

Point-of-care ultrasound in paediatric clinical practice: transforming tomorrow today

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Abstract

Point-of-care ultrasound (POCUS) has emerged as a valuable tool for clinicians. It is best considered as an extension of the clinical assessment, where it can provide greater information than is available via traditional physical examination alone. POCUS fulfils several roles within clinical paediatrics; most commonly it serves as a diagnostic aid, helping to further a clinician's working hypothesis by excluding less likely diagnoses or helping to improve certainty in confirming others. Its use can obviate the need for other investigations such as blood tests and in doing so it can streamline the patient journey. In certain scenarios POCUS can fulfil the role that a conventional imaging investigation has done previously. It has emerged as a tool to guide resuscitation and stabilization of the seriously unwell patient and, as is perhaps most familiar, it can be used to help guide procedures. The aim of this article is to summarize the current applications of POCUS in acute paediatric care as well as to highlight more novel, emerging applications.

Keywords Abscess; appendicitis; cellulitis; pneumonia; pneumothorax; POCUS; ultrasound

Introduction

Over the past two decades, point-of-care ultrasound (POCUS) has emerged as a valuable tool for clinicians. It is best considered as an extension of the clinical assessment, where it can provide greater information than is available via traditional physical examination alone. As an adjunct, POCUS confers particular benefit to those caring for children where eliciting traditional clinical signs can be difficult because of a child's anxiety, pain, or the fact that they may be pre-verbal. In addition, where POCUS can obviate the need for x-rays this reduces exposure to ionising radiation in the population most vulnerable to its negative effects.

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POCUS as a diagnostic aid

The principle underpinning the use of POCUS is that it should answer specific, often binary, questions which can then enhance clinical assessment and aid decision making. Below are some common paediatric clinical scenarios along with the specific questions facing the clinician and how POCUS can help.

A very tall, teenage boy presents following sudden onset unilateral, pleuritic chest pain. He looks well and has SpO₂ 99% in room air.

Can I use POCUS to help exclude pneumothorax?

Lung sliding is visualized on POCUS during normal respiration as a result of the normally closely adhered visceral and parietal pleural layers moving to-and-fro with each breath. The presence of pleural slide identified throughout the lung fields on POCUS can reliably rule out pneumothorax as a cause of chest pain, particularly when combined with the low pre-test probability that the clinician had after history and clinical examination. The ability of POCUS to exclude pneumothorax is one of the most well studied applications over the past 2 decades. The sensitivity and specificity of POCUS has been shown to be superior to x-rays at identifying pneumothoraces in the context of trauma and as a primarily medical condition.¹⁻⁴

Overnight, working at a District General Hospital you are reviewing a 3-year-old with pneumonia who, despite adequate antibiotic therapy develops worsening hypoxia.

Is there evidence of a complicated pneumonia?

For this child, readily identifying a pleural effusion or developing empyema is crucial to guiding management. Ultrasound is the initial investigation of choice for identifying pleural fluid but formal departmental ultrasound can often be difficult to obtain for children, particularly out-of-hours. POCUS can identify complicated effusions at the patient's bedside thus expediting referral to specialist care. Studies have demonstrated strong inter-rater agreement between POCUS and CT scans for patients with pneumonia with effusion, as well as for uncomplicated pneumonia. It is also helpful in determining the likely size of any effusion. Only larger parapneumonic effusions of greater than 2 cm depth are suitable for drainage.

A 2-year-old girl presents with a 24 hour history of intermittent limp but is able to weight bear. Nursery recall she had a very minor fall 2 days earlier, but report that she was able to walk normally afterwards. The treating clinician would like to undertake X-rays to look for traumatic injury, but you feel her presentation is more in keeping with transient synovitis.

Can POCUS help to localise the source of a limp?

