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Review Article

Role of Ultrasound in Pediatric Anesthesia

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ABSTRACT

Aim of review: The use of ultrasound for diagnosis and intervention has become a mainstay in pediatric anesthesia. It is safe to provide nerve blocks, caudal, epidural and spinal blocks under general anesthesia in children. Ultrasound use enhances the safety of these procedures. There is a wide range of applications for ultrasound. This review aims at addressing the most common applications for ultrasound in pediatric anesthesia.
Methods: Systematic literature search and author expertise are incorporated in this review.
Recent findings: Ultrasound is routinely used by pediatric anesthesiologists for diagnosis, regional anesthesia, and vascular access. Focused cardiac US (FoCUS) and Point of care US (PoCUS) is gaining popularity due to the ease of access to an ultrasound in the peri-operative setting.
Summary: Ultrasound in pediatric anesthesia increases safety and has become the standard of care for central vascular access and regional anesthesia under general anesthesia. All practitioners who provide pediatric anesthesia care should become familiar with both the diagnostic and therapeutic uses for ultrasound in children.

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The use of Ultrasound (US) for diagnosis and Intervention has become a mainstay in pediatric anesthesia. Multiple studies have shown that it is safer to provide nerve blocks, caudal, epidural and spinal blocks under general anesthesia. US use enhances the safety of these procedures. There is a wide range of applications for ultrasound. This review aims at addressing the most common applications for ultrasound in pediatric anesthesia.

Common diagnostic uses of ultrasound include evaluation of airway, pulmonary, cardiac, vascular, abdominal, and spinal structures.

Common interventional uses of ultrasound include intubation and confirmation of endotracheal tube placement, central and peripheral vascular access, neuraxial and regional nerve blocks.

Most of these are discussed in this article.

Point of care ultrasound (PoCUS) is a growing part of anesthesiology – it is the quick bedside use of ultrasound for rapid diagnosis and is soon becoming a part of the decision making an algorithm for perioperative diagnosis. Some common uses are bladder and gastric volumes in pre and post-operative periods.

Likewise, the Focused Cardiac US (FoCUS) is another increasingly used modality. Some examples include a murmur that has not been evaluated preoperatively or sudden unexplained hypotension in the operating room.

Focused cardiac ultrasound (FoCUS) is increasingly used in adults to diagnose acute perioperative conditions and is gaining popularity in the perioperative pediatric setting (1, 2). Implementation of the point of care ultrasound (POCUS) in medical school and residency curriculum has significantly improved user accuracy and sensitivity for diagnosis and intervention. The American College of Cardiology and the American Society of Echocardiography guidelines in pediatric cardiac echo state that appropriate use of diagnostic cardiac USG in symptomatic patients can improve patient care (2).

The aim of this review article is to discuss pediatric-specific uses of the ultrasound and is meant for readers with prior ultrasound use and knowledge.

Probe Selection and Frequencies

There are four commonly used probes in the clinical practice (Figure 1).

1. A planar linear high frequency (4–15 MHz) probe has a large footprint with good resolution for superficial structures and is versatile in pediatric imaging and nerve blocks.
2. A curvilinear multi-frequency (2–9 MHz) probe is used for assessment of neck and airway and abdominal structures in older children.
3. A linear 'hockey stick'-high frequency (4–15 MHz) probe has a small footprint and can be used in small areas for imaging – short neck, vascular access, intercostal etc. especially in small infants.
4. A wideband phased array (1.7–4.0 MHz) probe can be used for pediatric cardiac imaging.

Techniques

In-Plane Technique

The needle is placed in the plane of the ultrasound beam of the transducer. As the needle is advanced the whole needle shaft and tip can be observed.

Figure 1. Commonly Used Probes.

Out of Plane Technique

The needle is inserted perpendicular to the transducer. The needle shaft is imaged in a cross-sectional plane as a bright dot on the image. The tip of the needle position cannot be reliably ascertained.

