Getting started in paediatric emergency medicine point-of-care ultrasound: Five fundamental applications

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Abstract

Point-of-care ultrasound is a valuable tool in the Paediatric Emergency Medicine department. It can be utilised at the patient bedside to augment the physical examination, improving clinical accuracy. Alternatively, it can safeguard needle guided procedures and improve their success rate. It allows real-time information to be gathered without exposing the child to ionising radiation. This article outlines five fundamental applications and how it can be incorporated into clinical practice.

Keywords: bladder, forearm, hip, needle-guidance, paediatric emergency medicine, point-of-care ultrasound.

Introduction

Point-of-care ultrasound (POCUS) is a valuable tool in the paediatric emergency medicine (PEM) department.[1,2] At the bedside, it can augment the physical examination, to increase diagnostic accuracy, or guide a needle tip, and to safeguard procedures, without exposing the child to ionising radiation. This may assist with expediting the care of the patient or triaging imaging requests, particularly after hours. It is a skill that can be readily learnt by breaking it down into its core components: understanding the anatomy and indications, image acquisition, image interpretation and clinical integration.[3] It requires practice with repetition of these elements over time.[4,5] A common impediment to learning PEM POCUS is that new users often feel overwhelmed with its perceived complexity. However, the best way to learn is to start practicing by scanning patients and then refine technique with the support from experienced users. This article will outline five fundamental applications to get started in this emerging field, demonstrating how it can then be easily incorporated into clinical practice.

Ultrasound-guided peripheral intravenous cannula insertion

Paediatric trained clinicians pride themselves on their ability to insert peripheral intravenous cannulas. Nevertheless, they still encounter paediatric patients with difficult intravenous access.[6] POCUS is generally indicated when there is a history of difficult access or when veins are difficult to visualise or palpate, all of which can occur at any age. A topical anaesthetic cream should be applied prior to the procedure, to ameliorate pain.[7,8] It is essential that the patient is appropriately held with immobilisation of the limb being cannulated. This can be achieved in a younger child, with caregiver permission, by wrapping them in a bedsheet with the target arm extended, with a minimum of two holders: one for the arm and another for the patient's body. Stability of the arm can be achieved by locking the elbow joint in extension with a hand behind the olecranon with counter-traction applied to the distal forearm, which is held in full supination. Typical suitable vein locations include the volar surface of the forearm, antecubital fossa or the saphenous vein, as it tracks along the medial aspect of the distal lower limb.[9]

As an aseptic procedure, it should involve the use of a sterile ultrasound probe cover and sterile ultrasound gel. A high-frequency linear transducer is placed over the target vessel, usually in a short axis.[10] The needle tip, typically at least 23 gauge in size, is then guided under direct vision into the vein and the cannula secured, being careful when wiping away the gel. Additionally, a twisting motion up to 180 degrees can be used after entering the vessel to reduce the chance of penetrating through the posterior vein wall, with the blunter bevel becoming the leading edge. The short-axis view requires the vessel being brought into the centre of the screen and tracking the tip of the

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needle at all times by sliding the probe off the tip each time it is advanced. The long-axis view allows direct visualisation of the needle throughout but requires a steady hand to avoid moving off the centre of the vein, which can be challenging in smaller diameter vessels or with slight movements of the child. In the 2-axis technique, the cannula is inserted using the short-axis, then confirmed by turning into a long-axis view with demonstration of the real-time venous flow of isotonic saline as it is flushed through the cannula (Figure 1).

Bladder volume

Assessment of bladder volume in children is a simple but efficacious application of PEM POCUS. Although there are variations in the literature, the bladder volume can be estimated visually or can be quantified using the ellipsoid formula of length × height × width × 0.5, which provides a volume in millilitres.[11,12] However, this is likely to underestimate the actual volume and does not account for the various shapes of paediatric bladders.[13] Orthogonal measurements are made with the longest length and height measured in the longitudinal view and the width in a transverse view (Figure 2). Foremost, the bladder volume forms part of the assessment of patient hydration by quantifying current urine production. This may expedite the discharge of a patient who is having a trial of oral fluid intake or to assess urine output in a patient being actively fluid resuscitated. Alternatively, it can rapidly confirm urinary retention and potentially identify an underlying cause, such as faecal impaction or an obstructing mass.[14,15] The normal bladder capacity for age can be calculated using the formula: age of child (years) × 30 + 30, giving the bladder volume in millilitres.[16] Assessment of bladder volume is helpful prior to urine collection in the neonate, informing when a clean catch collection is imminent or to increase success rates prior to invasive collection, such as catheter or suprapubic aspiration. Suprapubic aspiration can also be conducted under ultrasound guidance.[17] Finally, it can inform bladder fullness prior to a radiology performed female pelvic ultrasound. This avoids having to return the patient to the ED whilst awaiting a full bladder, thereby decreasing the time for the pelvic ultrasound scan to be completed.[18]

