Point-of-care ultrasound is currently widely used across the landscape of pediatric care. Ultrasound machines are now smaller, are easier to use, and have much improved image quality. They have become common in emergency departments, ICUs, inpatient wards, and outpatient clinics. Recent growth of supportive evidence makes a strong case for using point-of-care ultrasound for pediatric interventions such as vascular access (in particular, central-line placement), lumbar puncture, fluid drainage (paracentesis, thoracentesis, pericardiocentesis), suprapubic aspiration, and soft tissue incision and drainage. Our review of this evidence reveals that point-of-care ultrasound has become a powerful tool for improving procedural success and patient safety. Pediatric patients and clinicians performing procedures stand to benefit greatly from point-of-care ultrasound, because seeing is believing.

The practice of modern medicine has been significantly changed by the use of bedside ultrasound. More than 30 years ago, ultrasound was introduced as a tool to improve provider performance and patient safety during central venous cannulation. Now, ultrasound machines are ubiquitous in their presence across the landscape of pediatric care. Greater familiarity with the technology has expedited technical performance in commonly encountered procedures, led to novel approaches to clinical challenges. Accumulating literature has led the American Academy of Pediatrics and Society of Critical Care Medicine to endorse ultrasound use within the scope of pediatric procedural performance. The European Society for Pediatric and Neonatal Intensive Care is currently working on evidence-based guidelines for the use of point-of-care ultrasound in PICUs and NICUs across Europe. The scope has widened among procedural applications and, although we anticipate a growing body of supportive literature, common sense tells us that visualization of equipment and anatomy is a benefit to both patients and providers. In this article, we highlight current and emerging applications in the field of pediatric procedural ultrasound.

ULTRASOUND-GUIDED PROCEDURES: BASIC PRINCIPLES

Axis and Orientation

When performing ultrasound-guided procedures, it is essential for the provider, procedural site, and ultrasound screen to be aligned (Fig 1A). For accurate procedural guidance, it is important to understand the axis and orientation of any anatomic structure with its corresponding ultrasound image. Any organ or vessel can be visualized in a short-axis view, or “out of plane” (when the ultrasound probe is placed perpendicular to the structure of interest; Fig 1 B and D), or in a long-axis view, or “in plane” (when the ultrasound probe is placed parallel or...
along the course of the structure of interest; Fig 1 C and E).

**Needle Visualization**

Identification of the needle tip at all times while performing a procedure will contribute to its success; however, this can be challenging and requires certain expertise. The needle appears as a bright echogenic dot or line in the short-axis view and long-axis view, respectively. It is often easy to visualize the needle tip in a short-axis view (Fig 2A, Supplemental Video 1) and by performing a 90° probe rotation the full length of the needle, and the needle tip will be seen in the long-axis view (Fig 2B).

**VASCULAR ACCESS**

Vascular access is the most common lifesaving procedure in medicine. Historically, palpation and anatomic landmarks have been used to guide arterial and venous line placement. Landmark techniques present unique challenges in pediatric patients because of significant variances in anatomic vascular structure orientation and size.\(^{10-12}\) Pediatric-specific literature has grown exponentially over the past decade with the development of international and national consensus recommendations supporting the use of ultrasound in vascular procedures.\(^9,13,14\) The correct choice of vascular access should be individualized depending on estimated length of therapy, diagnosis, patency of the venous system, and size of the patient.

**Peripheral Intravenous Access**

Peripheral intravenous (PIV) access is required in a variety of clinical settings. Ultrasound guidance is helpful in patients in whom vascular access is difficult to obtain secondary to inability to palpate peripheral veins or history of multiple previous punctures.\(^ {15}\) However, pediatric literature does not reveal a clear benefit for routine PIV placement.\(^ {16}\) The use of ultrasound guidance for PIV cannulation can circumvent the need for central venous line placement or surgical cutdown, which has been associated with increased risk of venous stenosis and strictures.\(^ {17}\) A high-frequency linear transducer is used to assess potential target vessels and to evaluate for vessel trajectory, depth, and the presence of bifurcations or venous valves to accurately select the best cannulation site (Fig 3, Supplemental Video 2). Verification of venous versus arterial structure before cannulation should be determined not only by easy compressibility of veins and lack of pulsatility but also, and most importantly, by confirmation of venous flow by using pulsed wave Doppler (Fig 4).