Diagnostic Applications

Airway Structures and Trachea

Oropharynx, tonsils and trachea can be visualized by ultrasound in a perioperative setting prior to any airway management (3)(Figure 2). This is especially useful to identify neck masses and tracheal position. It can also be used to identify tracheal size to determine appropriate endotracheal tube (ETT) size to optimize successful placement especially in patients with difficult airways (4). Both curvilinear and linear probes can be used to evaluate oropharynx and airway structures based on the size of the pediatric patient. Scanning sequentially from the mentum of the mandible to the hyoid bone will provide information about supraglottic structures and above the sternal notch inferior to the larynx. Subglottic airway diameter predicts optimal outer ETT diameter over standard criteria (4, 5) this is helpful in instances of disproportionate airway sizes in syndromic children and in children with abnormal body mass index. ETT depth can also be ascertained using the US by inflating the cuff

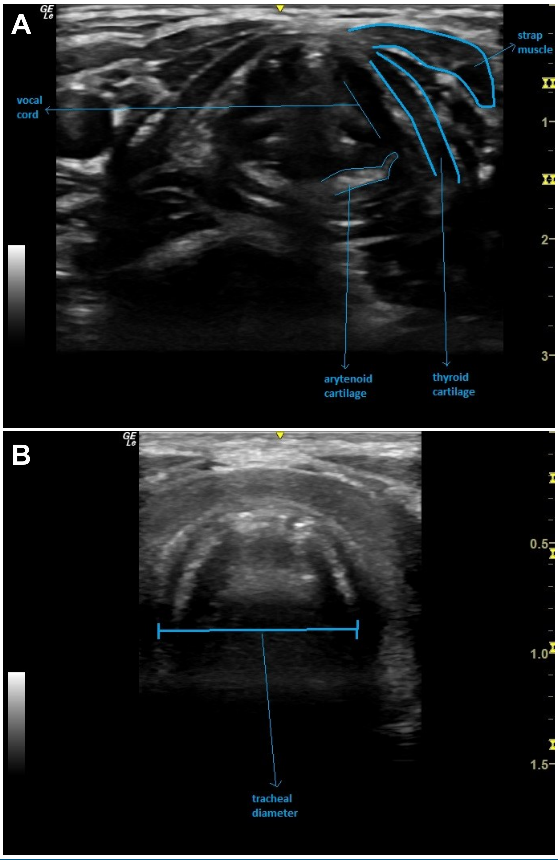

Figure 2. Airway Structures and Trachea. A. Airway structures. B. Tracheal diameter estimation.

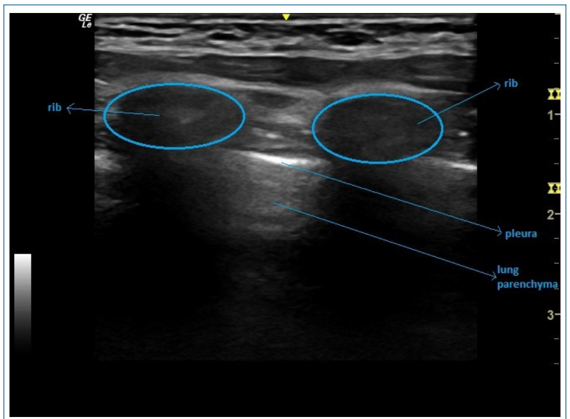

Figure 3. Lung and Pleura.

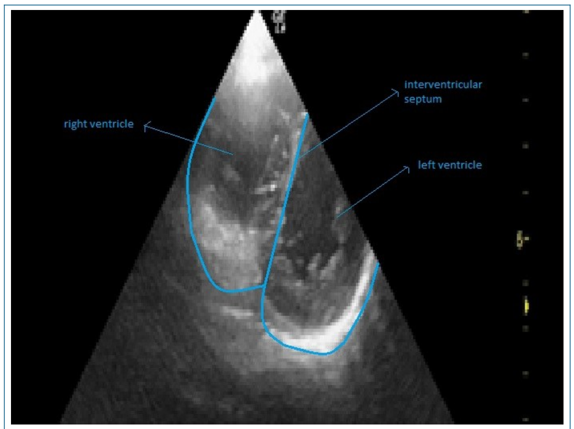

Figure 4. Cardiac Short Axis View.

with saline to detect tracheal versus endobronchial intubation (6).

