Chapter

15

Regional Anaesthesia in Children

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Introduction

Regional anaesthesia is an important aspect of paediatric anaesthesia and should be considered for all suitable cases. The benefits of excellent analgesia need to be balanced against the potential risks; where possible, the most appropriate and peripheral technique should be used. Peripheral nerve blocks (PNB) should only be performed by those with the correct training, equipment and assistance. It is essential that the signs and management of local anaesthesia toxicity are understood by those performing and assisting with PNB.

In the United Kingdom, the bulk of paediatric PNBs are performed under general anaesthesia (GA). In the rare circumstance where blocks are performed awake (e.g. minor surgery on older, cooperative children), age-appropriate preoperative information, a quiet theatre environment and reassurance are essential to minimise the child's and their carers' anxiety.

Ultrasound (US) imaging is the gold standard for the majority of blocks and as such will in general be the only description outlined in this chapter.

The nerve blocks to be discussed are listed in Table 15.1.

Table 15.1 Common regional blocks

Head and neck	Superficial cervical plexus Auriculotemporal
Upper limb blocks	Interscalene Supraclavicular Axilla Forearm Ring block
Truncal blocks	Thoracic paravertebral Erector spinae plane Serratus anterior plane
Abdominal blocks	Rectus sheath Quadratus lumborum Penile
Lower limb blocks	Lateral femoral cutaneous nerve Femoral Adductor canal Fascia iliaca Lumbar plexus Sciatic – proximal and distal Ankle Metatarsal and ring blocks
Central blocks	Caudal – single shot

General Points

For all blocks, a thorough history and examination are mandatory to identify any contraindications to regional anaesthesia (see Table 15.2) along with appropriate preparation of the child and care:

- *History:* allergies, previous regional/general anaesthesia, comorbidities, current medications.
- *Planned procedure*: to determine the most suitable block, and whether a catheter technique would be beneficial for continued pain relief in the postoperative period e.g. to facilitate physiotherapy.

Table 15.2 General contraindications to regional anaesthesia

Absolute contraindications	Relative contraindications
Lesions (infective) at the site of injection	Neuromuscular disorders
History of allergy to LA	Systemic infection (catheter techniques)
Lack of consent	Bleeding disorders (US can avoid inadvertent damage to blood vessels)

- *Examination:* of the operative site and potential puncture site, to exclude local infection.
- *Weight*: to calculate maximum dose of local anaesthetic (LA).
- *Consent:* to explain potential advantages, side effects, complications and alternative methods of pain relief if the block fails. General complications include failure, nerve damage, LA toxicity, haematoma, infection and anaphylaxis.
- *Preoperatively:* where a GA can be avoided, the patient can be prepared by a play specialist if necessary and age-suitable distraction provided. Before coming to theatre, topical anaesthesia can be applied to the proposed puncture site. In these circumstances, parental presence can be reassuring. Administration of paracetamol and an NSAID to supplement the block should be considered.
- *Anaesthetic room:* a trained assistant should be present, along with accessibility to resuscitation equipment and drugs, including 20% Intralipid. Prior to performing the block, the airway and IV access should be secured and full monitoring instituted. Inadvertent wrong-sided nerve blocks are uncommon but do occur; a systematic check confirming the surgical site marking and consent form should be performed immediately before needle insertion ('stop before you block' process).
- *Equipment:* an insulated short-bevelled needle with extension tubing, gauze swabs, antiseptic solution, sterile gloves, sterile drapes, syringe, LA, a peripheral nerve stimulator (PNS) (for mixed nerves) and a US machine (with high-frequency probe, sterile gel and probe cover).
- *Procedure:* for those children not having a GA, the skin should be infiltrated with lidocaine first; the administration of Entonox can smooth proceedings.
- *Asepsis:* single-shot techniques require a basic sterile technique, but those involving catheters should have a full aseptic technique.

Technique

- As regional needles are quite blunt, it is useful to nick the skin first with a hypodermic needle. This ensures that the fascial planes are appreciated as the short-bevelled needle is advanced.
- If a PNS is used, an initial current of 2 mA is set; as the needle is advanced and the relevant motor response elicited, the current is decreased to 0.5 mA.
- After initial aspiration, 1 ml of LA is injected, abolishing the motor response. The injection is made slowly with intermittent aspiration to exclude intravascular placement.
- Usually a long-acting LA is appropriate, providing analgesia for 6–12 hours. If prolonged analgesia is required, the insertion of a catheter should be considered.
- To minimise the risk of dislodgement, the catheter should be tunnelled 3–4 cm subcutaneously. The use of a drop of Indermil® tissue glue over the puncture site limits the leak; this prevents the LA escaping and causing the dressing to lift off and the catheter to fall out.
- If planning a postoperative infusion, start it intraoperatively as this may highlight any occlusion issues.

Postoperative

In the recovery area, a failed block can be difficult to differentiate from emergence delirium; if in doubt, pain should be assumed and treated promptly with either 0.25–0.5 mg kg^{-1} of ketamine or 0.5 mcg kg^{-1} of fentanyl. This achieves quick control and the need for morphine can then be considered. Carers and patients should be advised to protect the anaesthetised area; this should include warning of decreased sensation (especially temperature) and motor weakness. Upper limbs should be kept in a sling. Where lower limb blockade is used, ensure means of ambulation and discharge are in place.

Local Anaesthetics

Levobupivacaine is our LA of choice owing to its longer duration of action, and low cardio/neurotoxicity. As the blocks usually accompany a GA, concentrations of 0.125–0.25% are adequate; low concentrations are essential if there is a risk of compartment syndrome. Ropivacaine is preferred in some centres as it may cause less profound motor block. Lidocaine is indicated for infiltration before performing a block in awake children (see Table 15.3).

Neonates and infants are at greater risk of LA toxicity because of lower protein binding and the

Table 15.3 Local anaesthetics

Local anaesthetic dose.LA	Single-shot block (mg kg^{-1})	PNB catheter infusions (mg kg^{-1} h^{-1})	Maximum dose per 4 hours (mg kg^{-1})
L-bupivacaine	2.5*	0.125–0.4	2.0
Ropivacaine	3	0.4	1.6
Lidocaine	4	NA	NA

Note: * halve dose in neonates.

immature blood–brain barrier and liver. Consideration should be given to halving LA doses in these patients and limiting LA infusions to 48 hours.

For non-minor surgery, the duration of analgesia can be extended by administration of dexamethasone IV and an alpha-2 adrenergic agonist IV. Clonidine 1–2 mcg kg^{-1} may be added to caudals.

Table 15.4 Signs of local anaesthesia toxicity

Restlessness or agitation, followed by slurred speech or loss of consciousness
Muscle twitching, which may progress to seizures
Respiratory depression
Bradycardia, heart block, hypotension
Ventricular tachyarrhythmias, progressing to cardiac arrest

Local Anaesthetic Toxicity

Prevention is preferable:

- Never exceed the maximum dose of LA (see Table 15.3).
- Always aspirate before injection.
- Use US to observe the injection (note that this is not infallible).
- Maintain a high level of suspicion.

Systemic toxicity results in depression of both the central nervous and cardiovascular systems with recognisable symptoms and signs, increasing in severity from somnolence through to convulsion and cardiac arrhythmia (see Table 15.4). However, as most children receive regional anaesthesia under GA, the earlier warning signs may be masked, and thus the first manifestation of a problem may be cardiovascular collapse.

In the event of toxicity, management should follow an established protocol such as that in Figure 15.1. Arrhythmias may be refractory, and resuscitation may be very prolonged.

Specific Blocks

Head and Neck Blocks

Superficial Cervical Plexus Block

Anatomy

The superficial cervical plexus (SCP) is formed by the anterior rami of cervical nerves C1–4, emerging at the midpoint of the posterior border of the sternocleidomastoid muscle (SCM) at the level of thyroid cartilage. The four terminal branches of this plexus provide innervation to the skin and superficial structures over the anterolateral part of the neck and the area immediately underneath the clavicle:

- Greater auricular: auricle of the ear
- Lesser occipital: superior posterior neck and scalp behind the auricle
- Transverse cervical: anterolateral aspect of the neck from the sternum to the mandible
- Supraclavicular: cape of the neck and shoulder to the level of the second intercostal space

Indications

For surgical procedures in the front of the neck, including excision of thyroglossal/branchial cyst, tracheostomy, thyroidectomy, carotid and vascular surgery, lymph node biopsy, tympanic and mastoid procedure, pinnaplasty, clavicular fracture and posterior neurosurgical incisions.

Technique

The aim of the SCP block is to inject LA behind the midpoint of the posterior border of the SCM between the muscle and the prevertebral fascia.