**Central Venous Access**

Pediatricians are often faced with balancing the benefits of central venous access with the risks associated with placement and maintenance of a central venous catheter (CVC), such as inadvertent arterial puncture, hematoma formation, thrombosis, pneumothorax, hemothorax, and nerve injury.\(^ {18}\) Ultrasound guidance for CVC placement can help avoid these complications by increasing first time success rate, decreasing failure rate, and decreasing incidence of inadvertent arterial puncture.\(^ {19-22}\) A recent meta-analysis of 23 pediatric studies confirmed that ultrasound guidance significantly reduced the risk of cannulation failure compared with the anatomic landmark technique.\(^ {23}\)
Internal Jugular Vein

The right internal jugular (IJ) vein is the most frequently accessed central vein by using ultrasound.9 Real-time ultrasound guidance of pediatric IJ CVC placement (Fig 5, Supplemental Video 3) is recommended by multiple national and international organizations and expert consensus statements.9,13,14,24,25 Several prospective studies have revealed that real-time ultrasound-guided IJ CVC placement leads to an overall decrease in complication rates and cannulation time.20,21,26

Femoral Vein

Femoral vein (FV) cannulation may be preferred by inexperienced operators, in emergent situations, in the setting of bleeding diatheses, or for cardiac procedures.27,28 Similar to IJ cannulation, ultrasound guidance of FV cannulation is recommended.9,13,23,24 Aouad et al29 randomly assigned 48 pediatric patients undergoing FV cannulation in the operating room and found that time to cannulation and first attempt success rate were improved by ultrasound guidance compared with the anatomic landmark technique. Furthermore, Iwashima et al30 reported that incidence of inadvertent femoral artery puncture was significantly reduced by ultrasound guidance. Continuous visualization of the femoral artery during vein cannulation prevents accidental arterial punctures, as shown in Fig 6 and Supplemental Video 4.

Subclavian and Brachiocephalic Veins

The use of ultrasound to guide cannulation of the subclavian and brachiocephalic veins has been described in children and neonates by using both the infraclavicular and the supraclavicular approach.30–33 These approaches are used especially when cannulation of the IJ is challenging, such as in neonates and children with short necks. These vascular sites have regained popularity recently with the introduction of ultrasound guidance and evidence supporting lower risk of complications and lower rate of thrombosis compared with IJ CVC placement.34,35 A prospective randomized study revealed that the supraclavicular approach yielded a shorter puncture time and decreased

FIGURE 2
Ultrasound view of needle tip. A, Short-axis view (“out of plane”) revealing needle tip (hyperechoic) in the middle of a vessel (or bull’s eye). B, Long-axis view (“in plane”) revealing needle shaft and tip entering a vessel.

FIGURE 3
Ultrasound view of BV bifurcation at the level of the elbow before PIV insertion. BV, basilic vein; MCV, median cubital vein.

FIGURE 4

FIGURE 5
Neck ultrasound for IJ CVC placement. A, Demonstration of left IJ and internal carotid artery adjacent to trachea. B, Short-axis view of needle tip (arrowhead) approaching the IJ vein. ICA, internal carotid artery; IJV, internal jugular vein.
incidence of guidewire misplacement compared with the infraclavicular approach. Within this study, no pneumothoraces or arterial punctures occurred, regardless of insertion site selection.31

Subclavian and brachiocephalic veins are not bilaterally symmetric, and the sharp angle of the right side while joining the superior vena cava (SVC) makes right-sided cannulations more challenging than left cannulations. Brachiocephalic vein cannulations offer the advantage of a long-axis approach with full visualization of the needle while accessing the vein behind the clavicle (Fig 7, Supplemental Video 5).