POCUS allows you to painlessly and readily identify a hip effusion which localizes the problem to the hip rather than a traumatic injury. Combined with a low pre-test probability of septic arthritis based on the history and examination findings you are

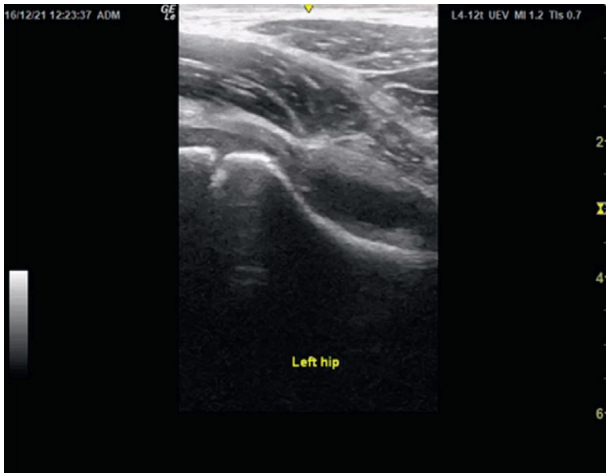


Figure 1 POCUS of hip demonstrating moderate sized effusion. The effusion is anechoic (dark) and causes the hip joint capsule to be convex.

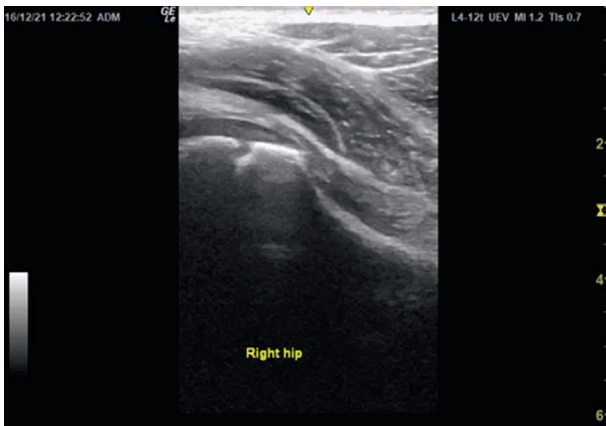


Figure 2 POCUS of hip demonstrating normal appearances with a concave hip joint capsule.

able to reliably make a diagnosis of transient synovitis. A follow-up scan 4 days later shows that her effusion has resolved and clinically she is back to normal. See [Figures 1 and 2](#).

POCUS is effective at correctly identifying hip effusions which, as part of a clinical decision aid has been shown to correctly diagnose transient synovitis.⁵ By providing enhanced diagnostic certainty POCUS can lead to a reduction in unnecessary blood tests and x-rays for children with atraumatic limp.

You are asked to review a 2-year-old boy who is refusing to use his left elbow after being pulled up from sitting by his older brother. You suspect this is pulled elbow based on the mechanism of injury and his examination. You attempt manipulation but do not feel a click.

Is it safe to attempt further manipulation or do I now need to undertake x-rays?

You undertake an elbow POCUS revealing a large joint effusion, and negative findings for pulled elbow. You scan the rest of his upper limb and identify a fracture of the distal humeral shaft which was the source of the child's pain. See [Figures 3–6](#).

For the younger child presenting following upper limb trauma, identification of the site of injury is not always straightforward. Pulled elbow is a very common paediatric injury and is usually easy to diagnose and manage. However, presentations can be less straightforward with up to 50% of children attending following an unwitnessed injury or with an atypical history.⁷ Use of POCUS to identify a positive “hook sign”, caused by the abnormal appearances of the supinator muscle becoming entrapped within the radiocapitellar joint space has been demonstrated to have 100% sensitivity and specificity for the identification of pulled elbow meaning the clinician can be reassured that their diagnosis is the correct one if sonographic signs are identified.⁸ In addition, POCUS can also readily identify traumatic elbow joint effusions and fractures thereby reducing the risk of painful attempted manipulation of a suspected pulled elbow and guiding radiological imaging where appropriate. For certain bony injuries POCUS can eliminate the need for x-rays completely. The BUCKLED Trial demonstrated how POCUS could be safely used to identify buckle/torus fractures of the wrist in children without the need for radiographs.⁹ There is also an increasing body of evidence supporting POCUS as the initial imaging modality for fractures of the clavicle, reducing the overall need for x-rays.¹⁰ Integrating POCUS into the clinical assessment of children with undifferentiated upper limb injuries confers significant benefit to both the clinician and the patient by localize the source of the problem, reducing the need for x-rays and to prevent any potential harm during attempts at manipulation of a pulled elbow where the underlying diagnosis is a fracture.

You are asked to urgently review a 10-year-old girl presenting to the PED with fever, lethargy and left-sided headache. Having initially appeared well at triage, she becomes unresponsive with a GCS of 8 and fixed, dilated left pupil.

Can I use POCUS help to confirm my suspicion of raised intracranial pressure?