Posterior in-plane (IP) approach: place the patient in a position similar for insertion of a

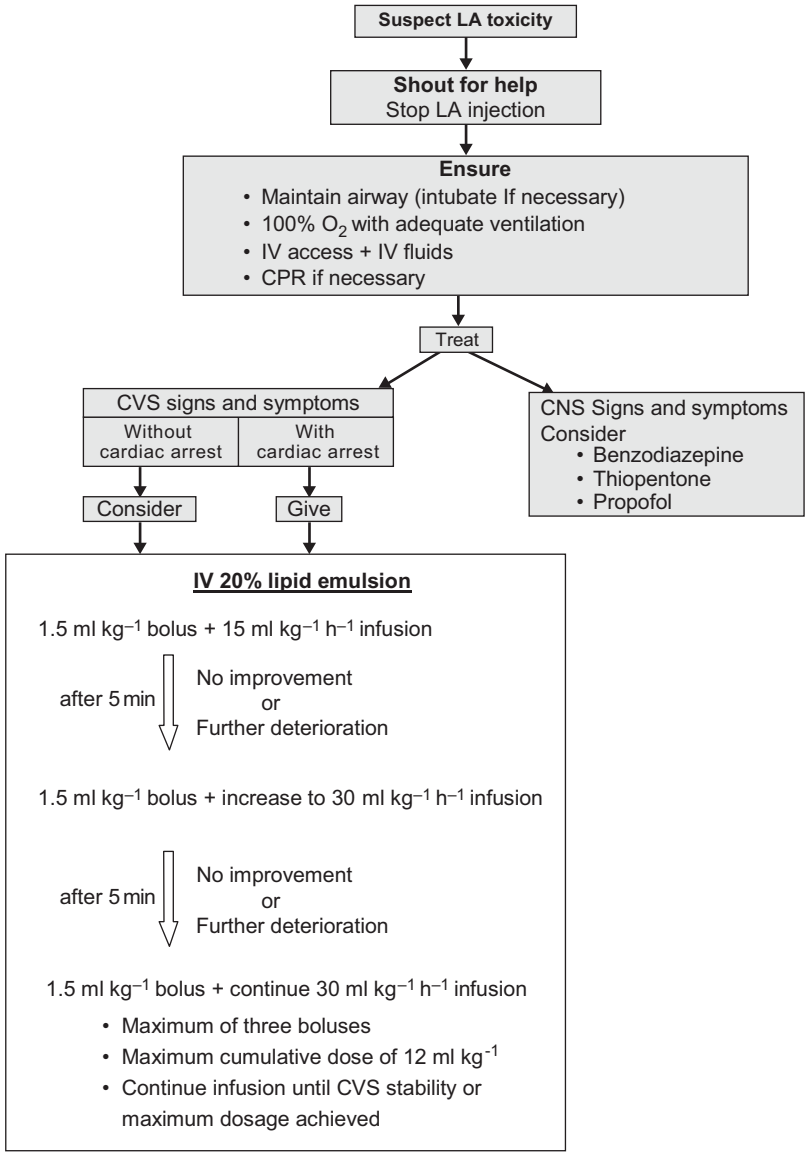

Figure 15.1 Management of LA toxicity.

central venous pressure (CVP) line in the neck with the face turned slightly away from the block site. A linear transducer probe of appropriate length is placed transversely over the front of the neck to identify the thyroid cartilage (the midpoint of a line from the sternoclavicular joint to the mastoid process) and moved laterally to visualise the tapering edge of the sternocleidomastoid muscle in the middle of the screen. The needle is inserted IP from the posterolateral edge of the probe position aiming for the tapered tip of SCM, to traverse a short distance along the posterior border of SCM directed towards the carotid artery. Needle position is confirmed with SCM being hydrodissected away from the prevertebral fascia before completion of injection as the needle is withdrawn towards the tapering tip, with a maximum of 5 ml of LA.

Specific Complications

Deeper injection without visualisation of the needle tip may lead to inadvertent vascular puncture or blockade of deeper neural structures, e.g. phrenic nerve, deep cervical plexus, brachial plexus and the recurrent laryngeal nerve.

Auriculotemporal Nerve Block

The SCP can be combined with an auriculotemporal nerve block for surgery on the ear and mastoid. This nerve supplies the superior two-thirds of the anterior surface of the ear, the external auditory canal and the temporal region of the forehead. It is blocked by subcutaneous infiltration of LA in front of the tragus behind the superficial temporal artery.

Upper Limb Blocks

Brachial Plexus Anatomy

The anterior primary rami of C5 to T1 form the brachial plexus. They emerge from the intervertebral foramina between the scalenus anterior and medius muscles enclosed within a fascial sheath. The roots come together to form trunks:

- C5 and C6 unite to form the superior trunk.
- C7 forms the middle trunk.
- C8 and T1 roots unite to form the lower trunk.

From the interscalene groove, the trunks pass over the first rib superoposterior to the subclavian artery. At the lateral border of the first rib, the trunks divide into anterior and posterior divisions. The anterior divisions of the upper and middle trunks join to become the *lateral cord*, the anterior division of the lower trunk continues as the *medial cord*. The posterior divisions of the three trunks join to form the *posterior cord*. The cords are named according to their position in relation to the axillary artery; they divide into the nerves that supply the arm.

- Lateral cord: becomes the *lateral root of median nerve and musculocutaneous nerve.*
- Medial cord: becomes the *medial root of median nerve, ulnar nerve and medial cutaneous nerves of arm and forearm.*
- Posterior cord: becomes the *axillary and radial nerves*.

Interscalene Block

Indications

Shoulder surgery and the upper medial aspect of the arm.

Technique

LA is injected into the interscalene groove between the scalenus anterior and scalenus medius muscles at the level of C6 (cricoid cartilage level) to block the nerve roots, resulting in analgesia over most of the shoulder region and the medial aspect of the arm, but with no block to the ulnar aspect of the arm, forearm or the hand.

The patient is placed supine with the head turned slightly to the opposite side of the block. A linear US probe is positioned transversely over the middle of the neck and slid laterally past the carotid artery and internal jugular vein following the SCM, until the tapered tip of the SCM is seen in the middle of the screen. The two scalenus muscles should be identified just underneath the tip of the SCM and the probe tilted or rotated slightly to appreciate the C5–7 nerve roots of the brachial plexus as hypoechoic circles stacked one above other vertically in the interscalene groove (Figure 15.2). If it is difficult to identify in this area, then the probe can be slid into the base of the neck as described for the supraclavicular block; once the plexus is identified, it can be easily traced back to the level of C6 vertebrae.

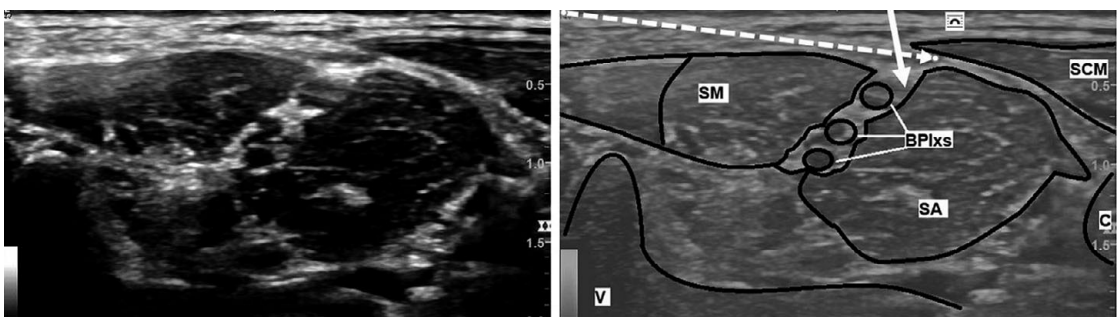

Figure 15.2 Ultrasound appearance of the brachial plexus in the interscalene region (BPlxs); scalenus medius (SM), scalenus anterior (SA), sternocleidomastoid(SCM), vertebra (V) and carotid artery (C).

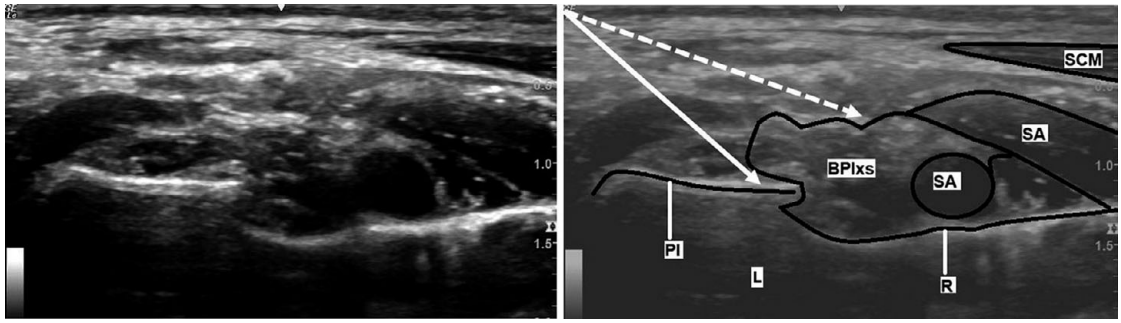

Figure 15.3 Ultrasound appearance of the brachial plexus in the supraclavicular region (BPlxs); subclavian artery (SA), pleura (PI), lung (L), rib (R) and sternocleidomastoid muscle (SCM).

The needle can be inserted out of plane directed to one side of the most superficial nerve root in the interscalene groove and then advanced deep along the side of the hypoechoic circles with hydrodissection until all of the nerve roots are covered with sufficient LA. The needle is then withdrawn and the procedure repeated on the other side of the nerve roots ensuring they are covered with LA on both sides.

