). The nerve travels distally sandwiched between the flexor digitorum superficialis (FDS) and the flexor digitorum profundus muscles. Before passing under the flexor retinaculum, the nerve passes laterally around the edge of FDS to lie between it and flexor carpi radialis. If present the palmaris longus tendon may partially overlie the nerve. The nerve is differentiated from the tendons by its route; the tendons have a fibrillar pattern, are more hyperechoic, and are continuous with their appropriate muscles (6). The probe is placed in the axial plane of the forearm and the nerve is blocked using a cross-sectional technique.

The radial nerve travels from behind the humerus and enters the lateral aspect of the antecubital fossa. It lies between the biceps tendon and the brachioradialis muscle. The nerve usually divides at this point into superficial and deep branches. Above the elbow and before division the nerve is round, at

![Figure 3](http://example.com/figure3.png)

**Figure 3**
Ultrasonographic appearance of the brachial plexus in the axilla.

![Figure 4](http://example.com/figure4.png)

**Figure 4**
Ultrasonographic appearance of the median nerve at the level of the antecubital fossa.
its point of division it is becomes flattened with two hypoechoic ‘bubbles’ (Figure 5). The probe is initially positioned in the axial plane using the standard landmark position. A cross-sectional needling technique is appropriate.

The ulna nerve passes from the arm via its sulcus into the forearm, it is deep to flexor carpi ulnaris (this muscle has a distinctive linear fascial plane within) in the proximal third of the forearm (Figure 6). As the nerve progresses distally the ulna artery joins. The nerve is difficult to image within the sulcus; however, distally it has a round shape. Injection is advised at a level removed from the artery. The probe is held in the axial plane over the medial aspect of the forearm and a cross-sectional technique is employed.

**Lower limb blocks**

Lower limb surgery commonly requires the use of multiple nerve blocks. Thus, a central block is often chosen as each peripheral block has a potential for failure and the LA dose available is limited. The use of US in our experience allows the volume of LA per block to be decreased by 30–50%, making it is easy to remain within maximum doses when performing multiple blocks whilst still achieving success.

**Sciatic block**

In adults, this is one of the hardest nerves to image because of its marked anisotropy, the lack of simple sonographic landmarks, the fascial planes may reflect the US and the muscle attenuates the higher frequencies. In children, the nerve is more superficial consequently the higher frequency probes can be used to provide better images. The block can be performed at any point from the gluteus to the popliteal fossa; however, the nerve is blocked where it is imaged best. Only the infragluteal block will be discussed here.

The patient is positioned lateral with the non-operative leg lowermost and flexed and the operative leg uppermost and extended. This makes it easier to scan the length of the posterior thigh, this is necessary as it is difficult to image the nerve well throughout its course, the operator can pick up the nerve at the easiest point and then scan proximally/distally. Moreover, if a catheter technique is employed it is easier to tunnel the catheter. The operator stands at the patient’s back with the US machine on the opposite side. A linear high frequency probe is positioned in the axial plane just inferior to the buttock crease. For gluteal approaches in older or obese patients a curvilinear probe with tissue harmonics may provide better imaging (7). The mapping scan is more difficult as the operator needs to identify the relevant muscles. Superficially is the gluteus maximus beneath which is located the quadratus femoris, the nerve lies between them lateral to the semitendinosis and biceps femoris.

![Figure 5](image1.png)

**Figure 5**

Ultrasonographic appearance of the radial nerve at the level of the elbow.

![Figure 6](image2.png)

**Figure 6**

Ultrasonographic appearance of the ulna nerve at the level of the proximal forearm.
muscles. Where the fascial planes meet the sciatic nerve is found. The nerve is flattened or elliptical in shape (Figure 7) (8). Frequently, the posterior cutaneous nerve is found medial and more superficial to the sciatic nerve, it is important to ensure LA comes into contact with this nerve if a tourniquet is used. A cross-sectional approach is used with the needle aimed to one side of the nerve; if the LA does not spread circumferentially about the nerve then a second injection is made to optimize spread.

**Popliteal block**

The main problem with this block is location of the sciatic nerve division, standard methods of nerve location do not allow for this normal variation. Recently, US has been shown to be a reliable technique in locating the division in children (9).

