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Review Article

Ultrasound-Guided Regional Anaesthesia in the Paediatric Population

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Ultrasound-guided regional anaesthesia is rapidly growing in popularity. Initially, most evidence was for the benefits when used in adults, but there is now a multitude of well-documented benefits in children. The practice of regional anaesthesia in children differs somewhat from that of adults in that in the majority of cases it is used for analgesia and performed under general anaesthesia to allow placement, rather than alone for anaesthesia as in adults. The purpose of this paper is to review the basic aspects of ultrasound regional anaesthesia before going into detail regarding specific techniques.

1. Introduction

Regional anaesthesia is an increasingly popular area within anaesthesia. In adult practice, it is used alone to provide anaesthesia, and in combination with general anaesthesia to provide analgesia. However, this differs in paediatric practice where it is almost exclusively performed in combination with general anaesthesia, as it would be neither safe nor possible to attempt in the awake child due to lack of cooperation and potentially painful muscle stimulation.

The benefits of regional anaesthesia in children are well documented. These include attenuation of the stress response, reduced opioid requirement, and therefore reduction in associated side effects, improved postoperative analgesia, and earlier extubation. Traditional methods of nerve localization include landmark and neurostimulation techniques, but these have significant failure rates.

Ultrasound is becoming an important adjunct in regional anaesthesia, allowing real-time imaging of nerves and their surrounding structures. This not only increases rates of achieving a successful block, by allowing visualisation of the injectate entering the correct plane, but can also reduce complication rates as surrounding structures can be avoided. In addition, the use of ultrasound allows a regional block to be performed in circumstances where nerve stimulation would not elicit muscle contractions, for example, following administration of muscle relaxant or after amputation [1]. Ultrasound-guided regional anaesthesia was first described in 1994 by Kapral et al. [2] and since then the supporting literature has continued to expand. Recommendation for the use of ultrasound in the insertion of central lines in the NICE guidelines of 2002 [3] has resulted in an increase in the availability of portable ultrasound machines in the theatre environment. A study in 2007 found that 86% of departments had access to ultrasound [4].

Using ultrasound (US) allows real-time imaging of the needle and the nerve throughout the procedure, therefore reducing complications of damaging structures in the vicinity of the nerve along with avoiding any direct injury to the nerve itself. The spread of the local anaesthetic (LA) can also be seen and assessed to ensure that it is directed into the correct plane and surrounds the nerve. US guidance, therefore, also facilitates the use of reduced volumes of LA, which is advantageous in the smaller child as this makes local toxicity less likely and permits the use of multiple individual nerve blocks.

The first step in performing an US-guided nerve block is preparation. Ensure that the US machine is available, charged, and working correctly. Flush your needle through to remove any air. In children less than 10 kg it may be prudent to start off with saline in your syringe and swap over to LA when you are satisfied with the needle tip position. For most paediatric nerve blocks a linear probe of greater than 10 MHz is appropriate; select one with a suitable footprint; generally this means a probe of 25 mm width for those patients under 15 kg and a 50 mm probe in those patients greater than 15 kg. Adjust the US machine settings so that the highest frequency is used for the estimated depth of target; in paediatrics, this will be usually anything above 10 MHz. Set a depth deeper than what you expect the target to be. Check your probe orientation. Some models of machine allow you to choose a specific tissue type, for example, nerve. Apply enough ultrasound gel to prevent air interference. Once the patient is anaesthetised, position yourself, the equipment, and the US machine ergonomically so that the US image is easy to see and the equipment is to hand. The procedure should be carried out under aseptic conditions; for single shots, a simple sterile dressing over the probe head is adequate; for catheter techniques, full aseptic precautions and a sterile sheath are employed. An initial "scout" scan is performed to locate the target nerve/fascial plane and to identify vulnerable structures such as vessels. Colour Doppler should be employed in all scans to search for vessels. During this process the depth should be adjusted so that the target is in the middle of the screen and the gain optimised. Although both in-plane and out-of-plane needling techniques can be used for the majority of blocks, the former is generally preferable due to greater needle visibility. Catheters are generally difficult to identify, their position can be confirmed by gentle pulling (looking for tissue movement) and by injecting down them whilst scanning for the spread of injectate.