An IP approach from the lateral edge of the probe with the needle advanced through the scalenus medius to reach the nerve roots in the interscalene groove is feasible. Risk of damage to long thoracic and dorsal scapular nerves exists with the latter approach, since these nerves pass through the scalenus medius muscle.

Specific Complications

Inadvertent neuraxial block by intrathecal injection may occur. Phrenic nerve block with resultant ipsilateral diaphragmatic palsy is common and should be taken into account if the patient has poor baseline respiratory reserve. Less common are ipsilateral Horner syndrome due to block of cervical sympathetic ganglion, and hoarseness due to involvement of the recurrent laryngeal nerve.

Supraclavicular Block

The brachial plexus at this point is close to the subclavian artery and pleura. For this reason, a block at this level should only be performed by experienced practitioners, and arguably only with ultrasound. Classically it is said that this approach can miss the lower nerve roots. However, with US poor LA distribution can be observed and corrected. Specific relative contraindications include previous neck surgery and contralateral pneumothorax.

When performed with US, the whole upper limb can be anaesthetised, with the exception of the shoulder.

Technique

The patient lies supine with a roll between the shoulders and the head turned to the opposite side to the intended surgery; this allows adequate room for needle manipulation. The US machine and equipment are positioned ergonomically.

A linear probe of appropriate size footprint is placed parallel to the clavicle. The three main structures to identify are the pleura, the subclavian and dorsal scapular arteries. The brachial plexus is seen as a group of hypoechoic (black) bubbles posterior and slightly superficial to the subclavian artery (Figure 15.3). The dorsal scapular artery often passes through the brachial plexus, so it should always be identified using colour Doppler. The needle is inserted using an IP technique, travelling in a posterolateral to anteromedial direction. The tip of the needle is aimed between the bubbles where the subclavian artery and pleura come together. LA injection is observed and appropriate needle manipulation made to ensure uniform spread.

Specific Complications

Pneumothorax, phrenic and recurrent laryngeal nerve blockade, and Horner syndrome.

Axillary Block

The three main branches of the brachial plexus lie close to the axillary artery. In the supine child the three main branches are commonly positioned with the median and musculocutaneous nerves superior, the ulnar nerve inferior and the radial nerve posterior to the artery. Note that the musculocutaneous and axillary nerves leave the

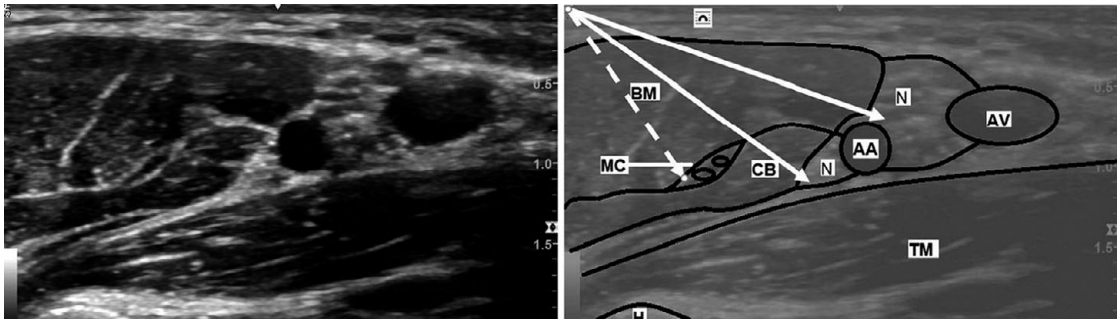

Figure 15.4 Ultrasound appearances of the brachial plexus in the axillary region showing axillary artery (AA), axillary vein (AV), biceps muscle (BM), musculocutaneous nerve (MC), coracobrachialis muscle (CB), triceps muscle (TM), humerus (H) and radial, median and ulnar nerves (N).

'sheath' at the level of the coracoid process, hence the absence of block in these nerves in up to 50% of blocks.

Indications

This block is appropriate for hand and forearm surgery.

Technique

The patient is positioned with the arm abducted and flexed to 90° at the elbow. With a linear probe held transversely across the upper arm at the level of insertion of the pectoralis major muscle, an IP needling technique can be used to block the four main nerves individually (Figure 15.4). The musculocutaneous nerve is easily identified and blocked as it passes between the biceps and coracobrachialis muscles, ensuring coverage of the lateral forearm. The musculocutaneous nerve is oval in appearance, changing to a triangular shape distally. As the arrangement of the nerves in the axilla is very variable, the most reliable way of identifying them is to follow their path distally with the US. The median nerve passes along with the artery to the elbow, the ulnar nerve becomes more superficial and moves away from the artery and the radial nerve can be seen to drop down towards the humeral groove with gentle to-and-fro movement of the probe. If it is not possible to visualise the nerves, then injection around the axillary artery with care after piercing the sheath can be performed to aid nerve block. The deepest nerve structures are blocked first in case an air artefact subsequently obscures the view. Each nerve can be blocked with as little as 1–2 ml.

Forearm

The three nerves can be blocked individually anywhere along their path within the forearm.

Indication

Hand surgery, or as rescue blocks for failed upper limb blocks.

Technique

Either an out-of-plane (OOP) or IP needling technique is suitable.

The *median nerve* is most easily blocked mid-forearm, where it sits between the deep and superficial flexor muscles. The probe is placed in a transverse plane mid-forearm (Figure 15.5). At this point, there is little vasculature to hit and few tendons to confuse with the nerve.

The *ulnar nerve* is best blocked in the proximal third of the forearm as the associated artery does not join the nerve till farther down. By placing the probe at the midpoint of the ulnar aspect of the forearm, the ulnar nerve can be imaged lying on the deep aspect of flexor carpi ulnaris muscle (Figure 15.6). The ulnar artery is adjacent, and the LA is injected where the nerve is separate from the artery.

The *radial nerve* is blocked preferably just above the elbow joint with the transducer probe placed transversely across the lateral epicondyle of the humerus. The nerve is seen as a triangular hyperechoic structure which can be traced up proximally into the posterior spiral groove of the humerus. Alternatively, the probe is placed transversely over the groove between the tendons of biceps brachii and brachioradialis. The division of the radial nerve into superficial and deep branches can be imaged at this point; an

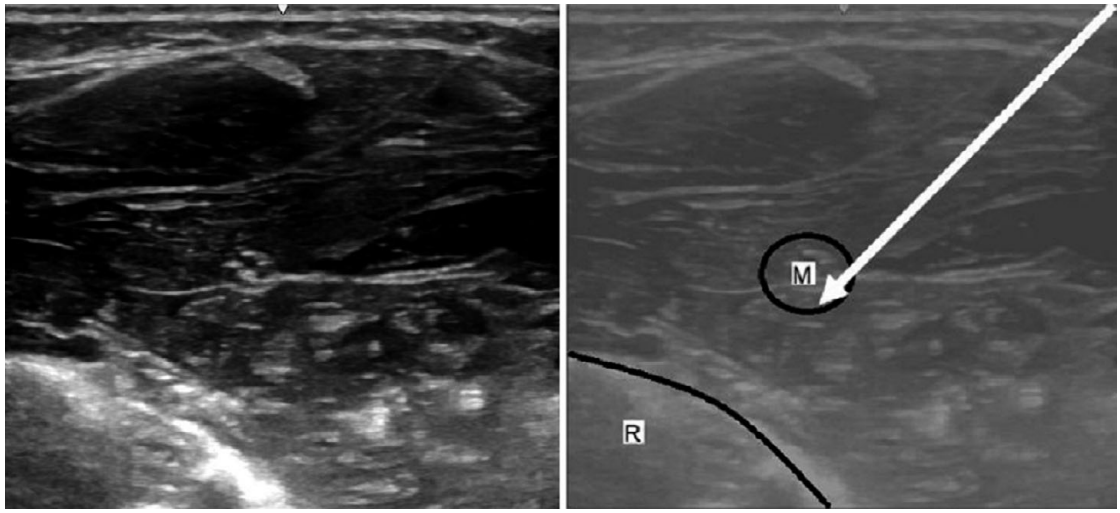

Figure 15.5 Ultrasound appearance of the median nerve (M) and radius bone (R) at mid-forearm.