Pulmonary

The pleural surface of the lungs can be examined with ultrasound (Figure 3). Probe selection is based on age. A micro- convex probe can be used to overcome ribcage interference in smaller children. It is valuable in the rapid detection of a pneumothorax in the operating room. Bilateral anterior imaging at different lung points helps with accurate detection of lung pathologies like pneumothorax, edema, and blebs. Lung parenchyma can also be evaluated and is useful as a diagnostic and prognostic tool for atelectasis, effusion, lung congestion, pneumonia, pneumothorax and diaphragmatic motion anomalies (7). Different grades of lung congestion can be determined based on the amount of "B" lines – None, few, moderate and severe (7). The same US windows can be used to ascertain lung parenchyma evaluation, detection of pneumothorax and effusions.

Cardiac and Vascular

Focused cardiac ultrasound (FoCUS) is increasingly used in adults to diagnose acute perioperative conditions and is gaining popularity in the perioperative pediatric setting (1, 2) (Figure 4). Implementation of a point of care ultrasound (PoCUS) in medical school and residency curriculum has significantly improved user accuracy and sensitivity for diagnosis and intervention. The American College of Cardiology and the American Society of Echocardiography guidelines in pediatric cardiac echo state that appropriate use of diagnostic cardiac USG in symptomatic patients can improve patient care (2, 8-10).

Abdominal

The FAST exam in pediatrics includes the assessment of lung or abdominal status, intravascular volume status based on the size of the inferior vena cava and its respiratory variation (11) (Figure 5). This is especially useful in pediatric trauma where vital signs are not predictive of volume status until late stages of severe intravascular volume depletion (12-16).