You perform an ocular POCUS which reveals an increased optic nerve sheath diameter and papilloedema indicating raised intracranial pressure. You promptly administer a bolus of intravenous hypertonic saline and urgently inform critical care. She is intubated and taken for CT scan which reveals a subdural empyema exerting mass affect.

One of the less well-known uses of POCUS is its ability to identify raised intracranial pressure. Ocular scanning is quick and well tolerated by even very young patients. By visualizing the optic nerve posterior to the retina, a measurement of the optic nerve sheath diameter (ONSD) can be taken, which given the direct anatomical communication with the subarachnoid space provides a reliable non-invasive indicator of increased intracranial pressure. The normal range for the ONSD is 5.5 mm in children with measurements beyond this indicating raised intracranial pressure. Sonography of the ONSD has been demonstrated to be both a sensitive test for ruling out raised ICP in low-risk patient groups as well as a specific test for ruling in raised ICP in higher-risk groups such as those with a reduced or fluctuating GCS. Ocular POCUS performs very well in terms of diagnostic accuracy for detection of raised ICP compared with CT

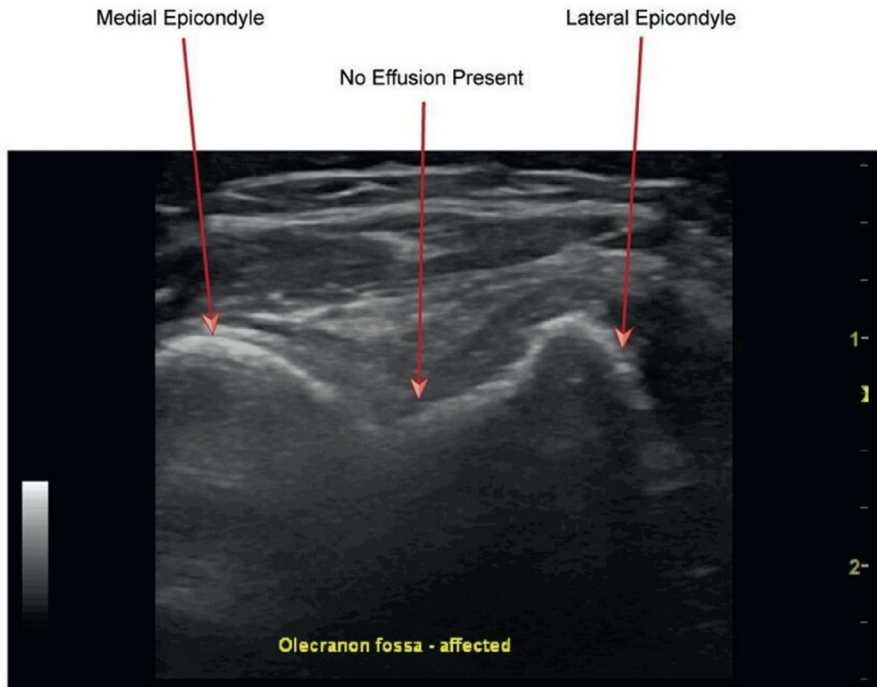


Figure 3 POCUS of the elbow in transverse axis with normal appearances. Reproduced from reference 6 with under the Creative Commons Attribution 4.0 International License.

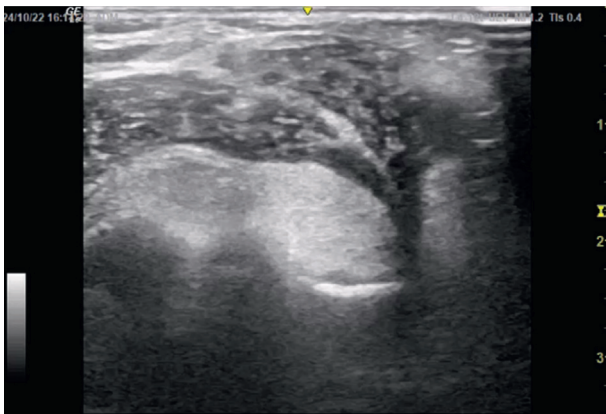


Figure 4 POCUS of the elbow in transverse axis revealing traumatic joint effusion.

with a sensitivity of 95.6% (95% CI, 87.7%–98.5%) and specificity of 92.3% in a large, recent systematic review.¹¹ Swelling of the optic disc can be also readily appreciated even by inexperienced users. See Figure 7. This is defined as an elevation of the optic disc by greater than 1 mm, shown as an anterior protrusion on POCUS. Fundoscopy remains a challenging skill in paediatric patients, particularly without dilatation of the pupil, meaning that important findings may be easily missed. According to Mackay et al. “many medical students never view an abnormal fundus” via fundoscopy.¹² Ocular POCUS on the other hand is a quick, well tolerated and readily teachable diagnostic aid which can be employed in paediatric and adult emergency departments.