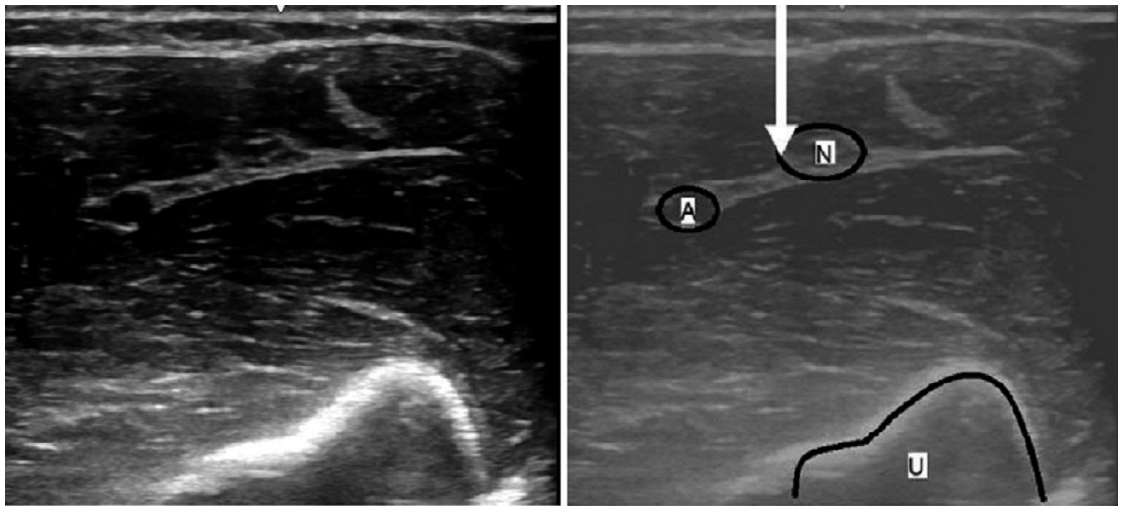

Figure 15.6 Ultrasound appearance of the ulnar nerve (N), ulnar artery (A) and ulnar bone (U) at mid-forearm.

accompanying artery is present and must be avoided (Figure 15.7).

Ring Block

This simple block is used for operations on the fingers, such as nail bed repair. The digital nerves are branches of the median and ulna nerves ventrally and the ulna and radial nerves dorsally. Each digit is supplied by four nerves in the 2, 5, 7 and 10 o'clock positions in relation to the phalanx.

The needle is inserted medially and laterally to the extensor tendon. The needle is passed subcutaneously down both the medial and lateral aspects of the phalanx.

The needle is inserted as far as the volar skin before being slowly withdrawn as LA is injected.

In the awake patient, this is a painful block to perform, therefore topical anaesthesia should be placed around the base of the finger. *Vasoconstrictors must not be used.*

Truncal Blocks

Anatomy

The upper thoracic nerves (mainly T2–6) provide the innervation of the skin and musculature over the chest wall. The thoracic spinal nerves divide into dorsal and ventral branches on exiting the

intervertebral foramen. The dorsal branch divides into a medial and lateral branch to supply the skin over the back, from the midline to the border of the latissimus dorsi muscle. The ventral intercostal nerve passes underneath the inferior border of the corresponding rib with the intercostal vessels, initially between the pleura and posterior intercostal membrane and then between the internal and innermost intercostal muscles. They give a lateral branch at the angle of the rib (mid-axillary line) and terminate at the edge of the sternum as the anterior cutaneous branches. The lateral cutaneous branch (except T2) divides into anterior and posterior branches supplying the skin over the anterolateral chest wall. The intercostobrachial nerve is the undivided lateral branch of T2, which in addition runs through the axilla and innervates portions of the axilla, tail of the breast, lateral chest wall and upper-medial side of the arm.

Thoracic Paravertebral Block

The aim is to inject LA into the wedge-shaped paravertebral space found either side of the vertebral column. The base is formed by the posterolateral part of the vertebral body, the disc and the intervertebral foramina with its contents, the anterolateral boundary by the parietal pleura and the posterior wall by the superior-costotransverse ligament (Figure 15.8). The LA spreads to at least two vertebral levels above and below, the intercostal space laterally and potentially to the epidural space medially and the contralateral paravertebral space.

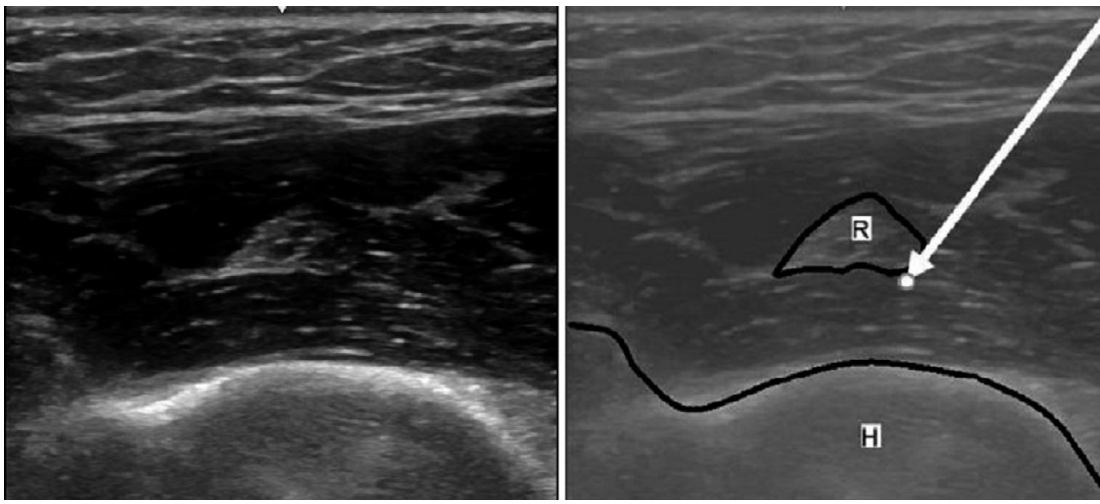

Figure 15.7 Ultrasound appearance of the radial nerve (R) and humerus (H) at the elbow.

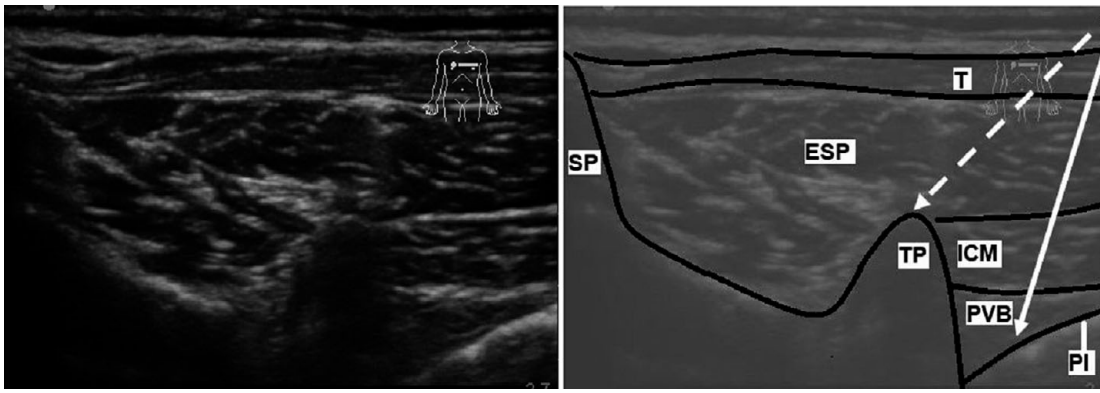

Figure 15.8 Ultrasound appearance of the paravertebral region; spinous process (SP), transverse process (TP), pleura (PI), trapezius (T), erector spinae (ESP), intercostal muscle (ICM) and paravertebral space (PVB).

Empyema and tumour occupying the space are contraindications. It may not be possible to find the space easily in children with kyphoscoliosis or be successful in children with a history of previous thoracotomy.

Indications

Thoracic and abdominal procedures, utilising unilateral or bilateral injections as appropriate. A catheter can be placed by the anesthetist or by the surgeon under direct vision during a thoracotomy.

Technique

The anaesthetised child is placed in the lateral decubitus position with the knees bent up and the side to be blocked uppermost. A linear probe is placed at an appropriate level in the midline (T4–5 for sternotomy, T6–7 for thoracotomy and T9–10 for abdominal procedures) to view the hypoechoic peak formed by the spinous process of the vertebrae and traced laterally to see the shiny lamina of the vertebral body and a more shallow second peak of the transverse process (TP) deep to the muscles of the back. Lateral to this the intercostal muscles are seen with a very hyperechoic pleura, and a characteristic lung shadow below disappearing medially underneath the shadow of the TP. The paravertebral space is the triangular space with the TP as the base, the pleura anteriorly and the lower border of intercostal muscle (internal intercostals membrane) posteriorly. A needle can be inserted IP from the lateral edge of the probe into the space, and the position confirmed by observing anterior displacement of the pleura on injection. Once the pleura is displaced, the needle is advanced just under the shadow of the TP and the rest of the LA injected. A volume of 0.3–0.5 ml kg^{-1} per side to a maximum of 20 ml is recommended. It can also be performed with the probe placed in the paramedian plane with the vertebral level of interest at the middle of the probe, and the needle inserted IP in a craniocaudal direction into the paravertebral space; position is again confirmed with anterior displacement of the pleura before the rest of the LA is injected.

Specific Complications

Pneumothorax, contralateral paravertebral spread, epidural spread and dural tap.

Erector Spinae Plane Block (ESPB)

ESPB is an interfascial plane block where LA is injected between the erector spinae muscle and the TP of the vertebrae; it is proposed as an alternative to paravertebral block. There is no clear consensus on its mechanism of action, but it is thought to be by diffusion into the paravertebral space. A low incidence of adverse events is reported with this block.

Anatomy

The erector spinae (ES) group of muscles are the intermediate layer of the intrinsic muscles of the back originating from the posterior part of the iliac crest and sacrum. They ascend between the spinous process medially and the angle of the rib laterally to insert into the base of the skull, the mastoid process, spinous process of upper thoracic vertebrae, TP of cervical and thoracic vertebrae and ribs.