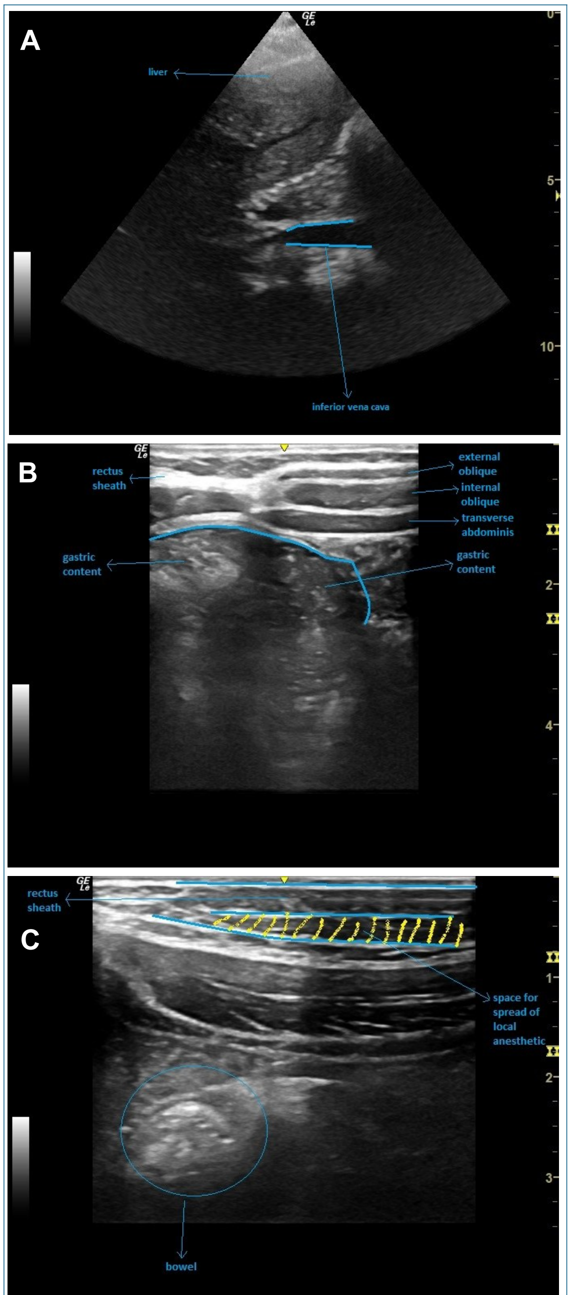

Figure 5. Abdominal USG.
A. Evaluation of inferior vena cava (IVC) (respiratory variation in IVC size can be a predictor of volume status).
B. Gastric contents and muscle layers.
C. Transversus abdominis plane block.

Procedural Guidance

Caudal and epidural space evaluation peri-operatively assesses for any neuraxial abnormalities (17) (Figure 6).

Extremities

Bedside assessment of circulation and vascularity and flow can help intra-operative interventions. Ulnar and radial artery circulation, vasospasm and flow through peripheral vasculature prior to cannulation can help avoid complications.

Interventional Applications

Airway

Ultrasound can be a useful adjunct tool for managing difficult airways (Figure 2). Ultrasound can be utilized to locate the location of the trachea in tracheal deviation caused by neck masses, oropharyngeal obstruction and to estimate the tonsillar size and to guide the endotracheal tube (ETT) under direct ultrasound visualization. It can also be used to confirm accurate ETT placement.

Vascular Access

Central vascular access is now almost exclusively done under ultrasound (18) in pediatrics as it decreases the risk of complications, especially with variable anatomy (Figure 7). A linear probe with a small footprint with high resolution is usually used in an out of plane technique for a cross-sectional view of the internal Jugular vein. It is recommended that in situations of difficult intravenous access earlier use of ultrasound improves the success of vascular access and improved patient care (19-21).

Peripheral Vascular Access

Based on the size of the child, a hockey stick probe or a small linear probe with a small footprint can be used in an out of plane technique for a cross-sectional view. The catheter placement in the vessel can be confirmed in an in-plane longitudinal view.

Neuraxial and Regional Nerve Blocks

Head and Neck Blocks

Head and neck blocks are commonly performed for facial plastics and ear surgery. It provides superior postoperative pain control without the use of narcotics and decreases the risk of apnea in the post-operative period. These blocks are frequently performed in the outpatient setting and can also decrease the risk for emergence agitation by blocking the component associated with inadequate pain management. Commonly performed blocks are maxillary, mental, occipital and greater auricular nerve blocks.

Maxillary Block

Indications: Cleft lip and palate surgery

Anatomic landmarks and technique: The frontozygomatic angle, at the junction of the upper edge of the zygomatic arch. The needle is inserted perpendicular to the skin and advanced to reach the greater wing of sphenoid at approximately 20 mm depth, then withdrawn a few millimeters and redirected toward the nasolabial fold in a 20° forward and 10° downward direction. The progression in the pterygopalatine fossa is 35 to 45 mm. Loss of resistance after passing through the temporalis muscle determines the puncture depth, and the real-time ultrasound visualizes the spread of local anesthetic in the pterygopalatine fossa. After a negative blood aspiration test, 0.15 ml/kg of 0.2% ropivacaine is injected on each side (22).

Mental Nerve Block

Indications: Procedures involving hemangiomata, laceration repair, and other surgery involving the lower lip, skin of the chin, and the incisive and canine teeth.

Anatomic landmarks and technique: The hypoechoic mental foramen is identified by scanning the mandible in a cephalad direction from the inferior border. A small amount of local anesthetic is injected after negative aspiration for a blood test is performed.