Femoral nerve block

Providing conventional analgesia to children with a femoral shaft fracture is problematic as large doses of intravenous opiates cause unwanted side effects, such as vomiting and sedation. An ultrasound-guided femoral nerve block is a means by which local anaesthetic can be infiltrated around a nerve under direct vision, to provide regional anaesthesia, decreasing the requirement for systemic analgesia.[19] The needle tip can be safely guided with ultrasound to improve the success rate and to avoid vascular puncture and inadvertent local anaesthetic systemic toxicity.[20] The femoral nerve arises from the L2-4 spinal root and is the largest branch of the lumbar plexus, innervating the anteromedial thigh, knee, and femur.[21] Therefore, a femoral nerve block can also provide anaesthesia for a painful procedure, such as abscess drainage or laceration repair in this distribution. Contraindications include skin infection overlying the intended puncture site, femoral nerve injury and allergy to local anaesthetic. A topical anaesthetic, such as EMLA®, can be applied at least 60 min prior to the procedure to anaesthetise the skin puncture site.[8] The patient should have cardiorespiratory monitoring attached and be in an area of the department with resuscitation equipment, along with the presence of staff who can provide advanced airway support and resuscitation. A weight-based dose of a cardiac stable local anaesthetic agent, such as levobupivacaine or ropivacaine, should preferentially be used to decrease the risk of local anaesthetic systemic toxicity.[22]

The femoral nerve travels behind the inguinal ligament under the fascia iliaca and lies anterior to the psoas muscle and lateral to the femoral artery. The ideal ultrasound view contains a cross-sectional image of the femoral vein (medial), artery and nerve (Figure 3). The patient is positioned supine, with the groin region exposed and the machine placed on the opposite side to the proceduralist. The needle is introduced from a lateral to medial in-plane approach using a high-frequency linear probe with sterile cover and gel. Additional tactile feedback can be provided if a blunt nerve block needle is utilised, with 'pops' felt as the fascia lata then fascia iliaca are breached, respectively. The needle tip should be visualised just lateral to the femoral nerve with aspiration prior to administration. A small volume

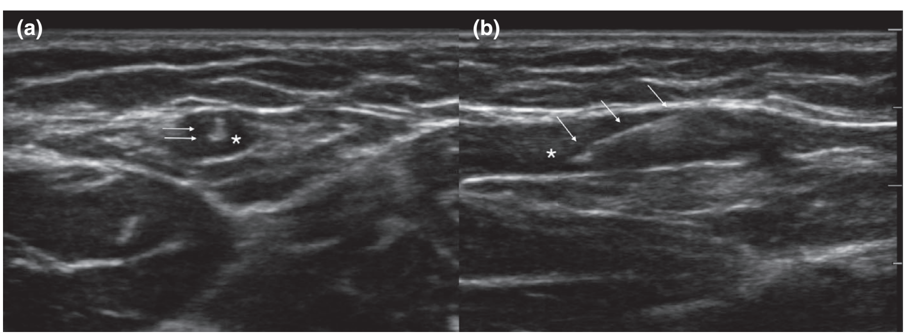

Figure 1: Ultrasound-guided intravenous access in a 5-year-old girl, demonstrating the needle tip (arrows along shaft) situated within a peripheral vein (*) in both (a) short-axis and (b) long-axis views.

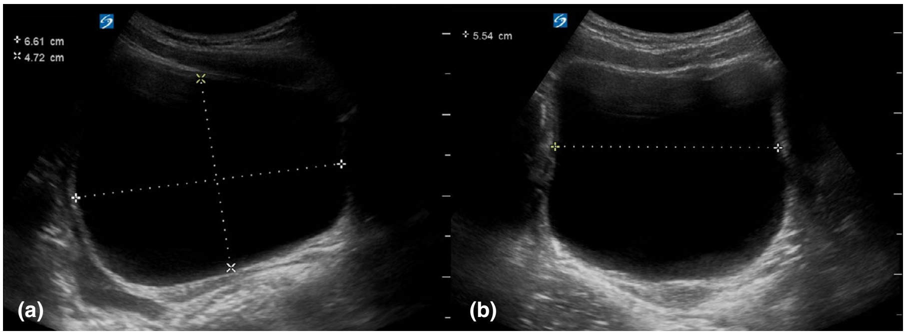

Figure 2: Bladder volume measurements on (a) longitudinal and (b) transverse views in a 9-year-old girl.

is initially injected to demonstrate hydro-dissection of the surrounding fascial planes, before the rest of the volume is delivered, bathing the nerve. Procedural sedation, with an agent such as ketamine, may be utilised on a case-by-case basis for younger children to tolerate the block and subsequent application of traction.