The patient, US machine and operator are positioned as for a proximal sciatic block. A high frequency linear probe is used. The probe is placed over the popliteal fossa in an axial plane. The operator should scan the patient proximally to map out the anatomy. The popliteal fossa is bordered laterally by biceps femoris and medially by semimembranosus and semitendinosus. The nerve is hyperechoic and round, and lies deep to theses muscles (Figure 8). At the cephalad level of the fossa the popliteal artery is identified and the nerve is posterolateral. Imaging of the sciatic nerve at this level can also be difficult. The nerve can be highlighted by passive or active dorsiflexion and plantarflexion of the foot (10). The nerve is seen to ‘seesaw’, during dorsiflexion the tibial component moves towards the posterior skin of the leg, and during plantarflexion the common peroneal component moves towards the posterior skin of the leg. This phenomenon occurs because the tibial nerve lies posterior to the axis of the talocrural joint and is pulled during dorsiflexion. The peroneal nerve lies anterior to the axis of the talocrural joint and is pulled during plantarflexion. This maneuver is of limited value in children with congenital talipes equina varus. A cross-sectional technique is used, the sciatic nerve is blocked prior to division with a single medial injection, if adequate LA spread is not attained a second lateral injection is made. Alternatively, the needle can be directed between the common peroneal and tibial nerves and a single injection made. In the conscious trauma patient, a lateral approach utilizing an in-line needling technique can be useful. The depth of the nerve is measured and the puncture site is made the same distance anteriorly on the lateral aspect of the thigh. This means that the needle is parallel to the probe thus maximizing needle imaging. When using this approach, it is necessary to use adequate LA to infiltrate the needle path. The needle is first directed anterior (deep) to the nerve; if a second posterior (superficial) injection is required the image will thus not be distorted by the first injection.
Lumbar plexus block

This block is uncommonly performed on children. The plexus travels within the psoas muscle (usually within the area where the middle and posterior third of the muscle meet), though not within a specific compartment *per se*. The risk of spinal or epidural anesthesia, renal or ureteric damage deter the practice of this block. On inspiration the kidneys descend to varying levels, commonly reaching the level of L4/5.

Ultrasound imaging of the lumbar paravertebral region was first described in adults, due to the depths involved a 3–5 MHz curvi-linear probe was required. The anatomy was defined but the lumbar plexus could not be identified, as this is a deep block. Due to the small body mass of children the lumbar plexus is more superficial; therefore, higher frequency probes can be used. The younger the patient the more reliably the lumbar plexus can be imaged (11). In children older than 8 years of age the lumbar plexus was less reliably imaged at the L4/5 level compared with L3/4, which may be due to the iliac crests interfering with the US.

The following description refers to infants. The patient is placed in the left lateral position with the hips flexed. The operator sits facing the patient’s back, with the US machine on the other side of the patient. A linear probe with a small footprint is appropriate. The initial mapping scan aims to identify the level of puncture. This is assessed by scanning in a paramedian longitudinal plane. The probe is placed over the sacrum and as it is moved cephalad the transverse processes can be identified. Once the L4/5 interspace is identified the probe is rotated through 90° to provide a transverse axial plane of the interspace. Sequentially, from medial to lateral the spinous process, erector spinae, and quadratus lumborum muscles are identified. Deep to these muscles and posterolateral to the vertebral body is the psoas muscle. The lumbar plexus is imaged as an ovoid structure with similar sono-anatomy to peripheral nerves (Figure 9). The needle is introduced using a cross-sectional technique, as the target is usually <3 cm from the skin. By rotating the probe back into the longitudinal paramedian plane the precise position of the needle tip in relation to the lumbar plexus can be ascertained. LA spread is then observed and appropriate adjustments to needle position made as necessary.

In older children, a curvi-linear 5–8 MHz probe is more appropriate as it gives greater penetration. As the target is deeper an in-line technique is advised so as to image the needle tip at all times (12). It should be emphasized that this is a complicated technique to master and should only be practiced by those with adequate experience of both the block and US methods.