Occipital Nerve Block

Indications: can be used for post craniotomy pain control, revision or insertion of ventriculoperitoneal shunts, as well as for diagnosis and treatment of pain secondary to various headache syndromes, such as a primary headache, cervicogenic headache, migraine, occipital neuralgia,

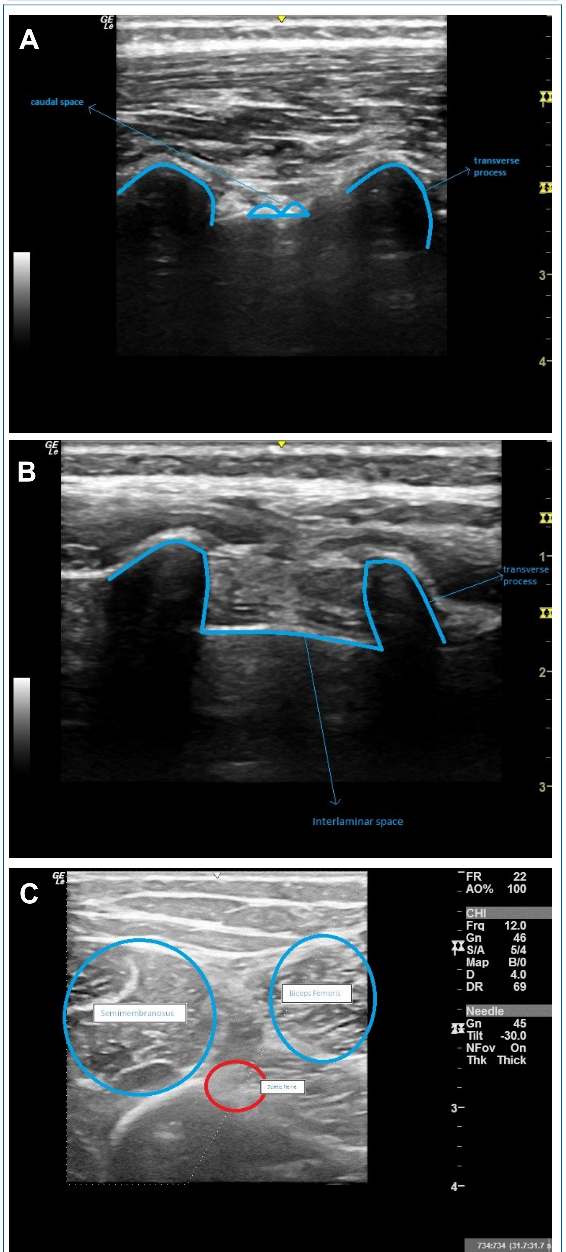

Figure 6. Neuro-Axial and Lower Extremity.
A. Caudal space – the point of entry for block highlighted.
B. Epidural space.
C. Sciatic nerve.

and headaches.

Anatomic landmarks and technique: At the superior nuchal line, the US probe is initially placed in a transverse plane with the center of the probe lateral to the external occipital protuberance. Hockey stick probe is usually used and a few mL of 0.2% ropivacaine is injected after negative blood aspiration test.

Great Auricular Nerve (GAN) Block

Indications: Provides postoperative pain relief in patients undergoing mastoidectomy and otoplasty. A significant advantage is a reduction in postoperative nausea and vomiting in children undergoing this block compared to the intravenous opioids (23, 24).

Anatomic landmarks and technique: GAN is identified and blocked at the level of cricoid on the sternocleidomastoid muscle. Moving the ultrasound probe cranially on the muscle can identify the nerve a small amount of local anesthetic can be injected to achieve appropriate post-operative pain relief.

Ilioinguinal Nerve Block

Indications: Pain control for groin surgery, inguinal hernia repair, orchidopexy or hydrocele repair.

Anatomic landmarks and technique: A linear high-frequency probe is placed in the superior aspect of the anterior superior iliac spine (ASIS); a short-axis view of the ilioinguinal nerve between the internal oblique and transverse abdominal muscles is obtained and local anesthetic is injected in a cross-sectional view to hydro dissect the plane (21, 25).

Rectus Sheath Block

Indications: Pain control for umbilical surgery and midline abdominal incisions.

Anatomic landmarks and technique (Figure 5): A linear high-frequency probe is used laterally to the umbilicus in an in-plane technique. Rectus abdominis muscle gets displaced superiorly on injection. Midline abdominal surgeries and umbilical hernia repairs are common indications.