Indications

Thoracic and lumbar ESPB have been used for various surgical procedures, including cardiothoracic, breast, fractured ribs, spinal, abdominal, gynaecological and hip surgery.

Technique

Similar to the paravertebral block, the transducer probe is placed in either transverse or paramedian position lateral to the relevant spinous process. Once placed, the anatomy is similar to the paravertebral block, with the focus on the TP laterally and the erector spinae muscle superficial to it. A needle is inserted IP aimed at the superficial surface of the TP (see Figure 15.8) and the position confirmed by visualising the hydrodissection of the ES muscle from the TP by the LA.

Serratus Anterior Plane Block (SAPB)

This blocks the lateral cutaneous branches of the intercostal nerves which pass through the serratus anterior muscle (SAM) to reach the subcutaneous area, in addition to the thoracodorsal and long thoracic nerves.

Indications

It is an alternative to epidural and paravertebral blocks for breast surgery, thoracotomy and thoracoscopic procedures.

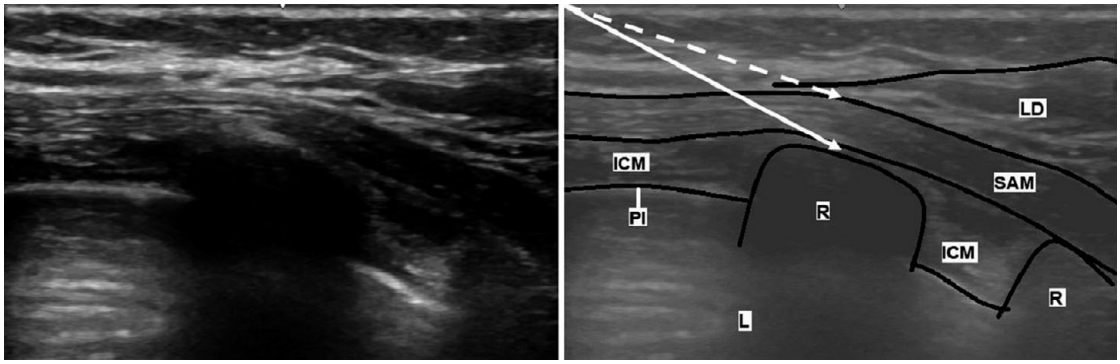

Figure 15.9 Ultrasound appearance of the serratus anterior plane block, showing serratus anterior muscle (SAM), latissimus dorsi (LD), intercostal muscle (ICM), rib (R), pleura (PI) and lung (L).

Technique

The patient is positioned supine with the ipsilateral arm abducted. A linear transducer probe is placed in a transverse plane at the fifth intercostal space in the mid-axillary line. The SAM is identified above the rib shadows. Deep to the SAM, the intercostal muscles and pleura can be identified. Superficial to the SAM, the lateral part of the latissimus dorsi muscle should be seen, confirming correct probe position. The needle is placed IP directed to the plane between the SAM and the surface of the rib (Figure 15.9) and the position confirmed with separation of the SAM from the rib. An injection superficial to the SAM can be performed, but a deep injection avoids blocking the long thoracic nerve and hence winging of the scapula.

Abdominal Blocks

Anatomy

The ventral rami of the lower thoracic nerves (T7–12) and first lumbar nerve provide segmental innervation to the skin and muscle of the anterior and lateral abdomen. The intercostal nerves pass between the digitations of the diaphragm and the transverse abdominis muscles (TAM) to run anteriorly in the fascial plane between the TAM and internal oblique muscles (IOM). Lateral cutaneous branches arise at the mid-axillary line to pierce the oblique muscles and divide into anterior and posterior branches to supply the anterolateral (to the margin of the rectus sheath) and posterior (latissimus dorsi region) parts of the abdomen. The nerves terminate as anterior cutaneous branches supplying the anterior abdominal wall from midline to the border of rectus muscle after entering the lateral aspect of the rectus sheath via the posterior laminae of the internal oblique muscle and traversing the rectus muscle. The 12th thoracic nerve (subcostal) gives a branch to the first lumbar nerve forming part of the lumbar plexus. Its lateral branch does not divide into an anterior and posterior branch but, after piercing the oblique muscles, descends over the iliac crest to supply the skin of the anterior part of the gluteal region. The iliohypogastric and ilioinguinal nerves emerge from the lateral border of the psoas muscle and pass anteriorly over the quadratus lumborum (QL) to pierce the TAM at the level of the iliac crest. The iliohypogastric divides into a lateral cutaneous branch, which pierces the IOM and external oblique muscle (EOM) to supply skin over the gluteal region, and an anterior cutaneous branch, which passes between TAM and IOM to then pierce the EOM aponeurosis to supply skin over the hypogastric region. The Ilioinguinal nerve, after passing into the TAP, pierces the IO to supply the skin over the inguinal region, upper and medial thigh and some parts of the genital region. The skin over the back of the abdomen is supplied by the dorsal branches of these nerves.

Rectus Sheath Block

The rectus sheath is formed from the aponeuroses of the TAM and has an anterior and posterior wall. The sheath encloses the rectus muscle and fuses in the midline to form the linea alba. The rectus muscle is adherent to the anterior sheath at the level of the xiphisternum, the umbilicus and midway between these two points. The anterior cutaneous branches of the lower five thoracic nerves can be blocked.

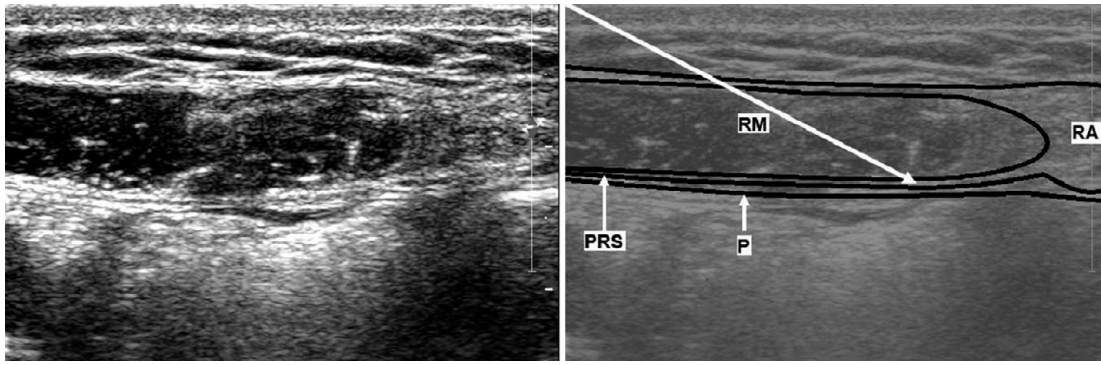

Figure 15.10 Ultrasound appearance of the rectus muscle (RM), posterior rectus sheath (PRS), peritoneum (P) and linea alba of the rectus abdominis (RA).

Indications

Pyloromyotomy, umbilical hernia, epigastric hernia repair, umbilical laparoscopic port site, and midline mini-laparotomy incisions.

Technique

A high-frequency linear probe is placed transversely just above the umbilicus. The linea alba is identified and the probe moved laterally to appreciate the rectus muscle enclosed in its sheath, which appears as a hyperechoic line above and below the muscle (Figure 15.10). The peritoneum, with the bowel underneath, can be seen deep to the posterior sheath. The inferior epigastric vessels can be identified with Doppler. As the probe is moved laterally, the lateral abdominal muscles are imaged. A 22 g regional block needle is inserted IP and advanced through the anterior sheath and the rectus muscle to reach the plane between the muscle and posterior sheath. After aspiration, 0.5 ml LA is injected to ensure the muscle splits from the posterior sheath. The rest of the LA is then injected (0.1–0.3 ml kg^{-1} per side). Placing the probe longitudinally allows assessment of spread. The procedure is then repeated on the opposite side.

Specific Complications

Peritoneal puncture and organ damage.

Quadratus Lumborum Block

LA can be injected at either posterior, lateral or anterior injections points underneath the thoracolumbar fascia (TLF) around the quadratus lumborum muscle (QLM) resulting in varying degrees of block in the T5–L4 distribution (consistent block T12–L2 since iliohypogastric, ilioinguinal and subcostal nerves lie on the anterior aspect of QLM within the endothoracic fascia). The TLF is formed by the aponeurosis and fascia enveloping the back muscles and is described as having either two or three layers. It blends with the endothoracic fascia and diaphragm above and with the fascia iliaca below, aiding the spread of LA to lower thoracic and lumbar nerves. Visceral analgesia may result from spread of LA via the splanchnic nerves to the coeliac ganglion and sympathetic nerves, or from blockade of the adrenergic pain and mechanoreceptors present in the TLF.

Indication

Described for procedures in the abdomen and pelvis, as well as for hip and femur surgery. Paediatric trials demonstrate non-inferiority compared with caudal analgesia.