Femoral block

The femoral nerve can be blocked individually or as part of a 3-in-1 block. A right-handed operator stands by the patient’s right leg; the machine is positioned on the left side. The probe (linear) is held close and parallel to the inguinal ligament this allows the nerve to be imaged before division. The initial mapping scan should identify the femoral artery and vein, only light pressure is applied else the vein will collapse. The nerve is found lateral to the vessels, superficial to the iliopsoas muscles and beneath the fascia iliaca (Figure 10). The infrainguinal nerve appears predominantly oval (95%) though it can appear triangular (13). A cross-sectional needle approach is employed for both single shot and catheter techniques. The nerve is positioned in the middle of the screen and the needle should be aimed just lateral to it, as this minimizes risk of intraneural and arterial injection. The needle tip is imaged (or its position inferred by tissue movement) and felt to

Figure 9
Ultrasonographic appearance of the lumbar plexus nerve.
breech both the fascia lata and fascia iliacus. The operator’s assistant then injects 0.5 ml of saline or LA to ensure the needle tip is beneath the fascia iliacus, if this is the case the injection is continued and the spread monitored. If a 3-in-1 block is required the medial and lateral spread of LA is monitored. If lateral spread does not occur, e.g. in patients with prior hip surgery, then the needle position can be altered to try to improve spread or a separate lateral cutaneous nerve block is performed. US imaging of the lateral cutaneous and obturator nerves is very difficult.

An alternative method of blocking the femoral nerve and possibly more reliably the lateral cutaneous nerve is a fascia iliacus block. The probe is positioned transverse below the inguinal ligament and the needle tip is guided to below the fascia iliaca, once again medial and lateral LA spread to the femoral and lateral cutaneous nerve is monitored.

**Truncal blocks**

*Illoinguinal block*

This commonly used block is indicated for inguinal surgery. The landmark technique involves inserting the needle at a point 1 cm medial and slightly inferior to the anterior superior iliac spine (ASIS). As the needle is advanced one or two pops are felt. It has been shown that half of patients have only two muscle layers at this level (the external oblique having turned into an aponeurosis); this may affect the number of ‘pops’ felt. The success rate is far from perfect (70–80%) and serious complications have been described, e.g. bowel perforation and pelvic hematoma. Misplaced LA can also lead to unwanted femoral nerve block (up to 9%), leading to delayed discharge.

The US machine is positioned on the opposite side to the operator. A linear probe is held in a transverse plane with one end of the probe resting on the ASIS. A mapping scan is then performed to identify the muscle layers and peritoneum. The nerves are usually seen as hypoechoic ellipses between the internal oblique and transverse abdominal muscles (14), they are more lateral than standard techniques allow for (mean distance from ASIS 7 mm), and can be as little as 1.3 mm from the peritoneum (Figure 11). Both the cross-sectional and in-line (medial to lateral direction) approach have been described. The advantages of the latter are greater needle visibility, and should the operator lose the needle tip image, the needle is being directed towards the ASIS so the chance of intraperitoneal injection is diminished. Usually, in blocking the illoinguinal nerve the LA also spreads to block the iliohypogastric nerve. Blocks can be performed with as little as 0.075 ml\(\text{kg}^{-1}\) of LA whilst maintaining a superior success rate (15).

*Rectus sheath block*

The rectus sheath encloses the rectus abdominis and pyramidalis (if present); it is formed by the aponeurosis of the three lateral abdominal muscles. The
two sheaths are separated from one another by the midline linea alba. The anterior rami of T7–12 travel between internal oblique and transverses muscles before piercing the posterior wall of the sheath. The anterior wall is attached to the muscle by tendinous intersections; however, the posterior wall is not attached to the muscle. For LA to spread throughout the sheath the needle must be placed in the posterior part of the sheath. The peritoneum is directly beneath and there is a potential for penetration and possible visceral damage.

The operator stands on the opposite side to the US machine. The right rectus sheath block is performed with the operator facing the feet and the left side is blocked with the operator facing the head of the patient, this assumes right-handedness. A linear probe is positioned in a transverse plane just above the umbilicus, in a neonate the probe will straddle the linea alba and both rectus sheaths can be imaged. In larger patients, the probe is positioned over each side separately. The initial scan should identify the transversus abdominis, internal and external oblique muscles and the formation of the rectus sheath by their aponeuroses (Figure 12). The needle is inserted under the skin at the semilunaris; using an in-line approach the needle is inserted from lateral to medial until its tip lies at the posterior of the sheath, to confirm correct placement a small volume of LA or saline is injected and the sheath is seen to peel away from the muscle. If the probe is turned 90° to a sagittal plane the spread of the LA caudad and cephalad beneath the tendinous intersections can be monitored. Recent work has shown poor correlation between patient weight, height or age with depth of puncture; and that as little as 0.1 ml·kg⁻¹ of LA per side is effective (16).