Peripherally Inserted Central Catheter

Peripherally inserted central catheter (PICC) lines are the central lines of choice in neonates after the first week of life, when umbilical lines are usually removed. Although it is occasionally necessary to place large-caliber CVCs in newborns, the insertion of 1F to 2.6F PICCs into peripheral veins is more common. The target vessels in infants with extremely low birth weight are small (1–2 mm), which makes vascular access in neonates challenging. Ultrasound offers a tool to improve success rates.36 Ultrasound guidance may improve success and safety for PICC placement, but to our knowledge, no randomized controlled trials used to compare ultrasound-guided PICC placement with landmark-guided PICC placement in preterm or term neonates exist. In the lower extremity, a common target vessel for PICC placement is the great saphenous vein, just above the medial malleolus or the popliteal vein. In the upper extremity, several veins in the antecubital fossa, cephalic, and basilic and brachial veins are common options. Radiography remains the classic method for evaluation of the PICC tip position after placement. In several studies, investigators have questioned its accuracy, reporting a discordance of 20% to 40% when radiography is compared with point-of-care ultrasound. Because the use of radiography may be misleading, ultrasound has been recommended for this purpose.37-40 A recent study in neonates revealed that point-of-care ultrasound used for PICC placement was associated with fewer catheter manipulations, fewer radiographs, and decreased time required for catheter insertion.4 It is not unreasonable to assume that point-of-care use should become the standard of care for tip position evaluation after placement in the near future.41 For lower-extremity PICCs, the tip is visualized in the longitudinal inferior vena cava view (Fig 8A). For upper-extremity PICCs, a high parasternal view is used to visualize the tip in the SVC (Fig 8B).

Arterial Access

Arterial catheterization is a standard procedure in neonates and children who are critically ill, which allows for both intermittent arterial blood sampling and continuous hemodynamic monitoring. Strong evidence in adults has revealed that the use of ultrasound guidance for peripheral artery catheterization improves first attempt success rate while reducing both the overall procedure time and the incidence of complications.42-46 In pediatrics, randomized studies have revealed that ultrasound guidance for radial artery cannulation is more successful and expeditious than the usual palpation technique.47 Both short-axis and long-axis approaches to arterial access have been described in the pediatric literature, each with its advantages. The short-axis approach allows for visualization of adjacent structures, and...
the long-axis approach allows for visualization of the posterior wall of the vessel during needle, wire, and/or catheter advancement. It is important to highlight that the smaller the infant, the more difficult it is to obtain a long-axis view of an artery 1 mm in diameter. On the basis of our experience in neonates, we recommend a short-axis approach (Supplemental Video 6).

**LUMBAR PUNCTURE**

Lumbar puncture (LP) is an essential procedure in pediatrics for establishing an infectious or metabolic diagnosis and determining treatment. LP failure (defined as the inability to obtain cerebrospinal fluid [CSF] or defined as obtaining a traumatic puncture) rates can be as high as 15% to 50%. Bedside ultrasound performed by pediatric providers may allow for a safer procedure and increase success rates, as it has been demonstrated in adults. However, this benefit is not yet clear in neonates and infants.

The traditional landmark technique for performing an LP involves palpation of the iliac crest corresponding to the L3 to L4 or L4 to L5 interspace and ensuring that the needle enters the subarachnoid space below the level of the conus medullaris. Below the L4 to L5 level, the spinal canal quickly narrows relative to its size more cranially. Thus, at the spinal level of needle insertion, the spinal canal may be relatively small. This may provide 1 explanation for low success rates.

Bedside ultrasound offers a solution for these drawbacks through direct visualization of anatomic landmarks, such as the subarachnoid space and conus medullaris (Fig 9 A–C), and identification of the level at which the spinal canal begins to narrow (Fig 9 D and E). Furthermore, it can also provide evidence of sufficient CSF within the canal space, identify a hematoma from previous LP attempts, and recognize anatomic cord abnormalities before insertion of the needle. A spinal ultrasound examination is usually possible during the first months of life when ossification of the spinous processes has yet not taken place.

In the neonatal and pediatric population, ultrasound utility has been shown in determining interspinous process distance, subarachnoid space width, needle entry angle, and needle insertion depth. Several pediatric studies report higher success rates and fewer traumatic LPs with the use of ultrasound compared with the landmark technique.

There are 2 basic approaches for ultrasound-guided LP: the static approach and the dynamic approach. By using a linear transducer, a longitudinal view of the lumbar spine is obtained (Fig 9 A and E). The conus medullaris is identified as a hypoechoic cone-shaped structure, and narrowing of the spinal canal is easily visualized (Fig 9 D and E). The termination of the conus medullaris and the level at which the spinal canal narrows can be marked on the overlying skin with a surgical marker (Fig 9 F and G). These 2 levels define the optimal level for needle insertion when using a static approach. In the dynamic approach, the needle is guided and visualized in real time, entering the CSF space by using either an out-of-plane (Fig 10A) or in-plane technique (Fig 10B, Supplemental Video 7).