2. Truncal Blocks

The intercostal nerves are the anterior primary rami of the spinal nerves T1–T11. The typical intercostal nerves supplying the thoracic wall are T4–T6. The upper thoracic nerves (T1–3), in addition, join the brachial plexus and the lower five thoracic nerves (T5–12) in conjunction with L1 nerves supply the abdominal wall.

3. Thoracic Paravertebral Block

The aim of this block 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 is formed by the parietal pleura and the posterior wall by the superior costotransverse ligament (see Figure 1).

3.1. Indications: Thoracotomies and Upper Abdominal Procedures. Although commonly done unilaterally, bilateral paravertebral blocks have been described and both single-shot and catheter techniques are used. Alternatively, a catheter can be placed by the surgeon under direct vision during thoracotomy.

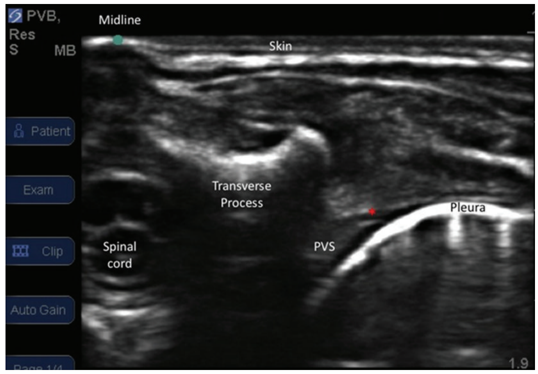

Figure 1: Ultrasound view of paravertebral space. Probe in a transverse paramedian position. *Internal intercostal membrane.

Contraindications include empyema and tumour occupying the paravertebral space. It may not be possible to find the space easily in children with kyphoscoliosis. Also, scarring from previous thoracotomy or inflammation, for example, can reduce the success of both locating the space and the spread of the local anaesthetic.

3.2. Techniques. The patient is placed in lateral position with the operative side uppermost and knees bent towards the chest. The level of block is dictated by the surgery, T5 for thoracotomies and T10 for abdominal surgery. US can be used to assess the depth to the transverse process and pleura prior to the landmark technique. Alternatively, US is used to identify the paravertebral space, guide needle insertion, and confirm correct spread of injectate. Both in-plane and out-of-plane techniques have been used, with the former nothing less than a perfect visualisation of the needle should be accepted as the needle is being directed towards the spinal cord. A volume of 0.5 mL/kg is injected, its craniocephalad spread is then assessed, and in neonates, it is possible to identify epidural spread.

3.3. Complications. Pneumothorax, contra lateral paravertebral spread, epidural spread, and dural tap.

4. Rectus Sheath Block

The rectus sheath is formed from the aponeuroses of the lateral abdominal muscles and has an anterior and posterior wall. The sheathes enclose the rectus muscles and fuse 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 5 thoracic nerves can be blocked.

4.1. Indications. Pyloromyotomy, umbilical hernia, and duodenal atresia.

4.2. Technique. The patient is positioned supine. The US technique is performed by placing the probe in a transverse

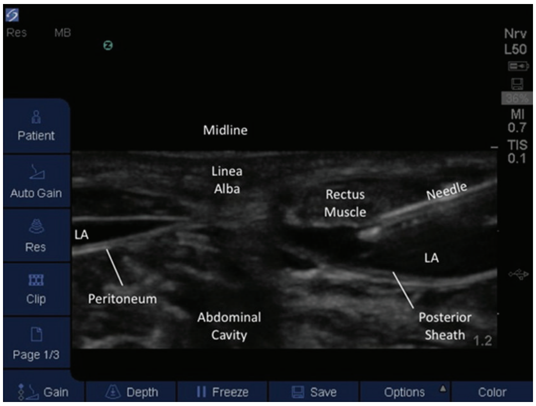

Figure 2: Rectus sheath block as seen by ultrasound. Probe in transverse position just superior to the umbilicus. LA: local anaesthetic.