Central techniques

Basic sonoanatomy

The neuroaxial structures can only be imaged through the soft tissues of the spine. These views are referred to as echo windows and are bordered by the bony posterior arches. In the neonate these windows are at their largest as the posterior arch is predominantly cartilaginous. After the first 3–4 months of life increasing ossification diminishes the quality of US assessment.

The cord itself is a tubular hypoechoic structure with a hyperechoic border (Figure 13); its central canal complex is seen as a simple hyperechoic line though more detail is seen with frequencies >10 MHz. The cord should be positioned between a half to a third of the way between the anterior and posterior vertebral canal walls. The vertebral level of the conus medullaris in healthy children varies from T10 to T11 interspace to the superior aspect of the L-3 vertebra. In preterm infants the conus can be as low as L4. The cauda equina is seen as numerous hyperechoic linear shadows projecting from the conus medullaris. Within the cauda equina the filum

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Figure 12
Ultrasonographic appearance of the rectus sheath, showing in line needle technique.

Figure 13
Ultrasonographic appearance of the spine.
terminale is seen as a hyperechoic continuation of the cord, in the neonate it should be <2 mm thickness. The surrounding cerebrospinal fluid (CSF) is hypoechoic. The dura is seen anteriorly and posteriorly as a hyperechoic layer, the ligamentum flavum is seen as a less defined hyperechoic layer in close proximity to the posterior dura (17).

**Caudal block**

The caudal is the most commonly performed block, and is considered both simple and safe. Failure occurs in up to 11% of patients and an overall complication rate of 1.5 : 1000 is reported. Problems associated with this technique include locating the sacral hiatus (particularly in older or obese children), and intravascular and intrathecal injection. Simple techniques (looking for leakage or aspiration of CSF/blood from the cannula) to identify the latter two problems are unreliable. A number of methods have been described to detect these complications; they include the ‘whoosh’ test, ‘swoosh’ test, the addition of epinephrine to the LA injectate, and nerve stimulation (18–21). None of these tests has become routine as they all have significant deficiencies, e.g. they do not prevent intrathecal injection. The use of US for caudals was first described in the adult population (22,23). In children, the US technique allows initial assessment of the anatomy, specifically the relation of the sacral hiatus to the dural sac, and in the presence of cutaneous markers for dysraphism it may be used to screen patients (24).

The patient is placed in the lateral position, with the US machine opposite the operator. A linear probe with a large footprint is preferable as it allows more intervertebral spaces to be imaged at a time. The probe is positioned in a sagittal midline position over the lower sacrum. The dural sac, sacral hiatus and sacrococcygeal membrane (SCM) are identified (Figure 14). Within the caudal epidural space sacral roots can be observed as hypoechoic ellipses. With the SCM in the middle of the image the probe is rotated 90° to the transverse plane and the exact position of the cornua defined, this is particularly useful in the presence of a fat pad. Where landmarks are not palpable a US-guided caudal can be performed with the probe in the sagittal plane and the needle in-line. The cannula may be visible but this relies on the needle and US beam being exactly aligned. To ensure epidural placement a saline test bolus (0.1–0.2 ml·kg⁻¹) is injected under US-assessment (25). The saline expands the epidural space displacing the dura ventrally (Figure 15). The reliability of this test may be limited to children under the age of 2 years because of the increasing level of ossification obscuring the view of the caudal space. If this phenomenon is not observed the possibility of intravascular or intrathecal placement should be considered. The use of saline prevents wastage of LA with a misplaced cannula. The subsequent LA injection can be monitored with US by moving the probe cephalad up the spine to confirm continued epidural placement and the level of spread. To

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maintain a good image, the probe may have to be placed in a paramedian sagittal plane, as this provides a larger echo window.

**Lumbar and thoracic epidurals**

Cork *et al.* first investigated the application of US imaging of the epidural space (26). This initial work showed that in adults US reliably measured the distance from skin to epidural space. Other adult US studies have demonstrated an increased accuracy at estimating vertebral level and a decreased puncture rate (27,28). Recent work in children has demonstrated accurate US measurement of epidural depth (29), easier and quicker insertion, and improved success rates (30). The major obstacle to imaging is ossification and thus age. It is also easier as the structures in children are more superficial so allowing the use of higher frequency probes. The best images in children are obtained with linear probes in the longitudinal paramedian plane (31).