A 6-year-old girl presents with a large left sided neck swelling following a coryzal illness. She is currently well appearing but has a low-grade temperature. You can feel what you believe to be enlarged upper cervical lymph nodes.

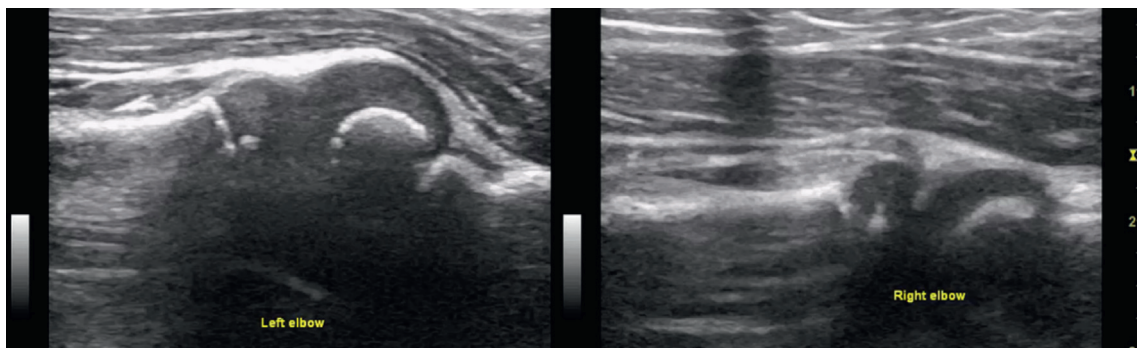


Figure 5 POCUS along radiocapitellar line demonstrating the normal appearances (left elbow) along with those demonstrating pulled elbow for comparison (right elbow). In pulled elbow the classical hook sign is produced by the abnormal proximal advancement of the supinator muscle into the joint space.

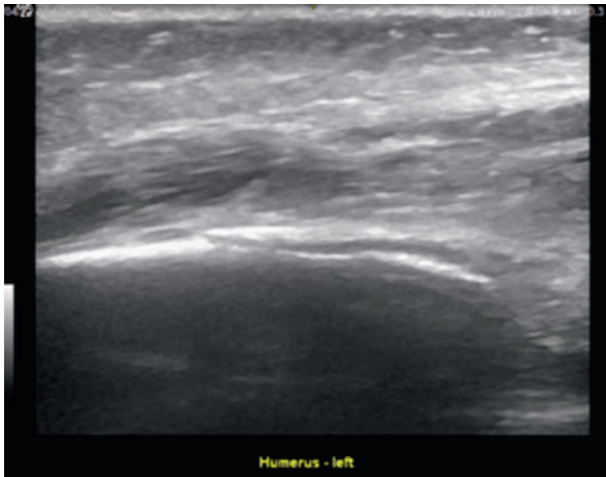


Figure 6 POCUS of distal humerus in longitudinal axis demonstrating a breach within the hyperechoic bony cortex consistent with a fracture.

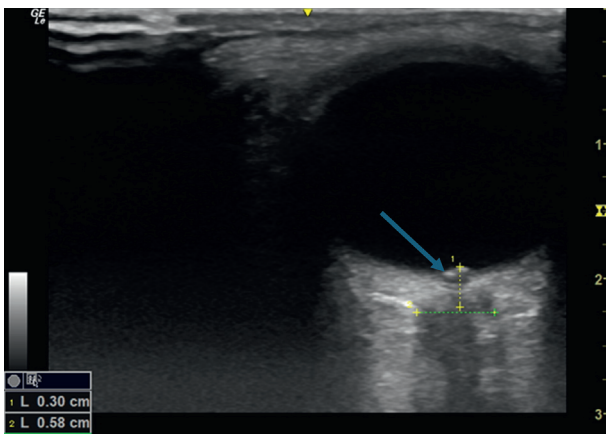


Figure 7 Ocular POCUS demonstrating an increased optic nerve sheath diameter of 0.58 cm (green dotted line) measured 3 mm posterior to the retina (yellow dotted line). There is also evidence of papilloedema with anterior protrusion of the optic nerve head greater than 1 mm (arrow).