Hip effusion

The limping child is a common presentation to the ED and can represent a multitude of causes.[23] A thorough history and clinical examination are required to differentiate it from more sinister causes, which can be challenging in a young child who is non-compliant or upset. POCUS can augment this process by the rapid identification of the presence of a hip effusion as the localisation of the child's limp. The child is positioned lying supine with the hip joint in a neutral position and feet slightly externally rotated. A high-frequency linear probe is placed longitudinally over the child's femur and moved cephalad until the hip joint is visualised.[24] The anterior recess of the femur is identified, and the distance of the hypoechoic space between the bone cortex and iliopsoas muscle is measured perpendicularly (Figure 4a). Both hips should be scanned with a measurement of greater than 5mm or a difference of 2mm between sides considered abnormal.[25] Unfortunately, POCUS cannot reliably delineate between causes of the effusion, including septic arthritis, transient synovitis, reactive arthritis, malignancy, Perthes disease or haemarthrosis, which all rely on clinical context and further investigation.[25] The head of the femur should also be identified in relation to the physis, to identify slipped upper femoral epiphysis. Septic arthritis is a medical emergency that requires urgent surgical washout and intravenous antibiotics. Features on ultrasound that make a septic arthritis more likely include hyperaemia of the surrounding tissues, septation or turbidity of the fluid.[24] Restricted painful range of motion of the hip, in combination with the presence of an effusion on POCUS and raised inflammatory markers, increases the likelihood of a diagnosis of septic arthritis of the hip.[26] POCUS can also guide arthrocentesis to aid in the isolation of the causative

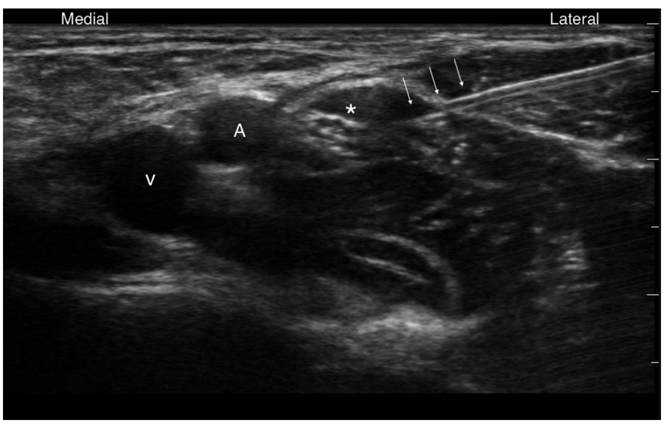

Figure 3: Ultrasound-guided femoral nerve block in a 3-year-old girl, demonstrating the anatomy (medial to lateral) vein, artery and nerve (*) and the needle tip (arrows along shaft) with hydro-dissection of the fascial planes with local anaesthetic.

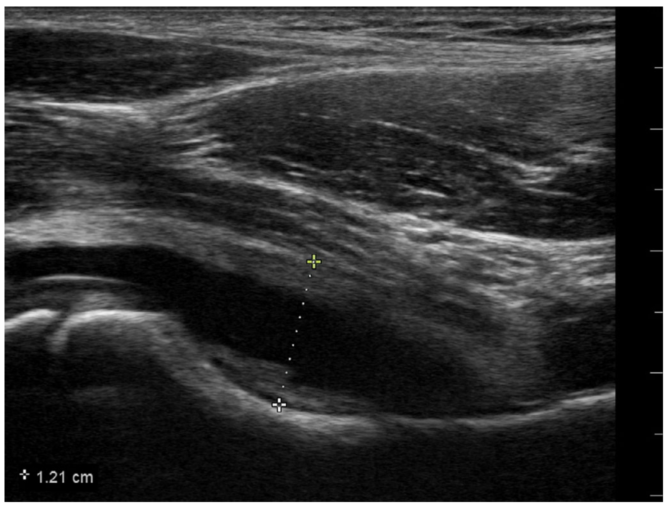

Figure 4: A 7-year-old boy with transient synovitis of the right hip, with an associated 12 mm effusion. The dotted line represents the measurement of the hip effusion.