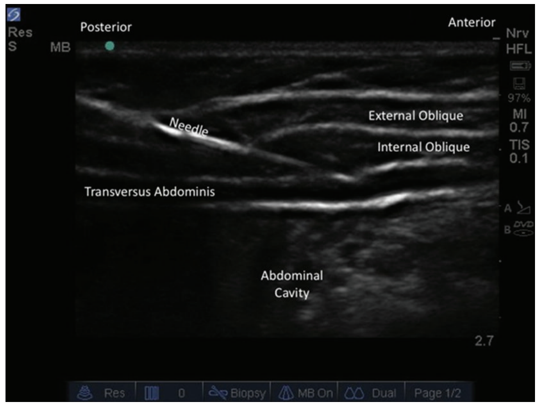

Figure 3: Transversus abdominis plane block as seen via ultrasound. Probe-positioned transverse over the lateral wall of the abdominal wall, midway between the subcostal margin and iliac crest.

plane just above the umbilicus. The linea alba is identified and the probe moved laterally, to identify the rectus muscle enclosed in its sheath. The peritoneum with the bowel underneath can be seen deep to the posterior sheath. As the probe is moved laterally the lateral abdominal muscles are imaged. Use of the colour Doppler will allow the identification of the epigastric vessels within the rectus muscle. A 22 g regional block needle is inserted in plane from lateral to medial and advanced through the anterior sheath and the rectus muscle to reach the plane between the muscle and posterior sheath. Aim for a shallow needle insertion as this allows the tip of the needle to more safely enter the fascial plane. After aspiration 0.5 mLs of LA is injected to ensure the muscle splits from the posterior sheath; the rest of the LA is then injected (0.1–0.2 mL/kg per side) (see Figure 2). Often the needle tip is not inserted far enough and an intramuscular injection is performed; very carefully advance the needle and a "pop" will usually be felt. Placing the probe longitudinally allows assessment of craniocaudal spread. The procedure is then repeated on the opposite side. This block is best learnt on older patients prior to attempting the procedure on neonates, because in the latter the muscle layers are only a couple of mm thick.

4.3. Complications. Intraperitoneal injection.

5. Transversus Abdominis Plane (TAP) Block

The lateral abdominal wall is made up of the external oblique, internal oblique, and transversus abdominis muscles. It is between these inner two muscles that the anterior primary rami of the lower 6 thoracic and the 1st lumbar nerves pass.

5.1. Indications. It is used unilaterally, for example, appendicectomy, inguinal hernia repair, and iliac crest bone graft. Alternatively, it can be performed bilaterally for laparoscopic operations and lower abdominal incisions, but it must be remembered that it does not provide visceral analgesia.

The subcostal approach provides analgesia above the umbilicus and is therefore suitable for subcostal incisions, for example, cholecystectomy.

5.2. Technique. The patient is positioned supine. The probe is placed in the transverse plane on the lateral abdominal wall halfway between the costal margin and the iliac crest. All three layers of muscles and the peritoneum can be imaged, though in the smallest neonates muscle, differentiation can be difficult. It is best to count the muscle layers from inside to out as the subcutaneous fat in larger patients can mimic a muscle layer to the inexperienced practitioner. A 22 g regional block needle is inserted in plane in an anterior-posterior direction. The angle of insertion is such that it will traverse through the external and internal oblique muscles to reach the plane posterior to the mid-axillary line thus blocking the lateral branches of the nerves (see Figure 3). A small volume of LA is injected to confirm correct placement of the needle seen as splitting of the two muscle layers, a total of 0.5 mL/kg/side is injected.

The subcostal approach to the TAP block is a technique where the LA is injected in the same plane as described above, however at a higher level. The ultrasound probe is placed in an oblique position under the 12th rib and moved laterally until the 3 muscle layers can be clearly identified.