Can I use POCUS to help guide further management by confirming reactive lymph nodes and exclude abscess?

Enlarged lymph nodes make up a significant proportion of attendances to both the PED as well as rapid access paediatric clinics. For the paediatric patient presenting with neck swelling, differentiating a lymph node abscess from either a reactive lymph node or lymphadenitis is crucial in order to inform proper management. This may range from simple reassurance to admission for intravenous antibiotics, with, in some cases consideration of surgical drainage. POCUS is emerging as a tool that can be integrated into clinical assessment in order to make decisions on whether further imaging is warranted based on a node's sonographic features.

For the infant with an undifferentiated neck lump, POCUS can confirm its origin as being from a lymph node or due to another soft tissue mass of which there are multiple potential aetiologies ranging from a simple fibromatosis coli to more sinister causes. In addition, POCUS for neck masses has been shown to have good inter-rater reliability and to expedite the patient journey.

You are asked to review a 14-year-old girl with progressive, erythematous swelling to her lower leg. Your junior colleagues are concerned about the possibility of abscess and ask if they should contact the tertiary surgical team located in another hospital for consideration of drainage.

Can I use POCUS to help exclude an abscess and confirm simple cellulitis?

POCUS has been shown to assist in the evaluation of soft tissue and skin infections. In particular POCUS can help to identify or exclude abscesses as clinical examination may not be reliable in distinguishing cellulitis from an abscess requiring drainage. Cellulitis gives a cobble-stone appearance on ultrasound as a result of hyperechoic tissues surrounded by hypo-echoic soft-tissue fluid. Abscesses appear as irregularly walled cavities with a mix of hypo and hyper echoic fluid within (see [Figures 8 and 9](#)). One prospective study found POCUS to be 90% sensitive (95% CI 77, 100%) and 83% specific (95% CI 66, 94%) for distinguishing abscess from cellulitis, compared to clinical suspicions alone at 75% and 80% respectively. Where blood tests

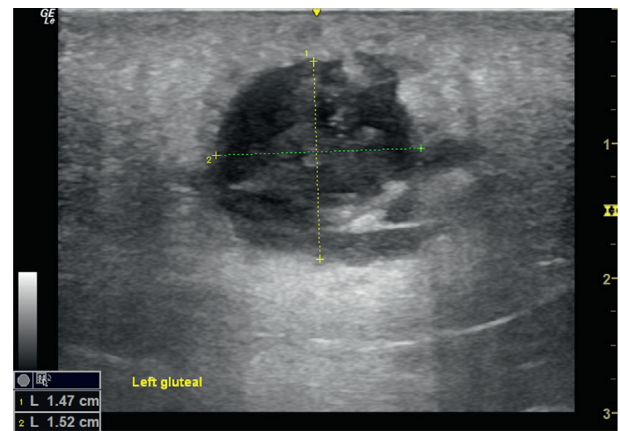


Figure 8 Soft tissue POCUS demonstrating early abscess formation in the gluteal region of 12 year old girl. The walls of the abscess are irregular with a mixture of hypoechoic (dark) fluid and regions of more complexity echogenicity (brighter).

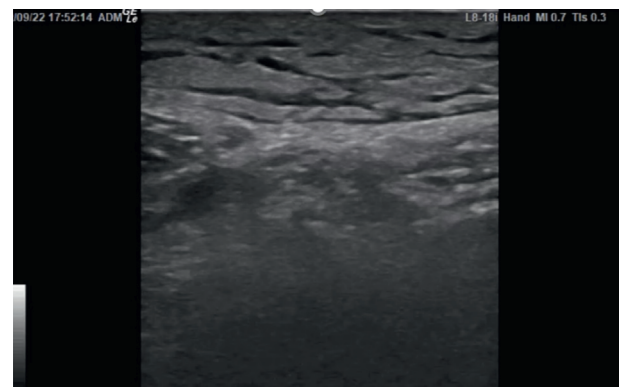


Figure 9 Soft tissue POCUS demonstrating cobblestoning pattern suggestive of cellulitis. The cobblestoning occurs as a result of hyperechoic (bright) fat lobules separated by hypoechoic fluid-filled areas.

may previously have been used to help rule out abscesses, POCUS is able to reliably answer this question promptly and painlessly for the child. In one review the addition of POCUS assisted with identification of clinically occult abscesses and helped to avoid invasive procedures in cases of simple cellulitis.¹³

You are asked to review a 9-year-old boy with vomiting, temperatures and worsening right sided abdominal pain. His Paediatric Appendicitis Score is 6/10 but his WCC and CRP were normal.