**FLUID DRAINAGE**

In pediatric patients, ultrasound-guided fluid drainage reduces complications and decreases costs relative to non–ultrasound-guided procedures. Choosing the right probe, right approach, and right target and identifying surrounding structures are vital to optimize procedural success and limit potential complications. High-frequency linear and microconvex probes are generally suitable for small superficial collections, whereas curvilinear probes are more suitable for large deep collections.
Ultrasound imaging enables confirmation of ascites (Fig 11A, Supplemental Video 8) and helps avoid unsuccessful punctures.\(^{63}\) The largest pocket of ascitic fluid, important surrounding organs, and epigastric vessels can be identified to avoid potentially catastrophic complications (Fig 11B). The left and right lower-abdominal quadrants are usually the preferred sites for drainage.\(^{64}\) The point of needle entry can be planned with careful attention to the distance from the skin to the peritoneal cavity and the depth of the most superficial bowel loop along the planned needle trajectory (Fig 11C, Supplemental Video 9).\(^{64,65}\) Sequential bedside ultrasound assessment of the ascites may aid with decision-making and timing for intervention and may provide insight into the possible etiology.

**Paracentesis**

Lung ultrasound may be used to guide thoracentesis and needle aspiration for pneumothorax and pleural effusions. A multicenter international collaborative study (Lung Ultrasound in Crashing Infants) demonstrated that lung ultrasound is safe, useful, and accurate in rapidly identifying and guiding chest drainage or needle aspiration in neonates with pneumothorax who are critically ill.\(^{69}\) Interestingly, lung ultrasound has been demonstrated to be more sensitive than conventional radiology to detect pneumothoraces,\(^{70}\) but ultrasound findings must always be integrated with clinical data before making medical decisions.\(^{71}\)

Chest tube placement for pleural effusion is commonly performed under ultrasound guidance in adult critical care\(^{72}\) (currently recommended by international guidelines\(^ {73}\)). Although there is still paucity of pediatric evidence, this is a well-recognized use of bedside ultrasound that allows for identification of the lowest intercostal space above the diaphragm where the

**Pericardiocentesis**

The technique of echocardiography-guided percutaneous pericardiocentesis was described at the Mayo Clinic in 1979\(^ {66,67}\) and has since been the preferred method for the diagnosis and management of cardiac tamponade.\(^ {67,68}\) Bedside ultrasound can be used to assess pericardial effusion size and evaluate the safety and feasibility of the procedure (Fig 12A). Dynamic ultrasound guidance can minimize injury to the surrounding structures, accurately guiding the needle to the pericardial space and avoiding the right ventricle, liver, internal thoracic artery, and lungs (Fig 12B, Supplemental Video 10).

**Thoracentesis**

Lung ultrasound may be used to guide thoracentesis and needle aspiration for pneumothorax and pleural effusions. A multicenter international collaborative study (Lung Ultrasound in Crashing Infants) demonstrated that lung ultrasound is safe, useful, and accurate in rapidly identifying and guiding chest drainage or needle aspiration in neonates with pneumothorax who are critically ill.\(^{69}\) Interestingly, lung ultrasound has been demonstrated to be more sensitive than conventional radiology to detect pneumothoraces,\(^ {70}\) but ultrasound findings must always be integrated with clinical data before making medical decisions.\(^ {71}\)
procedure can be safely performed (Fig 13, Supplemental Video 11).

