Ultrasound Guided Regional Anesthesia in Infants, Children and Adolescents

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INTRODUCTION

Regional anesthesia is experiencing resurgence in pediatric anesthesia. The use of a variety of techniques has improved with the use of ultrasound guidance. The increased safety of performing regional anesthesia with US-guidance has encouraged the practitioner to attempt to perform more difficult blocks compared to previously described using landmark techniques.1 The use of US-guidance can also allow minimal volumes of local anesthetic solutions thereby decreasing the potential risk of toxicity.2 This lecture will describe the equipment used for ultrasound guided pediatric regional anesthesia along with common applications of ultrasound guided nerve blocks. Central neuraxial as well as peripheral nerve blocks will be described with clinical techniques as well as images for reference while performing these blocks. Comprehensive reviews are available for greater depth of knowledge in this relatively newer field in pediatric anesthesia.3

EQUIPMENT

As the field of regional anesthesia is exploding, the use of ultrasound imaging is undergoing constant improvement. Several ultrasound imaging systems with the capability of offering a variety of applications including echocardiography have entered the market with greater emphasis on user-friendliness and portability. This may be of greater importance in the pediatric population since most of these blocks are performed in the operating room under general anesthesia. In children, it may be easier to perform regional anesthesia with deep sedation or under general anesthesia4 US probes commonly used in children include a high frequency hockey stick probe and a linear 25 mm high frequency probe. Since most of the neurovascular structures are located superficially in children, visualization of neural structures is easier with a high frequency probe. The physics and equipment descriptions can be found in textbooks on US guided regional anesthesia. US guidance can be used for central neuraxial blocks as well as for peripheral nerve blocks. A brief description of each of these blocks will be provided at this refresher course.

(i) Central neuraxial blocks:

Epidural Analgesia: Ultrasound imaging seems promising for use either pre-procedurally (prior to puncture) or during block performance (US-aided), although the latter may be most suitable in infants and children under 5 years of age where there is lack of significant ossification. The largely cartilaginous posterior vertebral column of neonates and infants enables good US beam penetration to view the spinal structures and can in some cases may enable a view of the needle tip trajectory.

TECHNIQUES

Sonoanatomy: A moderate-high frequency probe (hockey stick, 13-6 frequency probe) is utilized using a paramedian longitudinal view. The ‘window’ between the two spinous processes (appearing as a saw tooth hypoechoic structure) will allow the operator to visualize the anterior complex (anterior duramater, and the posterior longitudinal ligament), the posterior duramater and the ligamentum flavum. Our preference is to visualize the neuraxis using a paramedian approach. In a paramedian longitudinal view at the thoracic spine, the spinous processes are represented by slanted hyperechoic lines beneath the homogeneous-appearing paravertebral muscle mass. Dorsal shadowing will be apparent deep to the spinous processes and other posterior vertebral elements. The highly hyperechogenic ligamentum flavum and dura mater are captured lying in the alternate ‘windows’, and the underlying spinal cord appears largely hypoechoic with an outer bright covering of the pia and a central line of hyperechogenicity (median sulcus). In the first report of US imaging in central blockade, Chawathe et al. performed a pilot study in 12 patients (1 day old to 13 months) to evaluate the possibility of detecting catheters, and verifying their placement, within the epidural space after placement (within 24 hours) via the direct lumbar route.5 The important point from this paper is that US imaging (specifically using the midline approach) of static structures such as catheters can be performed, yet only reliably in very young patients where much of the posterior bony elements of the spinal column may exist as cartilage allowing good US beam penetration. An optimal angle of probe alignment needs to be evaluated in children and surrogate markers for viewing needles and catheters may be necessary to facilitate a dynamic technique. Willschke et al placed epidural catheters under real-time US-guidance using a paramedian longitudinal imaging plane in 35 neonates.6 Needle tip entry and the injection of local anesthetic solution within the epidural space were used to confirm epidural placement. Epidural catheters could only be identified via surrogacy through tissue movement (i.e., downward movement of the duramater) and fluid injection. This is the preferred technique that we use. It is important to
note that loss of resistance has to be carried out with the use of saline since LOR with air will obliterate the US imaging of the structures.

**Caudal Needle Placement**

Caudal blocks, including both single-shot caudal and lumbar or thoracic epidural catheters advanced from the caudal epidural space (thus avoiding the spinal cord), is a commonly practiced regional anesthesia technique in children. Although this technique is practiced with the identification of landmarks, there is a small, but not insignificant chance for failure.