Can POCUS help to improve certainty in the diagnosis of appendicitis?

You perform a POCUS which shows a 0.88 cm appendix with secondary signs of appendicitis such as hyperaemia on colour flow and increased peri-appendiceal fat echogenicity. He subsequently, has a laparoscopic appendicectomy and is found to have an inflamed, oedematous appendix.

POCUS has proven to be a valuable diagnostic aid in suspected appendicitis. Despite it being a very common presentation to the PED, appendicitis remains a challenging condition to correctly diagnose. Use of ultrasound has been shown to reduce the number of negative appendicectomies, quoted at more than 10% nationally. Several studies have evaluated the performance of POCUS in diagnosing paediatric appendicitis with encouraging results. One prospective study of 264 patients in the PED found a sensitivity of 85% (95% CI 75–95) and specificity of 93% (85–100); POCUS was conducted on average 2.5 hours earlier than formal radiology studies.¹⁴

In the UK, the national Getting It Right First Time (GIRFT) Pathway recommends ultrasound as the investigation of choice in paediatric appendicitis when imaging is required, typically where diagnostic uncertainty exists. The authors recommend expanding access to ultrasound for children with suspected appendicitis including training surgeons to perform scans for this purpose. Clearly this is just as relevant for paediatric and emergency medicine teams who are often the initial team caring for these children. POCUS training pathways for non-radiology specialists/sonographers are therefore required to meet this currently unmet need.

POCUS as an investigation

In specific cases POCUS can replace traditional irradiating imaging modalities in answering specific clinical questions.

You review a 5-year-old boy who presented to the PED after standing on something sharp while barefoot 3 weeks ago. During this time, he continued to experience pain, redness and swelling but multiple x-rays have not revealed any abnormality.

You conduct a POCUS.

See [Figure 10](#). This reveals a linear, hyperechoic structure within the soft tissues on the plantar aspect of the child's foot consistent with a retained foreign body. The orthopaedic team take the patient to theatre where a large piece of wooden barbecue skewer is removed. See [Figure 11](#).

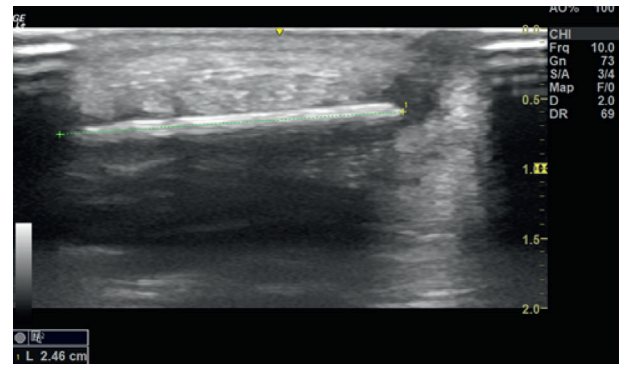


Figure 10 POCUS of foot with hyperechoic linear appearance suggestive of foreign body. The clean shadowing beneath the foreign body is a hallmark feature.

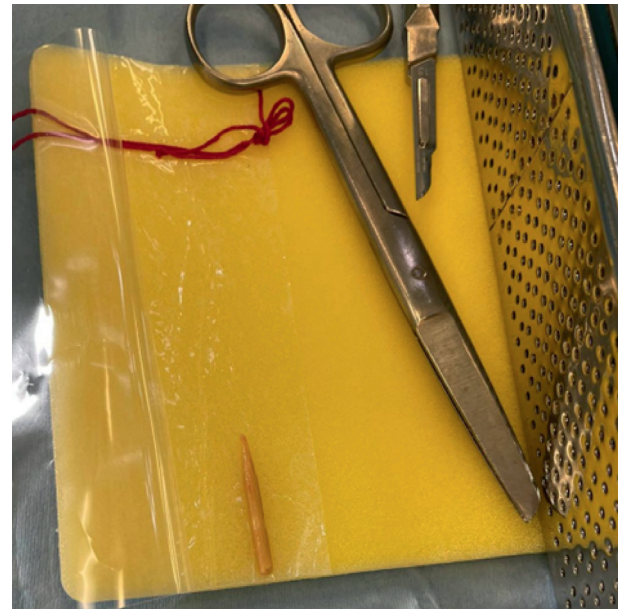


Figure 11 Wooden barbecue skewer foreign body retrieved from foot as demonstrated in the above image.