Technique

The patient is placed supine with a roll under the hip to elevate it and create a lateral tilt to the torso to aid probe position and needling. The probe is initially placed transversely resting on the iliac crest, and the anterior abdominal muscles (EOM, IOM, TAM) are visualised. The probe is then slid posteriorly to see the tapered end of the TAM, with the QLM seen in a deeper and lower position. The probe is adjusted to better visualise QLM, including its anterior borders, keeping the tapered end of the TAM in view (Figure 15.11). A needle is then inserted IP in an anteroposterior direction to inject LA and visualise hydrodissection, in one of the following locations.

- Lateral – the needle is positioned immediately underneath the fascia covering the lateral border of QL close to the tapered end of the

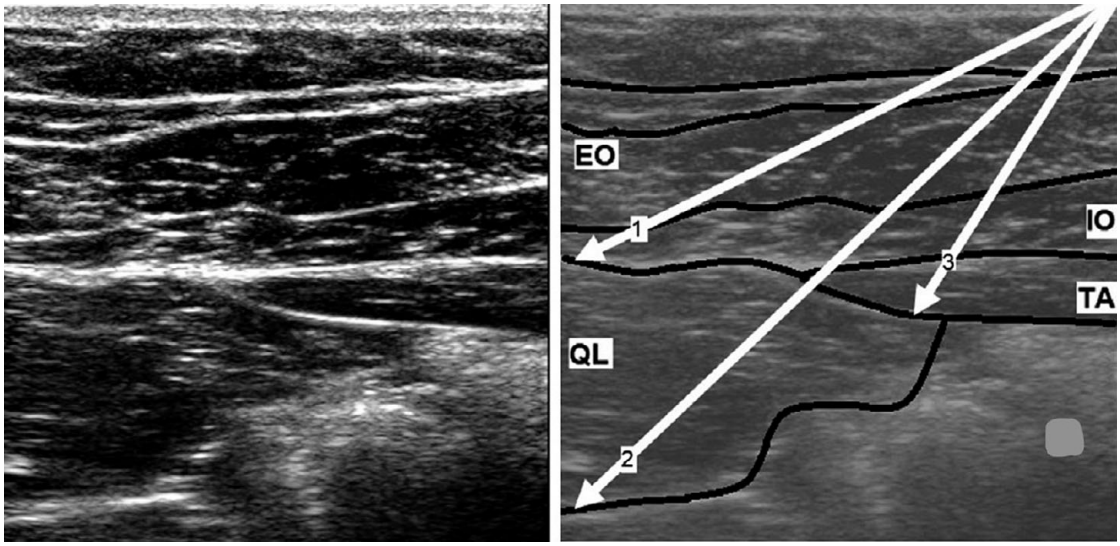

Figure 15.11 Ultrasound appearance of the quadratus lumborum (QL), external oblique (EO), internal oblique (IO) and transversus abdominis (TA).

TAM to allow spread along the TAM plane and subcutaneous area.

- Posterior – the needle is directed more posteriorly, towards the erector spinatus muscle, to a position between the TLF and posterior border of QL muscle to allow spread along the TLF midtransverse area.
- Anterior – the needle is passed through the QL muscle to reach anteriorly between the anterior border of QL and anterior TLF or fascia transversalis, close to psoas muscle, to block lumbar nerve roots and branches in addition to a paravertebral spread through the endothoracic fascia.

A lateral position and curvilinear probe may be required when there is an increased depth to access the QLM. A paramedian IP approach in the semi-prone position is also described for this block. Catheters can be placed after hydrodissection.

Specific Complications

Lumbar vessels may travel close to or in the QLM, and colour doppler inspection is important before proceeding with the block. Lower extremity weakness has been reported.

Penile Block

The aim is to block the dorsal nerves of the penis, which are branches of the pudendal nerve (S2–4) in the subpubic space.

This block is primarily used for circumcisions, although it may be used for distal hypospadias repair after discussion with the surgeon. It is useful when a caudal block is contraindicated. It requires injection into the subpubic space; this space is divided into left and right by the suspensory ligament. It is within this space that the dorsal penile nerves pass. It should be remembered that the vessels travel in the midline, and midline injection should be avoided. The penis is gently pulled caudally so that the skin is taut; the short-bevelled needle is then carefully placed under the skin in the midline aiming for the inferior aspect of the pubic symphysis. Once through the skin the needle is redirected deeper to the pubis, from the perpendicular so that it points laterally (10°) and slightly cephalad; it is then advanced until a 'pop' is felt as it passes through the Scarpa's fascia. The depth of the fascia is independent of age and weight (generally 8–30 mm). After aspiration, 1 ml + 0.1 ml kg^{-1} of LA is injected (preferably the highest concentration available); the process is then repeated for the contralateral side. Following this, a hypodermic needle is inserted subcutaneously into the ventral aspect of the base of the penis, and LA is injected whilst withdrawing the needle to form of a partial ring block bilaterally. *Vasoconstrictors should not be used.*

A US technique has been described, which is generally easier in older children. A linear transducer is placed transversely at the base of the penis

(apply gentle traction). The midline dorsal vein with the dorsal arteries on either side above deep Buck's fascia over the corpus callosum is identified. The needle is inserted from either side of the probe using an IP technique and directed towards the dorsal artery, and LA is then injected just lateral to these arteries.

Lower Limb Blocks

The nerve supply to the lower limb is derived from the lumbosacral plexus.

Lateral Femoral Cutaneous Nerve

This is a purely sensory nerve arising from the dorsal divisions of L2 and L3. The nerve emerges from the lateral border of the psoas muscle and then runs down and lateral across the iliac fossa before passing beneath the inguinal ligament just medial to the anterior superior iliac spine (ASIS). It divides into an anterior branch supplying the anterolateral thigh and a posterior branch supplying the lateral area from the greater trochanter to the mid-thigh region.

Indications

Slipped upper femoral epiphysis (used in conjunction with a femoral block).

Technique

A linear probe is placed just inferior to the ASIS in a transverse plane. The space between sartorius and tensor fascia lata is identified; within this fascial plane, a small elliptical nerve may be identified (Figure 15.12). An IP needling technique is used to deliver 0.1–0.3 ml kg^{-1} of LA.

Femoral Nerve Block

The femoral nerve is the largest branch of the lumbar plexus arising from the dorsal divisions of the second to fourth lumbar nerves. It emerges from the lower border of psoas and passes underneath the inguinal ligament into the femoral triangle. At the level of the inguinal ligament, it lies deep to fascia lata and iliaca in a groove between the iliacus and the psoas muscle; it is separated from the femoral vessels, which lie in a separate fascial compartment medial to the nerve. It supplies the anterior compartment of the thigh.

Indications

Femoral fracture or osteotomy. Patella reconstruction.

Technique

A linear multi-frequency transducer is placed on the inguinal crease. The femoral vein and artery are identified. The nerve is found lateral to the femoral artery in a triangular hyperechoic area (Figure 15.13). The needle is inserted OOP/IP (from lateral to medial). Often more than two 'pops' are felt as the needle pierces the fascias; ensure that the LA is deposited under the fascia iliaca and not in the iliacus muscle deep to the nerve. The increased contrast between the LA and nerve allows the latter to be imaged better. The nerve should be surrounded with LA.

Adductor Canal Block

The aim of this block is to minimise loss of motor function. As such, the nerves usually involved are the saphenous nerve and the nerve to vastus medialis.

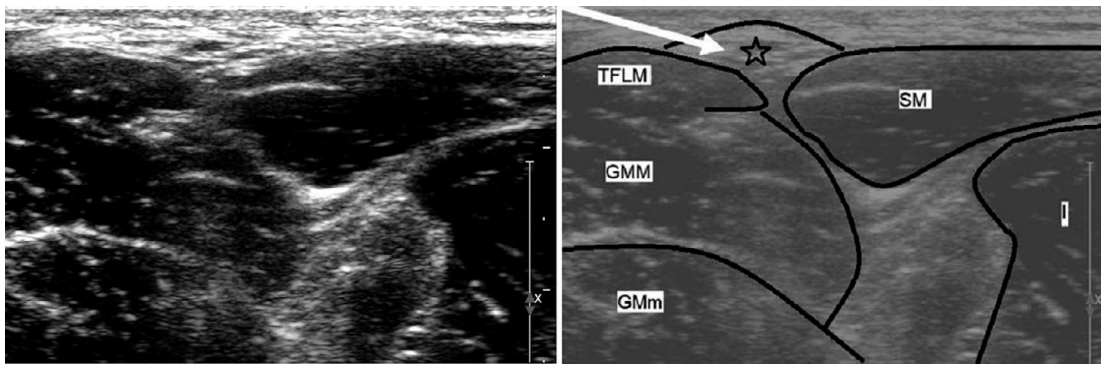

Figure 15.12 Ultrasound appearance of the lateral cutaneous nerve of the thigh ( ), tensor fascia lata muscle (TFLM), gluteus maximus (GMM), gluteus medius (GMm), sartorius (SM) and iliacus (I).