**Sonoanatomy:** Ultrasound imaging at the midline using both transverse and longitudinal alignment of the probe should be performed prior to needle placement in order to appreciate the patient’s anatomy and to identify the sacrococcygeal ligament, dural sac and cauda equina. A linear high-frequency small footprint or hockey-stick probe is a suitable choice, although a larger footprint may be used when viewing the longitudinal axis to allow an adequate field of view. Placing the probe initially in a transverse plane at the coccyx and scanning in a cephalad direction can help with landmark identification particularly during training in sonoanatomy. This view allows a good delineation of the sacral hiatus; the sacral cornua are viewed laterally (as “humps”) and the sacral hiatus is located between an upper hyperechoic line representing the sacrococcygeal membrane/ligament and an inferior hyperechoic line representing the dorsum of the pelvic surface (base) of the sacrum. Placing the probe longitudinally between the sacral cornua will capture the dorsal surface of the sacrum, the dorsal aspect of the pelvic surface of the sacrum and the sacrococcygeal ligament. The sacrococcygeal ligament covers the sacral base beyond the end of the dorsum of the sacrum. It appears as a relatively thick linear hyperechoic band, sloping caudally. The sacral hiatus is identified as a hypoechoic space located between the dorsum of the sacrum and the dorsal side of the pelvic surface of the sacrum. In older patients where the structures may be ossified at the midline, the paramedian longitudinal view may be necessary since it will allow the US beam to penetrate the spaces on either side of the spinous processes. This paramedian view would allow appreciation of the ventral movement of the duramater during fluid injection, but would not allow a real-time view of the needle along its axis.

**Technique:** During or after skin puncture with the needle, both transverse and longitudinal sonographic planes can be used for confirming caudal epidural needle placement. Roberts at al. published a prospective observational study of 60 children, in which they determined whether a saline test bolus could be reliably imaged with US in order to confirm cannula placement in the caudal epidural space. (Roberts, 2005 #29203; Roberts, 2005 #29204) The longitudinal plane may allow a view of the long axis of the needle as it penetrates the sacrococcygeal ligament. This technique may be particularly beneficial to allow adjustments in needle angle to ensure adequate length of advancement and depth of penetration without intraosseous placement. This is our preferred technique. When introducing a catheter into the caudal space to reach the lumbar or thoracic spine, a similar technique to the above is used for cannula placement and the catheter is viewed during advancement using US imaging at the level of the spine above the sacrum.

(ii) **Upper Extremity Blocks**

The most common approach to the brachial plexus in infants and children is the axillary approach and the supraclavicular approach. With the advent of US guidance, the interscalene approach has resurfaced as a viable technique for placement of a catheter.

**Interscalene Block**

**Sonoanatomy:** A small footprint hockey stick probe will allow optimal recognition of the superficial structures in this region for infants and small children. In a transverse oblique plane at the level of the cricoid cartilage and at the posterolateral aspect of the sternocleidomastoid muscle, the superficially-located sternocleidomastoid muscle appears triangular in shape and overlies the internal jugular vein and common carotid artery. In small infants, the US-probe footprint is wide enough to capture the great vessels along the brachial plexus in the same image screen. Lateral to the vessels and deep to the sternocleidomastoid muscle lies the anterior scalene muscle, and more posterolaterally, the middle and posterior scalene muscle (the latter two often appearing as a single mass). The hyperechoic (bright)-appearing tissue forming a lining around the muscles is presumably the fibrous tissue of the interscalene sheath. Brachial plexus trunks and/or roots in this sagittal oblique section are usually visualized as three (or more) round or oval-shaped hypoechoic (grey or dark) structures, lying between the scalenus anterior and medius muscles. It is important to note that the dorsal scapular artery is located in the scalenus medius, this may predispose the patient to develop a hematoma if the block is performed using an in-plane technique. Continuous interscalene blockade was performed for a 10-year old girl in the Philippines during a plastic surgery medical mission with an intravenous catheter. Without the availability of perineural catheters as well as stimulating needles, a 22 gauge Angiocath was used for the block, utilizing an in-plane alignment to the posterior edge of the probe using the US equipment borrowed from the obstetric suite. This case demonstrates the ubiquitous nature of US equipment in most medical centers across the globe.
Supravacuicular Block

**Sonoanatomy:** The probe is placed along the upper border of the clavicle. The carotid and the internal jugular vein are recognized. The probe is moved laterally while looking for the pulsation of the subclavian artery. The supravacular brachial plexus is located lateral to the artery and appears hyperechoic mixed with hypoechoic shadows in a grape like fashion surrounding the artery.

**Technique:** The supraclavicular block is performed using a high frequency hockey stick or linear probe. The subclavian artery to identified, and inferior to it is the dome of the pleura and lateral and inferior to it is the 1st rib. The plexus can be accessed using an in-plane approach from laterally or using an out of plane technique from superiorly. Nerve stimulation can be used in conjunction with US-guidance for this block.