Up to 38% of soft tissue foreign bodies may be missed due to their radiolucency on x-ray.

This is particularly true for wooden foreign bodies, which are among some of the most commonly encountered foreign bodies in injuries in paediatric patients. POCUS can therefore help to identify radiolucent foreign bodies at the point of initial presentation expediting treatment and minimizing discomfort and infection risk to the patient.

A 10-month-old girl who has been brought to the PED by her parents who have noted a lump on her head over the past 24 hours. You note a well infant with a shallow, yet diffuse lump approximately 6 cm in diameter on the right parietal aspect of the skull. The rest of your examination is unremarkable. A colleague asks could this be a skull fracture?

Can I use POCUS to confirm presence of skull fracture?

You quickly and painlessly obtain the images as shown in [Figure 12](#). They demonstrate a fracture of the parietal skull.

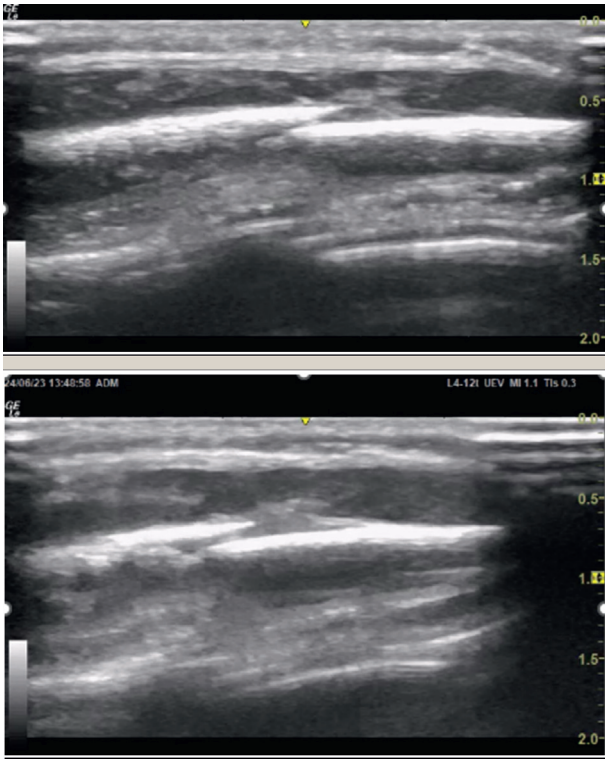


Figure 12 POCUS of parietal skull showing fracture.

A recent systematic review examining the performance of POCUS for detecting paediatric skull fractures comprising 7 studies and a total of 925 patients demonstrated a pooled sensitivity of 91%, specificity of 96%, positive predictive value of 88% and negative predictive value of 97% concluding that skull fractures can be reliably diagnosed using POCUS.¹⁵

Unexplained swelling over the skull is encountered relatively frequently in the PED. It is important to identify occult skull fractures for clinical management and because of the significant safeguarding implications in young children. POCUS has the potential to quickly identify skull fractures without the need for ionising radiation. This can aid decision making particularly around safeguarding and the need for further imaging. In appropriately trained hands it may be possible in the future to use POCUS as a rule out tool particularly where pre-test probability is low and/or an alternative diagnosis is identifiable e.g. delayed presentation of a cephalhaematoma.

POCUS to guide stabilization resuscitation in the PED

You are leading the resuscitation of a 7-year-old boy who presented following a sudden cardiac arrest at home. He had a period of 20 minutes downtime with evidence of asystole when paramedic crews arrived. Despite several rounds of intravenous adrenaline, he has remained in cardiac arrest for over 45 minutes with an un-recordable pH on his blood gas.

You undertake a cardiac POCUS in order to assess if there is any cardiac activity to help guide your decision in stopping active resuscitation.