Transversus Abdominis Plane (TAP)

Indications: abdominal wall incisions like laparotomy, laparoscopic surgery.

Anatomic landmarks and technique (Figure

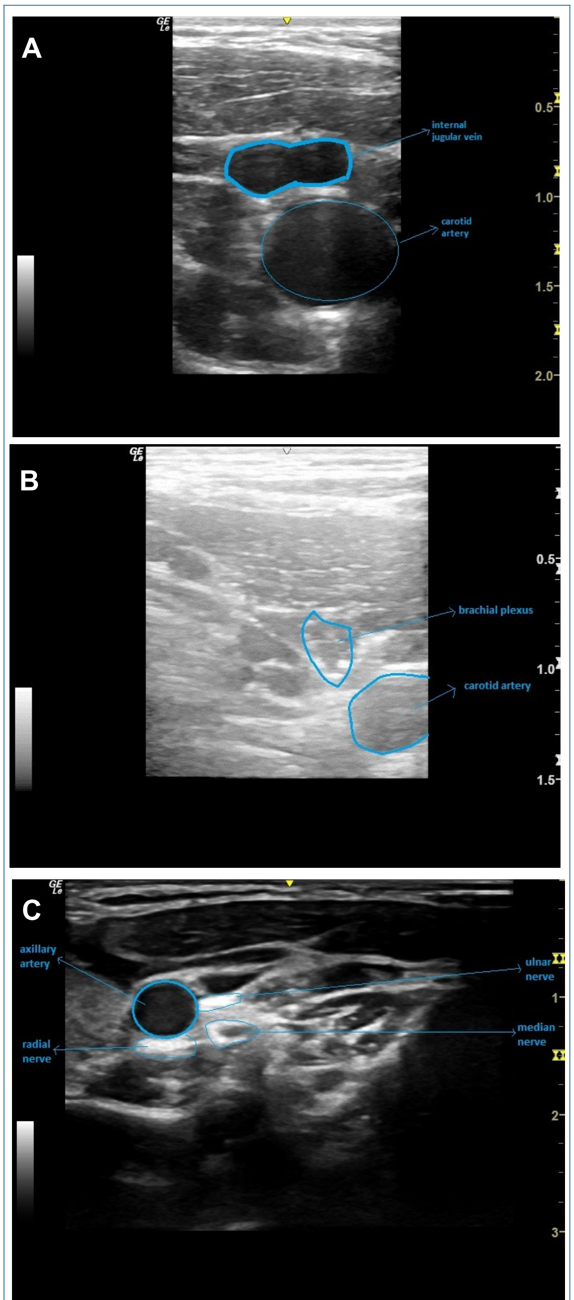

Figure 7. Neck and Axillary Structures.
A. At the level of C6 carotid artery, internal jugular. B. At the level of C6 carotid artery, brachial plexus. C. Axillary artery and brachial plexus at the axilla.

5): A linear high-frequency probe is used in an in-plane technique after the transverses abdominis and the internal oblique muscles are identified. The local anesthetic spread will block innervation to abdominal skin, muscles and parietal peritoneum (26).

Neuraxial Blocks

Caudal Block

Linear 25 mm high-frequency probe is commonly used since most neurovascular structures are superficial and better visualized with high-frequency probes (27). A high-frequency hockey stick probe can also be used based on the size of the infant or child. Both transverse and longitudinal views of dural sac, cauda equina, and sacrococcygeal ligament are ascertained prior to needle placement. Transverse views identify the sacral hiatus (hyperechoic) and cornua (humps). Longitudinal views are helpful for placement of the catheter and needle tip position confirmation with a saline test bolus (Figure 6).

Epidural Block

A hockey stick, 13-6 frequency probe is commonly used since the vertebral column is still cartilaginous in children under 5 years of age and the needle tip can be easily visualized (Figure 6). A paramedian longitudinal view is used to image the two spinous processes, ligamentum flavum, posterior longitudinal ligament and posterior duramater. The needle tip and catheter placement can be ascertained in the same view (27).