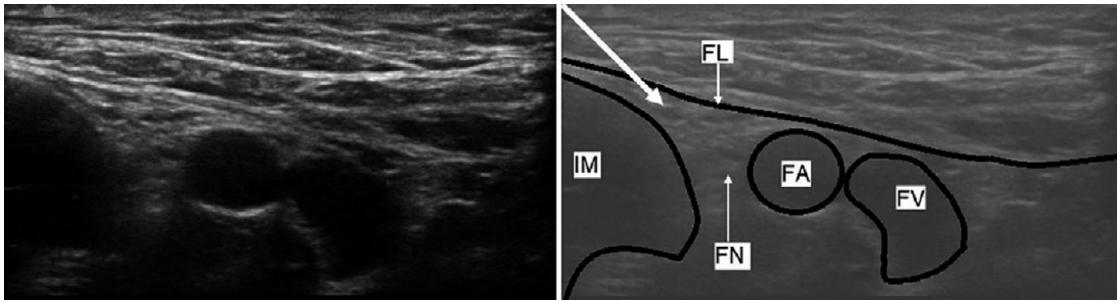

Figure 15.13 Ultrasound appearance of the femoral canal, showing the fascia lata (FL), iliacus muscle (IM), femoral nerve (FN), femoral artery (FA) and femoral vein (FV).

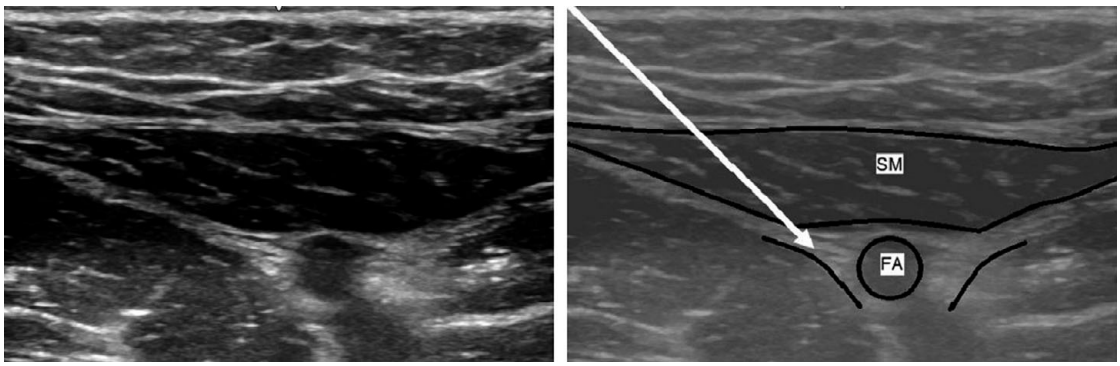

Figure 15.14 Ultrasound appearance of the adductor canal, showing sartorius muscle (SM) and the femoral artery (FA).

Indications

Knee surgery, such as ACL reconstruction.

Technique

The leg is positioned slightly externally rotated. A linear transducer is placed transversely over the junction of the middle and distal third of the thigh. The femoral vein and artery are identified lying beneath the sartorius muscle. The nerves are found anterolateral to the femoral artery (Figure 15.14). The needle is inserted IP and LA injected to surround the structures.

Fascia Iliaca Block

This block is used for above-knee surgery as it blocks the femoral (100%), lateral femoral cutaneous (90%) and obturator (75%) nerves with a single injection. It is more successful than the '3-in-1' block. The nerves lie in a compartment which is bound superficially by the fascia iliaca (investing the iliacus muscle), superiorly by the iliac crest and posteriorly by the psoas muscle.

Technique

A linear probe is placed in a longitudinal plane just medial to the ASIS. The iliacus muscle is identified and the probe moved cephalad, following the muscle as it passes over the pelvic brim. The needle is inserted IP from caudad to cephalad so the tip is positioned beneath the fascia iliaca. The LA is injected and the fascia lifted off the muscle; the needle can then be carefully advanced farther and the fascial plane dissected open farther. A large volume of LA (0.5 ml kg^{-1}, maximum 20 mls) is needed to get the required spread (Figure 15.15).

Sciatic Nerve Blocks

The sciatic nerve has tibial and common peroneal components. It enters the gluteal region from the pelvis through the greater sciatic foramen and runs down between the ischial tuberosity and the greater trochanter of the femur. It usually divides at the apex of the popliteal fossa, though this can occur anywhere along the course of the nerve. As it exits the gluteal region, it is usually accompanied by the posterior cutaneous nerve of the thigh on its medial side.

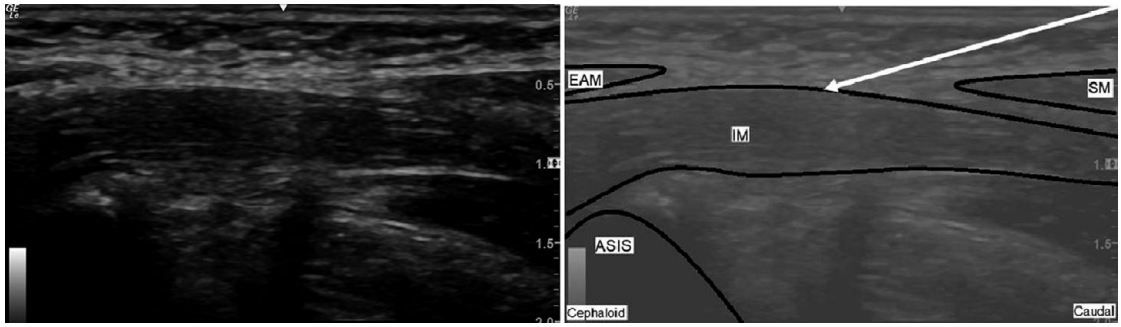

Figure 15.15 Ultrasound appearance of the fascia iliaca overlying the iliacus muscle (IM), the external abdominal oblique muscle (EAM), sartorius muscle (SM) and the anterior superior iliac spine (ASIS).

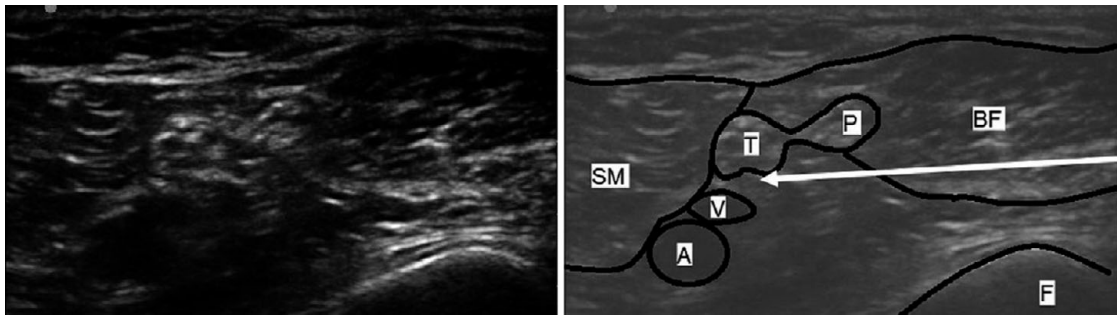

Figure 15.16 Ultrasound appearance of the popliteal fossa showing semimembranosus muscle (SM), biceps femoris (BF), tibial (T) and popliteal (P) nerves, popliteal artery (A) and vein (V) and the femur (F).

The nerve supplies the skin on the posterior thigh, the hamstrings, the biceps femoris muscles and most of the leg below the knee joint except for the area supplied by the saphenous nerve.

Popliteal Block

Indications

When used with a saphenous or femoral nerve block, a popliteal block can be used for any operation below the knee, such as club foot surgery.

Technique

The child is placed in the lateral position with the leg to be blocked on the top and straight. The linear probe is placed slightly superior on the popliteal crease. The popliteal vessels are identified. The tibial branch of the sciatic nerve is usually found slightly superior and lateral to the popliteal vein. Once identified, continue scanning proximally along the nerve to find the common peroneal nerve, which appears to join the tibial to form the sciatic nerve. Measure the depth to the nerve at this point, as this is probably the best site for injection (Figure 15.16). A 22G regional block needle is inserted in-plane into the lateral side of the thigh at the depth previously measured. The needle is advanced deep to the nerve until a subtle give is felt and half the LA is injected. The injection normally improves visualisation of the nerve. The needle is then withdrawn and directed superficially to the nerve where the rest of the LA is injected.

If it is difficult to identify the nerve above the popliteal crease, tilting the probe caudad or cephalad may help. Also, dorsiflexion and plantar flexion of the foot will produce the 'seesaw sign', where the tibial and peroneal components slide against one another and help with their identification. In cerebral palsy patients, nerve identification may be challenging owing to muscle fibrosis obscuring the nerve. The branching of the sciatic can occur more proximally, so scanning the nerve through its entire course is advised.

Infragluteal Block

Indications

Hamstring release.

Technique

The sciatic nerve is targeted in the groove where it lies between the ischial tuberosity and the greater trochanter of the femur. With the child lying supine, the leg is held straight. In patients under 50 kg, a linear probe will suffice; thereafter, a curvilinear probe may serve better. The probe is placed transversely just below the subgluteal crease; substantial pressure needs to be applied. The main difficulty with this block is the lack of vascular markers to indicate where the nerve may be found. Firstly, identify the femur, then observe the fascial planes as they come together to a point level with the anterior surface of the femur (Figure 15.17). The sciatic nerve is found at this juncture of fascial planes; due to its anisotropy, the probe will need to be angled to improve visualisation. Where the nerve is still not visible, reposition the probe longitudinally and scan from lateral to medial; as the nerve is passed over, a thick hyperechoic band will be seen. Stop at this point and rotate the probe transversely to see the nerve. Note the nerve depth and insert the needle IP from lateral to medial so that it comes in parallel to the probe at the nerve depth. LA (maximum 0.5 mg kg^{-1}) must be injected around the nerve.