**Suprapubic Aspiration**

Suprapubic aspiration (SPA) used to be the gold standard for the diagnosis of urinary tract infections in children younger than 2 years of age. Although recent randomized controlled trials revealed urine specimens obtained through catheterization to be 95% sensitive and 99% specific, SPA remains current in clinical practice. Traditionally, this procedure was performed by palpating the cephalad border of the bladder and assessing for dullness to percussion of the abdomen overlying the bladder. Potential complications include hematuria, bowel perforation, accidental puncture of surrounding structures, and unsuccessful aspiration. Ultrasound guidance provides direct visualization of the bladder and ability to confirm the presence of urine before aspiration. A prospective randomized trial revealed that dynamic ultrasound guidance of SPA compared with the traditional technique significantly increased the volume of urine obtained, first attempt success, and overall success while decreasing procedure time. To visualize the bladder, a high- or low-frequency probe can be used depending on the size of the patient. With the probe in the transverse orientation, just superior to the pubic ramus, the bladder appears as an anechoic structure with rounded, smooth muscular walls (Fig 14A, Supplemental Video 12), and by rotating the probe to a sagittal position, a long-axis view is obtained (Fig 14B). The bladder volume can be estimated by multiplying the bladder diameter in the anterior-posterior, transverse, and craniocaudal dimensions and multiplying by 0.52. A transverse diameter between 1 and 3.5 cm or a total bladder volume of 10 mL is considered sufficient to perform a SPA.

**SOFT TISSUE INCISION AND DRAINAGE**

Skin and soft tissue infections are ubiquitous in the primary care and emergency department settings. Clinical examination has shown to be an unreliable method of distinguishing cellulitis from abscess requiring drainage. The use of bedside ultrasound for diagnosis of abscess not only alters the management of these patients, compared with treatment based on clinical examination alone, but also improves care by avoidance of unnecessary incision and drainage, enhancement of procedural safety, and decreased treatment failure. Soft tissue bedside ultrasound is a skill that is easily mastered after a short period of...
instruction (reported to be as short as 6 hours).\cite{82}

A high-frequency probe is essential for adequate imaging of a soft tissue infection. The area of concern should be entirely scanned and interrogated in 2 planes, ensuring that borders of normal tissue are identified (Fig 15, Supplemental Video 13). Any area of abnormality should be further assessed with color Doppler, and if possible, compression should be applied to possible abscess cavities to assess for movement of pus, or the “squish sign.” A hyperemic area may indicate appropriate inflammation in the context of infection, but a structure with diffuse vascularity is not consistent with abscess and should raise concern for a lymph node, lymphatic malformation, or other anomalous vascular structure.

For drainage, both dynamic and static guidance are possible. The drainage should target the largest pocket of infectious material (Fig 16). Preprocedural measurements of the area can aid in guiding the length and depth of the incision and provide an estimate of infectious material requiring removal. Static technique may involve marking the skin to locate the target of the procedure, whereas dynamic technique can guide a focused probing of the cavity with drainage instruments. Ultrasound also allows for assessment of completion of drainage because the abscess cavity may persist even after infectious contents have been removed. Recent literature suggests that repeat ultrasound evaluation may decrease treatment failures when retained purulent material is noted, allowing for secondary drainage.\cite{81}

**ENDOTRACHEAL INTUBATION**

Endotracheal intubation is a routine intervention in the pediatric emergency department, ICU, and operating room. Improper placement of the endotracheal tube (ETT) is not infrequent and can result in rapid clinical deterioration. Ultrasound is used to visualize the pediatric airway and lungs, but because air is a poor conductor of sound waves, it is difficult to view the ETT.\cite{83} Nonetheless, in the literature, several simple and objective methods of ultrasound imaging to identify both esophageal and endobronchial intubations quickly at the bedside are described.

The current gold standard for confirmation of successful tracheal intubation is the presence of end-tidal carbon dioxide (ETCO2) via capnography, followed by auscultation to verify bilateral symmetric breath sounds. However, ETCO2 measurement can provide false-negatives in the presence of poor cardiac output, poor lung compliance, severe bronchospasm, or airway obstruction below the ETT tip. Ultrasound is not as
straightforward as ETCO₂ measurement, but it may be a useful adjunct. The quickest ultrasound imaging technique for verifying ETT placement uses a transversely oriented transducer placed over the trachea above the sternal notch to visualize the trachea and the esophagus (Fig 17A). During intubation, observation of an empty esophagus and widening subglottis indicates successful tracheal intubation, whereas the appearance of the ETT in the esophagus (“double trachea sign”84) indicates esophageal intubation (Fig 17B). Adult and pediatric literature reveal a sensitivity and specificity of 98.5% to 100% and 75% to 100%, respectively, for this method.84–87 Obesity, abnormal airways, and short necks may limit visibility. This technique has also been described in extremely preterm infants.88 Tracheal ultrasound alone cannot distinguish an endobronchial intubation or position within the trachea. The most used technique for confirmation of ETT tip placement is chest radiography, but in the operating room, this is not performed routinely. Bronchial intubation accounts for 4% of adverse respiratory claims in children anesthetized for surgery. With ultrasound imaging, the ETT tip position is inferred by observing bilateral pleural sliding from a sagittal view in the midaxillary line. In adult and pediatric studies in which tracheal intubations were differentiated from bronchial intubations, auscultation revealed a sensitivity and specificity of 66% and 59%, respectively, whereas with the ultrasound technique, sensitivity and specificity were 93% to 100% and 96% to 100%, respectively.86–89 Accurate identification of tracheal versus bronchial intubation was 62% in the auscultation group and 95% to 100% in ultrasound groups.86,89 The time to perform the ultrasound averaged 12 seconds.86