Upper Extremity Blocks

A small footprint high-frequency probe is usually used to identify neurovascular structures as they are very superficial.

Inter-Scalene Block

Sternocleidomastoid muscle, cricoid cartilage, internal jugular vein, and common carotid artery – all usually in the same screen in small children are used as landmarks. The brachial plexus is visualized as dark oval hypoechoic structures between the anterior and middle scalene muscles lateral to the large vessels and below the sternocleidomastoid (Figure 7). Confirmation of catheter and test dose can be done under direct visualization of the catheter tip (27).

Supraclavicular Block

A high-frequency linear probe is placed along the upper border of the clavicle and moved laterally to identify the subclavian artery and dome of the pleura. Care should be taken to prevent pneumothorax due to proximity to the pleura and apex of the lung (27).

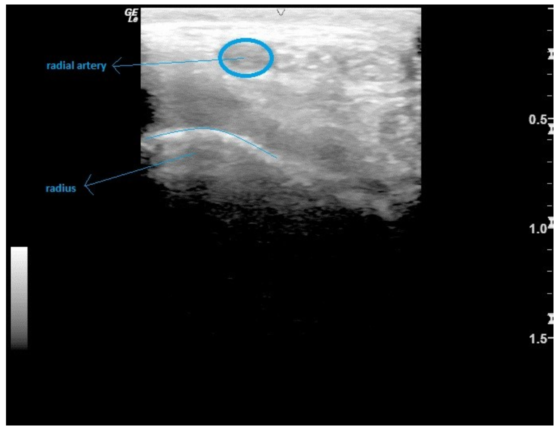

Figure 8. Radial Artery at the Wrist.

Axillary Block

A high-frequency linear probe is placed perpendicular to the anterior axillary fold. A short-axis view of the neurovascular bundle, biceps brachii, coracobrachialis and triceps brachii muscles is visualized (Figure 7). The pulsating axillary artery lies centrally, surrounded by the nerves. The radial nerve lies below the artery midline. The median nerve lies superficial to the artery and the ulnar nerve medial to the artery in a superficial plane. Between the biceps brachii and coracobrachialis muscles lies the musculocutaneous nerve. Smaller doses can provide adequate blockade of the brachial plexus in infants and children by multiple redirections and achieving circumferential spread (27). Careful injection under ultrasound with repeated aspirations is necessary as multiple vascular structures lie close to the nerves in the head and neck region.

Lower Extremity Blocks

Femoral Nerve Block

A linear high-frequency US probe is commonly used. An in-plane technique can be used at the inguinal crease. Circumferential injection of the nerve can be easily achieved with smaller volumes. A nerve stimulator can be used to avoid intraneural injections. The catheter can be placed in the same view or in an out of plane view (24).

Sciatic Nerve Block

The linear or curvilinear probe is commonly used in lateral, prone or supine position (with leg flexed) (Figure 6). Choice of probe is based on the size of the child. The popliteal artery is identified at the popliteal fossa and traced cephalad to the position just above the bifurcation of the sciatic nerve to common peroneal and tibial nerves. The needle can be placed using an in-plane or out of plane technique and a catheter can also be left in place. Smaller volumes can again provide circumferential spread. When combined with a nerve stimulator to prevent perineural injection, this technique can be a very safe block (28).

Conclusions

Ultrasound use in pediatric anesthesia has gained significant use. The Pediatric Regional Anesthesia Network (PRAN) data has shown that performing regional blocks are safer in children under general anesthesia than sedated (29). Focused cardiac USG and Point of care USG (FoCUS and PoCUS) are gaining significant popularity in all sub-specialties (21). The Society for Pediatric Anesthesia and the American Society of Anesthesiologists offer courses to practicing anesthesiologists to get proficient in both regional and diagnostic techniques using ultrasound.

The authors declare no conflicts of interest.

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