**Comment:** When performing a supraclavicular block there is a greater risk of pneumothorax as the apex of the lung lies just medial to the first rib, not far from the plexus; the distance of the plexus from the lung being especially short in children. It is critical to ensure that clear visibility of the needle shaft and tip is obtained by aligning the needle in-plane to the ultrasound probe at all times. Auscultation of the lungs should be performed before and after performance of the block as well as prior to discharge to detect clinical signs of pneumothorax. A simple algorithm to check neural viability prior to performance of the block is used in our institution to perform the block after surgery. The viability of nerves is performed using a ‘thumbs up’ sign for radial nerve; flexion of PIP for median nerve and finger scissoring for the ulnar nerve. This has proved to be valuable especially in children who may have fractures and may be prone for damage.

Axillary Block

**Sonoanatomy:** With the probe placed perpendicular to the anterior axillary fold, a short-axis view of the neurovascular bundle can be obtained; the biceps brachii and coracobrachialis muscles are seen laterally; the triceps brachii muscle is medial and deep to the biceps brachii muscle. The anechoic and circular pulsating axillary artery lies centrally, adjacent to both the biceps brachii and coracobrachalis muscles, and is surrounded by the terminal branches of the brachial plexus. The median nerve is typically located superficial and between the axillary artery and biceps brachii muscle, the ulnar nerve is commonly located medial and superficial to the artery, and the radial nerve often lies deep to the artery at the midline. At this level, the musculocutaneous nerve is located between the biceps brachii and coracobrachialis muscles.

**Technique:** The terminal nerves are visualized in an axial plane, the probe is placed in the axillary fold. A needle is placed in an in-plane approach to access the median, radial and ulnar nerves individually. Local anesthetic solution is placed to surround the plexus in its entirety to provide an adequate blockade. We feel that the use of ultrasound may allow reduction in dosing for the block although further studies are required to prove the pharmacodynamic ability of US guidance with decreased volumes for axillary blocks in children.

**Comment:** Multiple injections and needle redirections are commonly required to ensure circumferential spread of the local anesthetic solution around each of the individual nerves. Since there is an abundance of vessels in this region, complete avoidance of vessel puncture can be a challenge even when utilizing ultrasound imaging. It is important to understand that the plexus remains very close to the surface and hence the needle should be directed cautiously while this block is attempted. Smaller doses can be used to provide an adequate blockade of this plexus in infants and children.

Lower Extremity Block

**Femoral Nerve Block**

**Sonoanatomy:** Similar to using conventional technique, arterial pulsations of the femoral artery is the key landmark when using US guidance for femoral nerve blockade. With the probe placed at the level of and parallel to the inguinal crease, the nerve appears lateral to the large, circular and anechoic femoral artery (color Doppler may be used to identify the femoral artery and vein). The nerve often appears triangular in shape and may be variable in size. The fascia lata (most superficial) and iliaca (immediately adjacent to the nerve and in fact separating the nerve from the artery) are seen superficial to the femoral nerve and often appear as bright and longitudinally angled echogenic signals.

**Technique:** A linear high frequency US probe is placed at the level of the inguinal crease and using an in-plane approach, the femoral nerve is accessed from the lateral aspect. Once the needle enters the fascia iliaca compartment, local anesthetic solution is injected to envelope the nerve entirely. If a nerve stimulator is used adjunctly, quadriceps contraction is elucidated. Although one cannot be sure about intraneural injection while using US guidance, it may be prudent to place the needle in the fascia iliaca compartment and not place it directly into the neural plexus. An out of plane technique may facilitate easier placement of a catheter for postoperative pain control.

**Sciatic Nerve Block:**

**Sonoanatomy:** The sciatic nerve block is commonly used in children for providing analgesia for lower extremity surgery. We use it in combination with a femoral nerve block for providing analgesia for knee surgery. The sciatic nerve is imaged easily at the level...
of the popliteal crease. The biceps femoris tendon is identified. The popliteal artery is identified with the popliteal vein superficial to the artery. The tibial nerve is located immediately superficial to the nerve in most patients and should be used a landmark for imaging the nerve. On scanning further laterally, the common peroneal nerve can be located.

**Technique:** In the supine, lateral or prone position, the popliteal fossa crease is identified, a linear US probe is placed at the level of the popliteal crease. The popliteal artery is identified, the popliteal vein is superficial to it, and superficial to that structure is the tibial nerve. The US probe is moved laterally to visualize the common peroneal nerve. The probe is advanced cephalad to where the common peroneal and tibial nerves coalesce to form the single sciatic nerve. A needle is placed in an in-plane orientation; the sciatic nerve can be stimulated if a stimulating needle is used to elicit inversion or eversion of the foot.