One potential use of POCUS in cardiac arrest is in prognostication. For example, one systematic review looking at POCUS in traumatic cardiac arrest found that the proportion of patients with cardiac activity on POCUS who achieved return of spontaneous circulation (ROSC) was 98% (95% CI 0.13 to 1.0) while the proportion of patients with cardiac standstill while no patient with cardiac standstill survived. However, the authors concluded that the numbers involved were too small to justify changes to resuscitation guidelines. Other studies have shown similar results while noting that the use of POCUS to visualize cardiac standstill increased confidence in decision making in relation to stopping resuscitation. In the absence of robust evidence, the Resuscitation Council UK Paediatric Advanced Life Support Guidelines make no recommendation on prognostication while the European Resuscitation Council Guidelines advise against this use of POCUS.

The most recent Resuscitation Council UK Paediatric Advanced Life Support Guidelines advise that POCUS may be used by *competent providers* to identify reversible causes of cardiac arrest, particularly hypovolaemia, cardiac tamponade, tension pneumothorax and thromboembolism. They note that the evidence of benefit on outcome is limited. All guidelines that incorporate the potential use of POCUS stress the need to minimize interruptions to chest compressions. Another potential future use of POCUS in paediatric cardiac arrest is identification of recent signs of life that might indicate the need for invasive resuscitative efforts in traumatic cardiac arrest.

POCUS for guiding procedures

At the end of your busy shift in the PED you are asked to urgently assess a 10-year-old girl who fell at ballet class, hearing a loud crack and experiencing severe pain from her right thigh. She has a grossly swollen right thigh. X-rays reveal a displaced femoral shaft fracture. The orthopaedic SpR asks:

Can anyone perform femoral nerve blockade in order to facilitate application of a Thomas splint?

Using POCUS, you infiltrate local anaesthetic next to the femoral nerve under direct vision allowing pain free Thomas splint application.

Ultrasound-guided femoral nerve block insertion forms part of the Royal College of Paediatrics and Child Health (RCPCH) PEM subspecialty training curriculum and is now recommended by the Royal College of Emergency Medicine (RCEM) for their own trainees as being safer and more effective than a landmark approach.

Intraosseous (IO) line placement can be a life-saving procedure in the management of critically ill patients. Confirmation of correct IO line placement can be difficult. POCUS has been used to visualize the flow of agitated saline into the right heart via the IVC as a means of confirming suitable IO placement.

Considerations when using POCUS

POCUS has established benefits in a number of areas and potential/developing benefits in others. However, a 2018 review concluded that POCUS remained “the domain of a relatively small handful of physicians within the UK”. The situation within

paediatrics echoes this impression with slow progress. While it does appear on the Paediatric Emergency Medicine sub-specialty training curriculum this does not set out agreed standards for competence nor how to achieve it. The most often cited model for training includes an introductory course/series of modules followed by development of a scan logbook with oversight from a trained mentor until a required level of competence has been achieved. The greatest barrier slowing the progression of POCUS is the lack of available trainers and suitable training opportunities. A 2019 PERUKI survey across the UK PEM population concluded that 95% of all respondents stated they did not have a teaching program or an identified trainer to oversee development.

The key principles underlying POCUS, especially during periods of training, are that anyone picking up a probe should know their own limitations, understand the limitations of POCUS, be asking a specific question, and know their local governance arrangements, especially what to do/who to approach should they encounter an unexpected finding. In the absence of a more formalized training structure this, combined with non-contributory scanning for training, provides a safe approach to skill development while preventing potential POCUS overreach when it is used by inexperienced practitioners.

Impact on patient care

A study that examined the experiences of 654 patients for whom POCUS was conducted in general practice and found that patients felt more thoroughly examined (92%) and had their complaints taken more seriously (58%) when POCUS was part of the consultation. Furthermore, patients described feeling more secure (86%), and they felt and increased sense of trust in the physician's assessment (65%). Over 99% reported that POCUS was integrated naturally into the consultation.¹⁶

Conclusion

Originating as screening test for trauma patients over three decades ago, POCUS has developed into a valuable tool in clinical paediatrics. It serves as aid to decision making, as a means of improving patient safety for procedures and sometimes even as a reliable alternative to traditional imaging. The case to employ POCUS is perhaps most compelling in paediatrics where, for the care of our patients, the consideration to minimize exposure to ionising radiation and other harm is a constant consideration. ♦

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