A single pediatric study revealed that ultrasound visualization of a saline-inflated ETT cuff at the sternal notch can be used to determine appropriate ETT depth. This study reported a sensitivity and specificity of 99% and 96%, respectively.90 Overall, neck and thoracic ultrasounds of the trachea and lung

![FIGURE 15](image)


![FIGURE 16](image)

Identification of large purulent pocket before abscess drainage.

![FIGURE 17](image)

A and B, Suprasternal ultrasound image of the neck before endotracheal intubation and after esophageal intubation revealing a double-tracheal sign in the esophagus. AFTL, air-filled tracheal lumen; TC, tracheal cartilage.

![FIGURE 18](image)

Ultrasound-guided FN block: needle visualization (arrowhead) with hypoechoic space adjacent to the needle tip representing local anesthetic infiltration. FA, femoral artery; FN, femoral nerve.
are proving to be useful adjuncts in confirming proper placement of the ETT in pediatric patients and offer several advantages over current standard practice, with more rapid and accurate recognition of malpositioned ETTs. It is likely that, in the future, a systematic method for ultrasound-imaged verification of ETT placement will consist of combining tracheal ultrasounds to confirm an empty esophagus and using subsequent views to confirm symmetric lung sliding.

REGIONAL ANESTHESIA

The introduction of point-of-care ultrasound into the perioperative environment has dramatically changed the practice of pediatric regional anesthesia (RA). RA, the use of local anesthesia (LA) to selectively anesthetize a segmental area of the body, is an important pain-management technique for children having surgery and painful procedures because it provides excellent pain relief and reduces the need for intraoperative and postoperative opioids.91,92 Historically, the block needles were placed into the tissues blindly and guided solely by landmarks, nerve stimulation, and tactile sensations, which resulted in variable success and an increased potential for complications. Point-of-care ultrasound allows for accurate real-time identification of anatomic structures, relative to a visible advancing needle, and monitoring the spread of LA (Fig 18).93–98 By providing a reliable way to precisely locate nerves, observe needle tips, and observe the flow and distribution of LA, ultrasound has improved the quality and safety of pediatric RA. Numerous studies reveal improved success when comparing ultrasound-guided techniques with conventional block techniques and document a consistent increase in the percentage of successful blocks to a range of 87% to 100% compared with 60% to 90%.99–102 Ultrasound-guided RA results in a longer sensory blockade, compared with nerve stimulation techniques,103 and significantly lower postsurgery pain scores.101 In the adult literature, decreased incidence of accidental intravascular injection by using ultrasound guidance is documented,104 but pediatric-specific data revealing a reduction in procedural complications are still lacking, likely because of the infrequent nature of such events.

Pediatric anesthesiologists historically preferred neuraxial blocks (epidural catheters and single-injection caudal anesthesia), but a significant amount of data reveal a clear shift in RA practice over the past 10 years from a predominance of neuraxial blocks (historically 62%–100%) to an increasing percentage of peripheral nerve blocks (PNBs) (currently 48%–66%).105–108 During the same time interval, the use of ultrasound for PNBs has increased from 0% to 90%, likely propelling this trend.105–108 This has safety implications because there are data from large pediatric-specific databases that document an added safety benefit when PNBs are used as an alternative to neuraxial blocks and are, therefore, preferred when suitable.106,107,109 Although ultrasound is infrequently used for placement of caudal anesthesia and epidurals, there is evidence its use may increase success and reduce complications for neuraxial techniques as well.108,110–114

In addition to improving commonly known PNBs (ilioinguinal, femoral, brachial plexus), the use of ultrasound has also accelerated the creation of novel PNBs, especially those targeting nerves within fascial planes.115–119 There are still sparse data on the use of these novel blocks in children, but case reports are encouraging, with many of these blocks being used for applications in which RA was previously not available.