**BLOCKADE OF THE ANTERIOR TRUNK**
Among many blocks performed at the anterior trunk, ilioinguinal/iliohypogastric nerve blockade is one of the most commonly performed blocks for surgery in the inguinal region and may be one of the most common peripheral nerve blocks in children. (Pediatric Regional Anesthesia Network PRAN, 2010) Various other nerve blocks are also becoming popular to provide analgesia for procedures in the umbilical or epigastric regions. Ultrasonography can be particularly beneficial for truncal blocks in children due to the close anatomical relations between the nerves and various critical abdominal structures.

**Ilioinguinal/Iliohypogastric Nerve Block**

**Sonoantomy:** A linear high frequency probe is placed immediately medial to the superior aspect of the anterior superior iliac spine (ASIS) to capture a short-axis view of the ilioinguinal nerve sandwiched between the internal oblique abdominal and transverse abdominal muscles. The ASIS appears hypoechoic (due to dorsal shadowing beyond the highly-reflective peristomeum) and nodular-shaped at the lateral edge of the screen. The lateral abdominal muscles will appear with multiple hyperechoic dots within a hypoechoic background. The nerve can be identified as an elliptical-oval shaped structure with a hyperechoic film surrounding a hypoechoic core.12 A recent study examined the use of ilioinguinal nerve blocks in addition to a caudal block for prolonging the duration of analgesia; it was demonstrated that the block was effective only in patients undergoing hernia repair.13

**Technique:** A hockey stick probe will be suitable for many infants and younger children, since the nerves are closely situated beneath the skin (8 mm on average) and medial (7 mm on average) to the ASIS. The probe is placed with the axis pointed towards the umbilicus. A needle is inserted in an in-plane approach between the internal oblique and the transversus abdominis muscle. Local anesthetic solution is injected to hydro-dissect between the two layers thereby providing a blockade of the L1 nerve root. We use a volume of 0.1mL/kg with a total maximum volume of 5mL for this blockade.

**Rectus Sheath Block**

**Sonoantomy:** The rectus sheath is located between the rectus abdominis muscle and the posterior rectus sheath. A small footprint probe will be suitable for viewing unilateral anatomy. The anterior and posterior aspects of the rectus sheath and the enclosed rectus abdominis muscle are visualized. The sheath appears hyperechoic with multiple linear layers, lying on the anterior and posterior aspects of the rectus muscle.

**Technique:** A linear high frequency probe is placed on the abdominal wall lateral to the umbilicus. Using an in-plane approach and coming in from laterally, a needle is inserted posterior to the rectus abdominis muscle but anterior to the posterior rectus sheath. Superior displacement of the rectus abdominis muscle is seen with injection of the local anesthetic solution. This block can be used for umbilical hernia repairs as well as most midline abdominal surgeries involving the T10 distribution.14

**Transversus Abdominis Plane (TAP) Block**

**Sonoantomy:** The layers of the abdominal wall can be easily distinguished using ultrasonography. The thoraco-lumbar nerve roots (T10 to L1) provide the sensory supply to the abdominal wall. The nerves run in a plane between the internal oblique and transversus abdominis muscle, hence referred to as the transversus abdominis plane or TAP. A linear probe placed along the lateral aspect of the abdomen can distinguish the various layers of the abdomen including from superficially, fascia/fat, external oblique, internal oblique and the transversus abdominis muscle. A blockade at this level can provide analgesia for anterior abdominal wall surgery. This may be especially useful in infants and children who may have underlying coagulopathy, spinal dysraphism or as a rescue block following a failed neuraxial blockade. The block has been demonstrated to be effective for abdominal surgery in the adult population.15

**Technique:** A simple step by step approach to this block has been recently described.16 A linear high frequency probe or a hockey stick probe is used for the procedure. Recognize the various layers of the abdomen. A needle is inserted in the in-plane technique to enter the plane between the transverses abdominis and the internal oblique. Local anesthetic
solution (0.2mL/kg) is injected. The downward movement of the transversus abdominis signifies correct placement of the needle in the TAP plane.

**Conclusion:** US-guidance for peripheral and central neuraxial blocks is becoming the mainstay of regional anesthesia in children. As equipment improves and becomes more cost-effective, the use of US guidance may become the norm rather than the exception. Multiple hands-on workshops offered by the IARS, ASA, ASRA and SPA may shed greater insight into some of the common techniques. The steep learning curve for US guidance can be offset by offering it as part of the routine curriculum for training residents and fellows in anesthesia training programs. Future studies with greater importance for pharmacodynamics and technique enhancement with importance to surgery-specific blocks may allow for better utilization of nerve blocks in infants, children and adolescents.

**REFERENCES**