Ankle Block

The foot is supplied by the terminal branches of the femoral and sciatic nerves. The tibial branch of the sciatic nerve divides into a posterior tibial and sural nerve in the leg.

The posterior tibial nerve lies on the medial side of the Achilles tendon, posterior to the posterior tibial artery, and supplies the heel, the skin of the sole of the foot and the deep structures of the foot. It is blocked at the level of the medial malleolus. The probe is placed in a transverse plane over the medial aspect of the ankle, just posterior to the malleolus. As it is the only motor nerve to the foot, a nerve stimulator can be used. The nerve is identified deep to the tibial artery and veins. An OOP approach is simplest.

The sural nerve receives a branch from the common peroneal nerve and passes lateral to the Achilles tendon behind the lateral malleolus to supply the lateral border of foot up to the tip of the little toe. Place a linear probe in a transverse plane over this area; the nerve travels with the short saphenous vein in a fascial channel superficially between tendons. An IP or OOP approach is used.

The deep peroneal nerve passes beneath the external retinaculum midway between the lateral and medial malleolus to lie lateral to the dorsalis pedis artery. The linear probe is placed over the dorsum of the foot and the dorsalis pedis artery identified; as the probe is moved proximally over the talus, the artery comes into contact with the bone. It is at this point the nerve can be seen to travel from lateral to medial over the artery. The deep peroneal nerve is blocked at mid-foot immediately lateral to the dorsalis pedis artery. The saphenous nerve, which is the terminal branch of the femoral nerve, runs downwards in front of the saphenous vein anterior to the medial malleolus and supplies the medial border up to the base of the great toe. The ultrasound probe is placed transversely over the vein and LA injected around the vein using an IP approach.

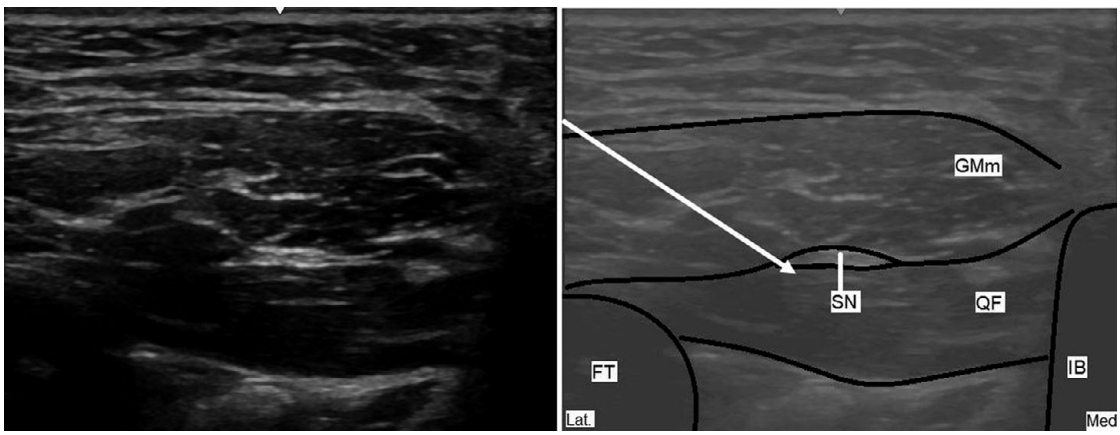

Figure 15.17 Ultrasound appearance of the sciatic nerve (SN) as it passes between the gluteus maximus muscle (GMm) and quadratus femoris (QF); the ischium bone (IB) and greater trochanter of the femur (FT) lie medially and laterally respectively.

The superficial peroneal nerve pierces the deep fascia in the lower part of the leg and runs in the superficial fascia over the dorsum of the foot. It supplies skin over most of the dorsum of the foot, except the cleft between the first and second toes, which is supplied by the deep peroneal nerve, and the medial and lateral borders of the foot. The US probe is placed over the lateral aspect of the lower leg in a transverse plane. Identify the anterior corner of the fibula and the fascial plane between the anterior and lateral peroneal compartments. As the probe is moved distally, the nerve can be seen to travel superficially to lie just beneath the skin.

Caudal Block

The sacrum is made up of five cartilaginous vertebrae that eventually ossify and fuse in adulthood. The posterior arch of the fifth and occasionally the fourth vertebra fails to fuse: this is the sacral hiatus. This area is covered by the sacrococcygeal membrane. At birth, the dural sac is low, at the S3/S4 vertebral level; by three years of age, it has ascended to the S2 vertebral level.

Indication

For surgery on the lower abdomen, pelvis and lower limbs.

Contraindications are as for any central block. Specific contraindications are the presence of cutaneous stigmata of spinal dysraphism, such as sacral pit and anorectal malformations. In these circumstances, the spine should be cleared by US and/or MRI prior to caudal.

Technique

The child is positioned in the lateral position with the knees drawn up towards the chest. The sacral hiatus is palpated in the midline; it forms the apex of a triangle formed by it and the two posterior superior iliac crests. For neonates, a 24G cannula is used, 22G thereafter. For the occasional older child where a caudal is appropriate, a 20G cannula is used. The US probe is placed in a transverse position at the bottom of the sacrum to identify the two hyperechoic sacral cornua (the 'frog eye' sign) with two transverse hyperechoic bands in between: the superficial sacrococcygeal membrane and the deeper (brighter) dorsal surface of the sacrum (Figure 15.18). The probe is then turned 90° to a longitudinal midline view of the sacral hiatus, the coccyx and the sacrococcygeal membrane. Scanning cephalad will allow the level of the dural sac to be identified. The cauda equina and the filum terminale can be appreciated in children under two years of age. A tethered cord is suspected where there is:

- An absence of cord pulsatility
- An excessively anterior placement of the cord within the vertebral column
- An abnormally low level of dural sac termination, or
- A thickened filum terminale

In these circumstances, the risks and benefits should be carefully considered before proceeding. The cannula is inserted IP from the coccygeal edge of the probe to pierce the sacrococcygeal ligament; it is

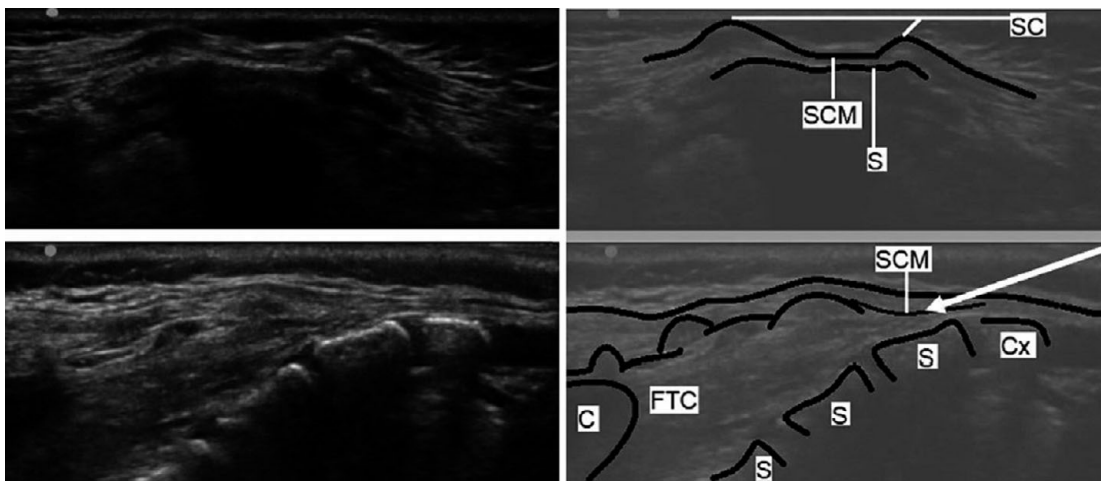

Figure 15.18 Ultrasound appearance of the caudal space, showing the sacral cornua (SC), sacrococcygeal membrane (SCM), sacrum (S), conus medullaris (C), filum terminale (FTC) and coccyx (Cx).

advanced a short distance with care not to puncture the dural sac. Needle position is confirmed initially with a 0.2 ml bolus of saline; correct placement is indicated by the anterior displacement of the posterior dura. LA can then be injected and its spread monitored by sliding the probe cephalad (this often requires a paravertebral probe angulation). Generally, 0.5 ml kg^{-1} is used to cover the sacral roots, and 1 ml kg^{-1} for high lumbar roots. Consider adding clonidine 1–2 mcg kg^{-1} to the LA.

Specific Complications

Dural tap, total spinal blockade, intravascular/intraosseous injection and perforation of the rectum.

Key Points

- Regional anaesthesia is an important component of paediatric anaesthesia and should be considered for all suitable cases.
- Neonates and infants are at greater risk of LA toxicity, owing to their lower protein binding and the immature blood–brain barrier.
- Cardiac arrhythmias and circulatory collapse may be refractory to treatment, and resuscitation should be prolonged.

Further Reading

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