Ultrasound can be used to assist or guide epidural placement. The former involves scanning the spine to gain information to aid puncture; this includes identification of vertebral level, depth to epidural space and angle of insertion. The latter guided technique requires two skilled anesthetists, one to perform the block and the other to scan the patient. The operators face the patients’ back, the US machine is positioned on the other side of the patient with the screen facing the operators. The US operator stands cephalad of the epidural operator. Full antiseptic precautions are taken; this includes placing the probe in a sterile sheath and using sterile US gel. The US operator places a hockey stick probe in the paramedian plane, whilst the epiduralist uses a midline approach (Figure 16). A loss of resistance to saline is preferred to air, as the latter interferes with US imaging. The catheter tip is imaged being inserted into the epidural space, though this is increasingly difficult with children over 3 months of age. Where the catheter tip is not directly imaged its correct position is inferred by injecting LA and observing the ventral displacement of the posterior dura. The thoracic US windows are smaller, despite the use of a paramedian probe position.

An alternative in infants and especially neonates is the introduction of the epidural catheter from the sacral hiatus. The use of the caudal catheter is well described, as is the potential for malposition of the catheter tip. Few UK anesthetists check catheter tip position despite this complication. A number of methods for catheter level assessment have been described. Plain X-ray can determine catheter tip level if the catheter is radiopaque, if not a contrast medium can be injected. This exposes the patient to radiation, possible anaphylaxis, and film interpretation can be difficult. Recently, the use of nerve stimulation has been described; the Tsui technique employs a styletted catheter connected to a nerve stimulator (32). Recognition of myotomal level stimulation relates to catheter tip level, and in expert hands it has an 89% success rate. However, the test can only be used in the absence of muscle relaxants and epidural LAs.

Tsui also described the use of electrocardiographic guidance; the epidural catheter is adapted so it functions as an ECG lead (33). Vertebral level is gauged by comparing a baseline ECG of the required catheter tip level against the evolving ECG of the catheter as it is advanced. It does not confirm the catheter is in the epidural space and at higher thoracic levels it can be hard to discriminate between vertebral levels, as ECG changes can be subtle.

Chawathe *et al.* first described the use of US to assess catheter position in children (34). The epidural catheters were detected in 75% of patients, but they were unable to demonstrate the catheter tip. Subsequently, it has been shown that US can locate the caudal catheter tip itself, or infer its position by injecting a saline bolus and observing the ventral displacement of the posterior dura (35).
Unlike a neonatal epidural a caudal catheter requires less experience to perform, though it still requires an experienced US operator. Patient and US machine are positioned as for lumbar/thoracic epidurals. However, a linear probe with a large footprint is preferred as it allows the observation of a greater length of spine at any given time. The catheter length for insertion is gauged externally. The catheter is then threaded cephalad through the sacral hiatus by one anesthetist whilst a second anesthetist attempts to image the catheter. The probe is held in a sagittal midline position but in infants a paramedian sagittal position provides better imaging of the neuroaxial structures. If the catheter cannot be imaged a small amount of saline can be injected and its effect looked for. It is important to look in both the anterior (minority) and posterior epidural spaces as the catheter can travel in either direction, and the saline may be difficult to see in the former. The use of a styletted catheter aids imaging, as the guide wire is highly echogenic (Figure 17).

Conclusions

Before performing blocks on patients, anesthetists should be familiar with scanning techniques; to develop the ability at creating a 3D image from the 2D US images. Secondly, using an US phantom they should practice manipulating needle and probe together to get the best image of the needle. Only then should they perform blocks on patients. The US novice should use a PNS and to start with simple blocks, e.g. femoral block before progressing to more complicated ones. As experience is gained these techniques can be used in the youngest of patients. The best way to gain these skills is to attend an US guided regional anesthesia course, of which there are an increasing number. Ultimately, the US machine is only as good as the anesthetist operating it.

References

Supplementary material

The following supplementary material is available for this article online:

**Video Clip S1** Caudal Block US.

The material is available as part of the online article from http://www.blackwell-synergy.com; doi: 10.1111/j.1460-9592.2006.02021.x.

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