5.3. Complications. Intraperitoneal injection, bowel perforation, and visceral injury.

6. Ilioinguinal and Iliohypogastric Nerve Block

The iliohypogastric nerve supplies the gluteal region and the skin over the symphysis pubis. The ilioinguinal nerve supplies the area of skin beneath that supplied by the iliohypogastric nerve and the anterior scrotum. There is much anatomical variation of nerve position between the abdominal wall muscles; this has resulted in many landmark techniques; none of which have a success rate greater than 70–80%.

6.1. Indications. Inguinal hernia repair, hydrocele.

6.2. Technique. The patient is positioned supine. Place the probe on an imaginary line between the anterior superior iliac spine (ASIS) and the pubic tubercle. One end of the probe should rest on the ASIS. The ASIS is seen as a bony triangular shadow (anechoic shadow with a hyperechoic border). The three lateral abdominal muscle layers can be identified inserting into the ASIS; as the probe scans the area, the external oblique muscle is observed thinning out to form its aponeurosis. Deep to the muscles, the peritoneum, bowel, and lying on the inner aspect of the ilium, the iliacus muscle is identified. Rarely the femoral nerve can be seen lying on the iliacus muscle. The iliohypogastric and ilioinguinal nerves are seen as small hypoechoic ellipses between the innermost two muscles close to the ASIS. Both an in-plane and out-of-plane technique can be used. In expert hands, as little as 0.075 mL/kg is used with an impressive 95% success rate.

6.3. Complications. Femoral nerve block (10% incidence with landmark technique), Intraperitoneal injection.

7. Lower Limb Blocks

7.1. Sciatic Nerve Block. The sciatic nerve has tibial and common peroneal components. It enters the gluteal region from the pelvis through the greater sciatic foramen, before running down the leg 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 proximally. As it exits the gluteal region, it is usually accompanied by the posterior cutaneous nerve of the thigh on its medial aspect.

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

7.1.1. Indications. In isolation, it is useful in ankle and foot surgery. In combination with a saphenous or femoral nerve block, it will provide analgesia for all procedures below the knee.

7.1.2. Technique. a variety of approaches have been described using US-guided techniques, including subgluteal [5, 6], midthigh [7, 8], popliteal [9], and more recently an anterior approach in adults [10]. The popliteal approach is most commonly used and is facilitated by placing the patient in the lateral position, with the operative side uppermost. The upper leg is slightly bent and rested on the flexed lower leg. The probe is placed transversely on the popliteal crease. Using colour Doppler, the popliteal vessels are identified. The tibial nerve is visualized just posterior to the popliteal vein; as the probe is scanned proximally, the common peroneal nerve can be seen laterally moving medial to join the tibial nerve (see Figure 4). Identification of the nerves can be enhanced by performing the see-saw sign. This entails passive or active dorsi/plantar flexion of the ankle leading to a rocking of the nerves within their fascial plane. Unfortunately, this is not possible in children with fixed flexion deformities. An in-plane technique is preferable, with out-of-plane being used for catheter insertions. A significant proportion of children presenting for surgery has cerebral palsy; the older they are, the more fibrosed their muscles can become; this causes distortion of the anatomy, and the fibrosed muscle is more hyperechoic than normal potentially obscuring the nerves. Where muscle spasms are expected to be a major problem postoperatively consider using high concentrations of local anaesthetic, for example, 0.5% levobupivacaine to induce a profound motor block.

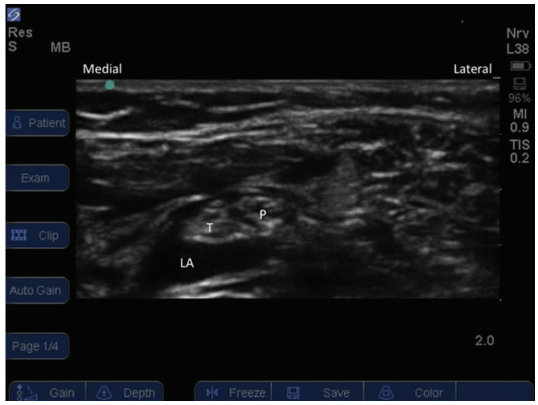

Figure 4: Ultrasound view of the sciatic nerve at the popliteal level. Probe positioned transverse, approximately 3 cm superior to the popliteal crease. LA: local anaesthetic, T: tibial nerve, and common peroneal nerve.