Overall, ultrasound increases the likelihood of getting the right drug in the right place at the right time.120 Convincing evidence favors the increased adoption of ultrasound into the practice of pediatric RA.

CONCLUSIONS

Point-of-care ultrasound is exponentially expanding across all disciplines in pediatrics. The evidence for the use of this technology is robust and reveals improved procedural success and patient safety. The current state of the art in procedural medicine includes point-of-care ultrasound. Seeing is believing.

ABBREVIATIONS

CSF: cerebrospinal fluid
CVC: central venous catheter
ETCO2: end-tidal carbon dioxide
ETT: endotracheal tube
FV: femoral vein
IJ: internal jugular
LA: local anesthesia
LP: lumbar puncture
PICC: peripherally inserted central catheter
PIV: peripheral intravenous
PNB: peripheral nerve block
RA: regional anesthesia
SPA: suprapubic aspiration
SVC: superior venacava

REFERENCES

1. Ullman JI, Stoelting RK. Internal jugular vein location with the
ultrasound Doppler blood flow
2. Kantor DB, Su E, Milliren CE, Conlon TW. Ultrasound guidance and other
determinants of successful peripheral
termary catheterization in critically ill
17(12):1124–1130
3. Froehlich CD, Rigby MR, Rosenberg ES,
et al. Ultrasound-guided central
venous catheter placement decreases
complications and decreases
placement attempts compared with
the landmark technique in patients in
a pediatric intensive care unit. Crit
Care Med. 2009;37(3):1090–1096
4. Katheria AC, Fleming SE, Kim JH. A
randomized controlled trial of
ultrasound-guided peripherally
inserted central catheters compared
with standard radiograph in neonates.
5. Doniger SJ, Ishimine P, Fox JC,
Kanegaye JT. Randomized controlled
trial of ultrasound-guided peripheral
intravenous catheter placement
versus traditional techniques in
difficult-access pediatric patients.
154–159
The effect of bedside ultrasonographic
skim marking on infant lumbar
puncture success: a randomized
69(5):610–619.e1
7. Horowitz R, Gossett JG, Bailitz J, Wax D,
Pierce MC. The FLUSH study—flush the
line and ultrasound the heart:
ultrasonographic confirmation of
central femoral venous line
63(6):678–683
Academy of Pediatrics, Committee on
Pediatric Emergency Medicine; Society
for Academic Emergency Medicine,
Academy of Emergency Ultrasound;
American College of Emergency
Physicians, Pediatric Emergency
Medicine Committee; World Interactive
Network Focused on Critical
Ultrasound. Point-of-care
ultrasonography by pediatric
emergency medicine physicians.
Pediatrics. 2015;135(4). Available at:
www.pediatrics.org/cgi/content/
full/135/4/1113
9. Frankel HL, Kirkpatrick AW, Elbarbary
M, et al. Guidelines for the appropriate
use of bedside general and cardiac
ultrasoundography in the evaluation of
critically ill patients–part I: general
ultrasoundography. Crit Care Med. 2015;
43(11):2479–2502
10. Mallinson C, Bennett J, Hodgson P,
Petros AJ. Position of the internal
jugular vein in children. A study of the
anatomy using ultrasonography.
11. P Souza Neto E, Grousson S, Dufo F,
et al. Ultrasonographic anatomic
variations of the major veins in
2014;112(5):879–884
12. Alderson PJ, Burrows FA, Stemp LI,
Hottby HM. Use of ultrasound to
evaluate internal jugular vein anatomy
and to facilitate central venous
cannulation in paediatric patients. Br
13. Lamperti M, Bodenham AR, Pittiruti M,
et al. International evidence-based
recommendations on ultrasound-guided
vascular access. Intensive Care
14. National Institute for Health and Care
Excellence (NICE). Technology appraisal
guidance no. 49: guidance on the use
of ultrasound locating devices for placing
central venous catheters. Available at:
https://www.nice.org.uk/guidance/ta49.
Accessed February 11, 2003
15. Oakley E, Wong AM. Ultrasound-assisted
peripheral vascular access in a
paediatric ED. Emerg Med Australas.
2010;22(2):166–170
16. Parker SIA, Benzie MS, Hayden KA. A
systematic review: effectiveness of
pediatric peripheral intravenous
2017;73(7):1570–1582
17. Kim S, Kim Y, Moon SB. Histological
changes of the unligated vein wall
adjacent to the central venous catheter
after open cutdown in rats. J Pediatr
18. Costello JM, Clapper TC, Wypij D.
Minimizing complications associated
with percutaneous central venous
catheter placement in children: recent
14(3):273–283
19. Quelego-Eroz R, Gonzalez-Cortes R,
Garcia-Soler P, et al; RECANVA
Collaborative Study. Ultrasound-guided
or landmark techniques for central
venous catheter placement in critically
ill children. Intensive Care Med. 2018;
44(1):61–72
20. Zanolla GR, Baldisserotto M, Piva J. How
useful is ultrasound guidance for
internal jugular venous access in
789–793
Ultrasound-guided internal jugular
venous cannulation in infants:
a prospective comparison with the
traditional palpation method.
Anesthesiology. 1999;91(1):71–77
22. Iwashima S, Ishikawa T, Oheki T.
Ultrasound-guided versus landmark-
guided femoral vein access in pediatric
cardiac catheterization. Pediatr Cardiol.
2008;29(2):339–342
23. de Souza TH, Brandão MB, Nadal JAH,
Nogueira RJJ. Ultrasound guidance for
pediatric central venous
catheterization: a meta-analysis.
Pediatrics. 2018;142(5):e20181719
Councils on Intraoperative
Echocardiography and Vascular
Ultrasound of the American Society of
Echocardiography. Guidelines for
performing ultrasound guided vascular
cannulation: recommendations of the
American Society of Echocardiography
and the Society of Cardiovascular
Anesthesiologists. J Am Soc
Echocardiogr. 2011;24(12):1291–1318
Guidelines on the use of ultrasound
guidance for vascular access. Anaesth
Cric Care Pain Med. 2015;34(1):65–69
26. Bruzoni M, Slater BJ, Wall J, St Peter SD,
Dutta S. A prospective randomized trial of ultrasound- vs landmark-guided
central venous access in the pediatric
939–943
27. Stenzel JP, Green TP, Fuhrman BP,
Carlson PE, Marchessault RP. Percutaneous femoral venous
catheterizations: a prospective study of