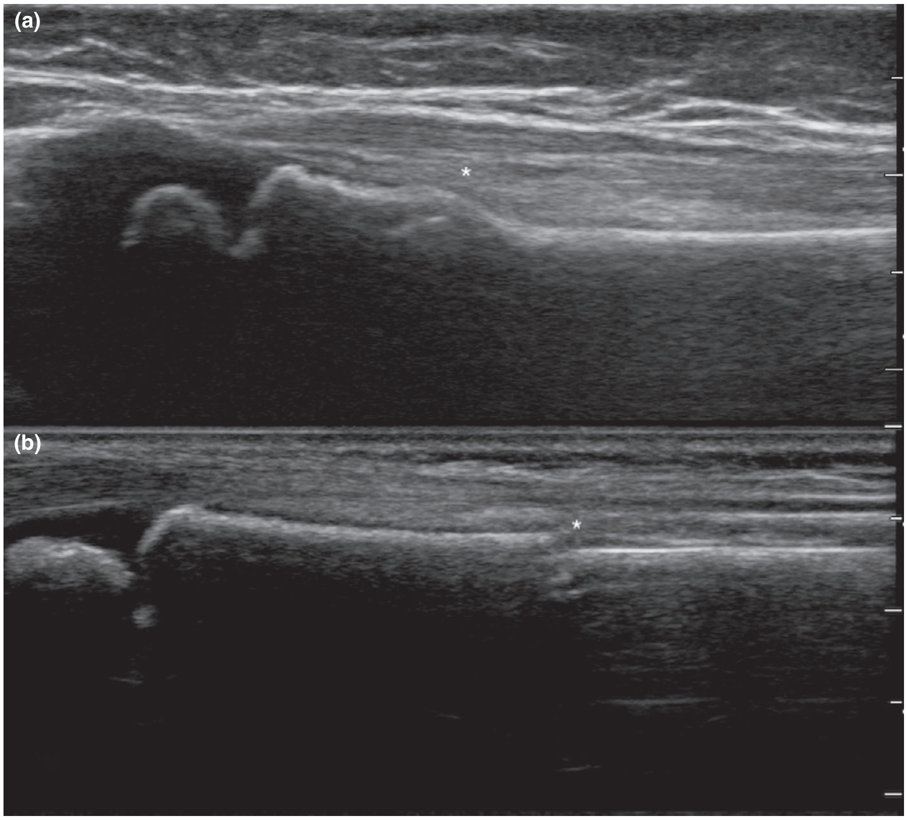

Figure 5: Forearm images demonstrating a buckle fracture of the distal radius (a*) and a cortical breach of a different distal radius (b*).

organism, particularly when there is a delay in access to surgical services, and antimicrobial treatment needs to be emergently initiated.[27]

Forearm fractures

Forearm fractures represent around one third of the children with fractures presenting to the emergency department.[28] Most of these are distal forearm injuries and occur as the result of a fall onto an outstretched hand. POCUS can rapidly and accurately detect fractures at the time of clinical review.[29–31] After judicious analgesia, copious gel is applied to the child's forearm and a high-frequency linear probe is placed longitudinally on the dorsal, lateral and volar aspects of both the radius and ulna bones and slid distally to the wrist joint to visualise the physis.[32] The pain associated with POCUS has been demonstrated to be similar to conventional radiographs of the forearm, but care must still be taken to avoid excessive movement or pressure.[29,30] Bone cortex appears as a bright echogenic line with posterior acoustic shadowing, as bone attenuates transmission and reflects the sound waves back to the transducer (Figure 5). A buckle fracture is identified by an asymmetrical (compared with uninjured side) angulation or deformity of the cortex without disruption on any aspect. Conversely, a greenstick or transverse fracture will have disruption or breach of the cortex at the point of mechanical strain, demonstrated by a hypoechoic zone through the cortex of the bone. Ultrasound cannot always determine the exact fracture subtype, particularly for fractures around the physis.[28,29] For this reason, radiographic imaging is currently still required to further define distal forearm injuries. However, it may be possible to avoid radiographs in a select group of children with uncomplicated buckle fractures or no fracture detected on POCUS (Snelling PJ, 2020, unpublished data). Finally, POCUS can also guide the reduction of forearm fractures without having to repeat any procedural sedation.[33]

Conclusion

PEM POCUS has many applications, and this article has outlined the approach to five common presentations. In the hands of a clinician, it provides additional information at the bedside that can be integrated into the clinical picture. Additionally, it is invaluable when safeguarding needle guided procedures, such as regional nerve blocks or vascular access. Further research is required to further validate the benefits of using PEM POCUS for patient-centred care.

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(i) The authorship listing conforms with the journal's authorship policy and (ii) that all authors are in agreement with the content of the submitted manuscript.

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