7.2. 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 the psoas muscle, runs between the psoas and the iliacus muscle, 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 and 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.

7.2.1. Indications. In isolation, femoral nerve block provides analgesia for femoral fracture, and post-op analgesia for knee surgery. In combination with sciatic nerve block, it can provide analgesia for all procedures below knee.

7.2.2. Technique. Place the probe just below and parallel to the inguinal ligament. Using the colour Doppler, identify the femoral vein and artery, and the superficial circumflex iliac vessels as they pass directly over the femoral nerve. The nerve is found lateral to the femoral artery in a triangular hyperechoic area. The regional block needle is inserted using either an out-of-plane or in-plane (from lateral to medial) technique. The former technique may be more suitable for catheter placement. Often more than two pops are felt as this needle pierces the fascias; ensure that the local anaesthetic is deposited under the fascia iliaca and not in the iliacus muscle deep to the nerve. The nerve should be surrounded with LA without exceeding toxic doses.

Lower down the leg, the individual branches of these nerves can be blocked, around the ankle, for example, to provide more isolated analgesia for procedures on the foot.

7.2.3. Complications. Damage to surrounding vasculature.

8. Upper Limb Blocks

8.1. Brachial Plexus Block

8.1.1. Interscalene Approach. The brachial plexus at this level lies superficially between the anterior and middle scalene muscles. Current literature is scarce in children, although in adult it does imply a higher success rate with ultrasound guidance than with electrical stimulation [11, 12].

Indication. The main indication for this technique is shoulder surgery, which is uncommon in the paediatric population.

Technique. The block is best performed with the head slightly turned to the contralateral side, and in young children positioning can be optimized by using a head ring and a small roll between the scapulae.

Using US as guidance, identification of the major structures begins with the trachea in the midline, moving laterally to the lateral lobe of the thyroid, the carotid artery and internal jugular vein, and finally the sternocleidomastoid muscle. Deep to the sternocleidomastoid muscle is the interscalene groove formed by the scalenus anterior and medius muscles, in which the brachial plexus nerve roots are seen as a series of hypoechoic round structures with hyperechoic borders. The minimum amount of LA to fully surround the nerve roots should be used. Either an in-plane or out-of-plane approach is suitable.

Complications. Phrenic nerve block, recurrent laryngeal nerve block, stellate ganglion block, epidural/spinal injection, vertebral artery puncture, bilateral spread, spinal cord injury, and pneumothorax.

8.1.2. Supraclavicular Approach

Indications. Procedures of the arm excluding the shoulder.

Technique. The patient is positioned as for the interscalene approach.

The probe is placed parallel to and just behind the clavicle. The subclavian artery is seen medially lying on or just anterior to the first rib. Colour Doppler must be used as there are numerous vessels to avoid in this area. The cervical pleura is seen at both sides of the rib and is seen to "slide" with respiration. The brachial plexus is found posterior to the subclavian artery as a cluster of hypoechoic nodules, described as a "bunch of grapes" (see Figure 5). An in-plane technique is recommended. The needle tip should be guided to a point 7-8 o'clock to the subclavian artery within the plexus and an initial test injection of saline can help confirm a good needle tip location.

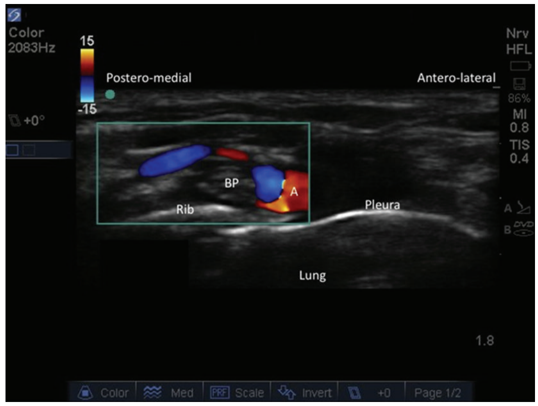

Figure 5: The brachial plexus approached at the supraclavicular level. The probe is positioned parallel to the clavicle to provide an oblique coronal view of the brachial plexus, BP. A supraclavicular artery.