88. Raimondi F, Yousef N, Migliaro F, Capasso I, De Luca D. Point-of-care lung ultrasound in neonatology:
classification into descriptive and functional applications [published online ahead of print July 20, 2018]. 
Pediatr Res. doi:10.1038/s41390-018-0114-9


Seeing Is Believing: Ultrasound in Pediatric Procedural Performance
Pediatrics 2019;144;
DOI: 10.1542/peds.2019-1401 originally published online October 15, 2019;

Updated Information & Services
including high resolution figures, can be found at:
http://pediatrics.aappublications.org/content/144/5/e20191401

References
This article cites 115 articles, 5 of which you can access for free at:
http://pediatrics.aappublications.org/content/144/5/e20191401#BIBL

Subspecialty Collections
This article, along with others on similar topics, appears in the following collection(s):
Administration/Practice Management
http://www.aappublications.org/cgi/collection/administration:practice_management_sub
Medical Technology and Advancement
http://www.aappublications.org/cgi/collection/med_tech_advancement_sub

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
http://www.aappublications.org/site/misc/Permissions.xhtml

Reprints
Information about ordering reprints can be found online:
http://www.aappublications.org/site/misc/reprints.xhtml
Seeing Is Believing: Ultrasound in Pediatric Procedural Performance
Pediatrics 2019;144;
DOI: 10.1542/peds.2019-1401 originally published online October 15, 2019;

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://pediatrics.aappublications.org/content/144/5/e20191401

Data Supplement at:
http://pediatrics.aappublications.org/content/suppl/2019/10/12/peds.2019-1401.DCSupplemental