Complications. Pneumothorax, and intravascular injection or vascular injury.

8.1.3. Axillary Approach

Indication. Procedures on the elbow forearm and hand.

Technique. Abduct the arm to 90° and place the probe transverse across the axilla. First, identify the axillary artery, veins, and then the individual nerves can be identified. The nerves may be highlighted by balloting the probe over the tissue; this causes the nerve to roll around the vessels. Usually the radial, median, and ulnar nerves can be blocked individually via a single insertion site. However the musculocutaneous nerve may require a second insertion site. Alternatively, the nerves can be found peripherally and backtracked to the axilla.

Complications. Intravascular injection.

9. Blocks of Individual Peripheral Nerves of the Forearm

The indications for these blocks as primary anaesthesia are limited but can be useful to supplement incomplete brachial plexus nerve blocks.

The median, ulnar, and radial nerves may be blocked in the mid-humeral region, the antecubital fossa, or the forearm—the latter two approaches are probably the easiest and are therefore described below.

The median nerve is first identified in the antecubital fossa medial to the brachial artery. With the probe placed in the transverse plane, the nerve is mapped distally to a convenient location in the midforearm to be blocked.

The ulnar nerve is located deep to flexor carpi ulnaris muscle in the proximal forearm and is joined by the ulnar artery as it passes distally. Therefore it is recommended to block this nerve in the midforearm, before it is in proximity with the artery.

The radial nerve enters the antecubital fossa laterally between the biceps tendon and brachioradialis muscle and can be seen to be divided into two hypoechoic ellipses—the superficial and deep branches. It is best to block the nerve proximal to this bifurcation [13].

10. Central Blocks

From birth, the process of full ossification of the spine takes approximately 20 years. The application of US to visualize the neuraxial structures is superior in the paediatric population. As US is blocked by bone, scanning of the anatomy can only occur through echo lucent windows. Imaging is also easier and more caudad as the echo lucent windows are larger. It is also preferable to scan with the probe placed paramedian longitudinal as once again a greater view is possible. In paediatrics, a linear probe is appropriate, though in large teenagers as with adults, a curvilinear probe is more suitable.

10.1. Caudal. The sacral hiatus is formed by the failure of the fifth (and sometimes the fourth) neural arch to fuse posteriorly. It is covered by the sacrococcygeal membrane (SCM), which consists posteriorly of sacral ligaments and anteriorly of ligamentum flavum. The distance from skin to epidural space is rarely greater than 2 cm, and in neonates, it is less than 0.5 cm.

10.1.1. Indications. Circumcision, orchidopexy, herniotomy, hypospadias repair, infraumbilical surgery, and lower limb surgery.

10.1.2. Technique. This block is usually performed with the standard landmark method; US is used to assess needle placement and LA spread. Rarely is an US-guided caudal warranted. Position the patient laterally with hips flexed. The sacral hiatus is the depression between and inferior to the sacral cornua. A preblock US assessment is performed to observe the level of the dural sac and angle of the caudal space; it is also useful in screening patients with stigmata of spinal dysraphism. The probe is placed initially in a midline longitudinal position; the probe can then be rotated into the transverse position over the sacral hiatus to confirm the anatomy (see Figure 6). Needle insertion is then performed; after negative aspiration, the probe is repositioned in the midline longitudinal position (see Figure 7). Care must be taken not to move the needle when scanning. An injection of 0.1 mL/kg or less of saline is injected; the saline is seen

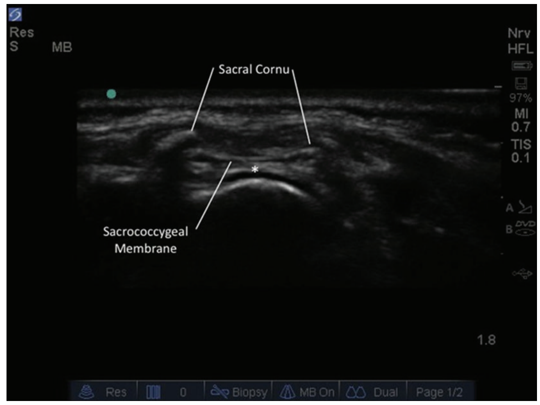

Figure 6: Transverse view of the caudal space. Probe positioned transversely over the sacral hiatus. *Caudal epidural space.

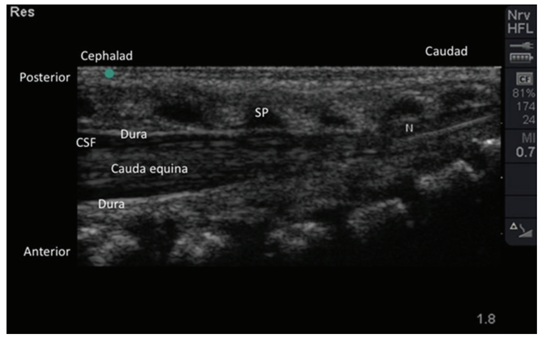

Figure 7: Longitudinal view of the caudal canal. Probe positioned longitudinally over the midline of the sacrum. SP: spinous process, N: needle tip, and CSF: cerebrospinal fluid.

entering the epidural space and pushing the posterior dura anteriorly. If the saline is not seen then modify the probe position, if it is not still observable, consider an intravascular placement and start again. When the needle is placed correctly, attach the LA; as the injection is performed the probe is moved cephalad to monitor spread. Where difficulty is found in needle insertion or where there is difficult anatomy, real-time needle guidance should be employed.

10.1.3. Complications. Dural puncture.

10.2. Epidural

10.2.1. Indications. The epidural space may be approached by thoracic, lumbar, sacral, and caudal routes. Therefore it is indicated in a wide range of procedures including thoracic, abdominal, pelvic, and lower limb.

10.2.2. Technique. The patient is positioned in the lateral position with neck and back flexed, and with knees pulled up towards the chest. Identify the level at which the block is required and mark this space. The epidural space is found using a loss of resistance technique and once this is confirmed, the catheter is inserted. The US can be used

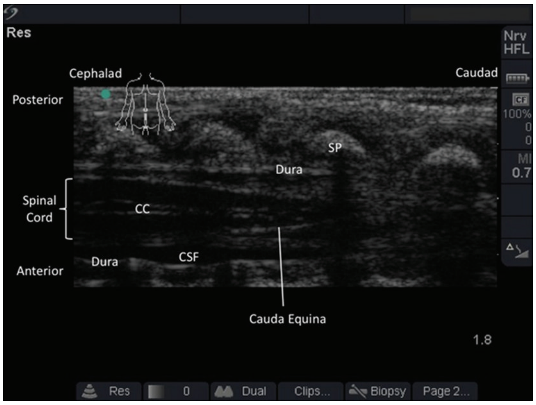

Figure 8: Spinal canal as seen via ultrasound. Probe positioned longitudinally over the midline of the thoracolumbar region. CC: central canal, SP: spinous process, and CSF: cerebrospinal fluid.

to measure the depth of the epidural space, level of conus medullaris, angle of insertion, and to confirm catheter tip location if required (see Figure 8). Ultrasound's ability to image is prohibited by bone, so with increasing age, (and therefore ossification) less of the spinal column contents can be observed. In the neonatal period, imaging in the midline longitudinal probe position is feasible, after this, a paramedian longitudinal probe position is required to obtain a view through the interlaminar space.

At this point in time, US for guided epidurals is the province of a few enthusiasts.

10.2.3. Complications. Epidural vessel puncture, dural puncture, post dural puncture headache, and high block or total spinal.

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