JOGM
Journal of Global Medicine

REVIEW ARTICLE

Point of care ultrasound in acute settings – a narrative review

Ernest Olszewski[1], Oluwatosin Olusanya[2], Segun Olusanya[3] and Hakeem Yusuff[2,4,5,*]

[1]Leicester Medical School, University of Leicester, Leicester UK; [2]Department of Anaesthesia and Intensive Care Medicine, Glenfield Hospital, Leicester, UK; [3]Department of Perioperative Medicine, Barts Heart Centre, London, UK; [4]Department of Respiratory Sciences, University of Leicester, Leicester, UK; [5]NIHR Leicester Biomedical Research Unit, Glenfield Hospital, Leicester, UK

Abstract

Point of care ultrasound (POCUS) has become a standard assessment tool for the acute medical practitioner. Ultrasound has traditionally been the preserve of radiologists and cardiologists; however, the use by practitioners outside these specialties in the treatment of acutely ill patients began in the emergency department. Patients presenting with trauma or shock were assessed looking for life threatening injuries to inform immediate management.

Over the years and more recently during the COVID-19 pandemic, numerous POCUS protocols have been developed to standardise the practice of POCUS and to guide training. However, there are pitfalls to POCUS which include cross-contamination of infection, inter and intra-observer variability, bias, and retention of skills amongst practitioners.

The use of POCUS has increased in resource limited settings as ultrasound machines have become cheaper and more portable. However, challenges remain with considerable lack of trained healthcare staff and paucity of training opportunities. This has led to a considerable variability in the practice of POCUS in these settings.

Artificial intelligence (AI) is increasingly being leveraged as a medium to improve image acquisition, interpretation, and POCUS training. POCUS devices are also significantly smaller, cheaper, and more portable, increasing their availability to resource poor settings. There is potential for remote training platforms to improve access to learning opportunities in resource poor countries.

Keywords: *ultrasonography*; *shock*; *critical care*; *emergency medicine*; *artificial intelligence*

Received: 30 January 2024; Revised: 14 March 2024; Accepted: 19 March 2024; First Published Online: 20 March 2024; Published: 27 May 2024

The use of ultrasound technology in modern medical practice has become a well-established part of many treatment algorithms with its use involving both diagnostic and therapeutic indications. Traditionally, the use of ultrasonography was restricted to cardiologists and radiologists; however, in recent times there has been a growth in the skill and expertise required to safely use ultrasound by healthcare professionals outside of these groups. The advantage of this has become particularly evident in acute care settings where the use of point of care ultrasound (POCUS) can provide vital diagnostic information to aid the immediate management of acutely ill patients. POCUS has recently been defined as 'the acquisition, interpretation, and immediate clinical integration of ultrasonographic imaging performed by a treating clinician at the patient's bedside, rather than by a radiologist or cardiologist' [1]. In this review, we will present and discuss the evidence for POCUS, discuss its applicability in acute care settings, highlight the challenges in its implementation-especially in resource poor countries and future perspectives.

Evolution of POCUS

The earliest use of POCUS was in emergency medicine, where ultrasound was used in hyper acute settings (trauma and shock) to aid the diagnosis of immediate life-threatening injuries [2]. Free intra-abdominal and pericardial fluid proved easy and quick to recognise with POCUS; this led to the development of protocolised ultrasound assessments such as Rapid Ultrasound for Shock and Hypotension (RUSH) and Focused Assessment with Sonography in Trauma (FAST) [3]. POCUS in intensive care units (ICU) was initially utilised for procedural guidance (e.g., central venous access). However, as POCUS grew in emergency medicine, it found increased use as not

Citation: Journal of Global Medicine 2024, **4**: 145 - http://dx.doi.org/10.51496/jogm.v4.145

only a non-invasive diagnostic tool but also as a dynamic multimodal assessment tool to guide ongoing ICU management. Where initial ultrasound machines were bulky and difficult to transport, the last two decades of the 20th century has seen the development of smaller, faster, and more portable ultrasound devices. This has provided an opportunity to address a need to increase diagnostic accuracy in the patients presenting with acute illness [4].

Current POCUS Applications and Protocols

The applications of POCUS at the bedside are theoretically unlimited, and there are descriptions of POCUS being used for:

- Airway assessment
- Neurological assessment
- Fractures and musculoskeletal assessment
- Echocardiography, including transoesophageal echo
- Lung ultrasound
- Abdominal ultrasound, including assessment of the genitourinary system and assessment of gastric content to provide safe anaesthesia
- Vascular access and deep vein thrombosis (DVT)
- Regional anaesthesia
- Lumbar puncture

The most common applications are focussed echocardiography, lung, and abdominal ultrasound, and we will mainly focus on these applications for the rest of the article.

Echocardiography

The use of echocardiography in acute clinical settings has improved the capability of the acute physician in the management of acute cardiovascular dysfunction. This is especially true when trying to decipher which form of shock predominates especially in complex clinical presentations. Most focussed protocols involve four basic views – parasternal long axis, parasternal short axis, apical, and subcostal (Fig. 1). This would allow a quick assessment of left ventricular function, preload responsiveness, right ventricular function/dilation, and pericardial effusion [5].

Current protocols (Table 1) often combine echocardiography with other body system ultrasound protocols to create a comprehensive structured assessment. This also facilitates training and standardises reporting of results. Most protocols focus on a visual and structural assessment for myocardial and/or valvular function. More recently, protocols have been developed that incorporate more advanced echocardiography skills such as haemodynamic assessments. The ORACLE protocol for example, added the assessment of right ventricular afterload

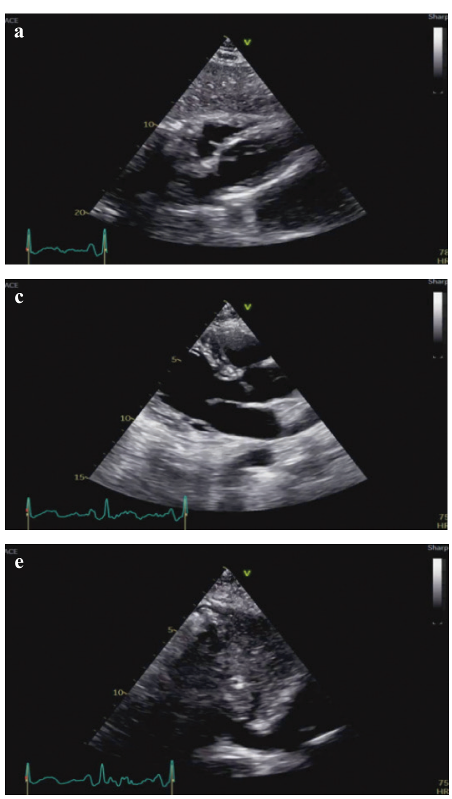

Fig. 1. Basic echocardiography views. a) Subcostal view, b) Apical 4 chamber view, c) Parasternal long axis view, d) Parasternal short axis view, e) Inferior vena cava view.

Table 1. POCUS protocols

Protocols	Regions assessed	Clinical utility
FAST Protocol (1970s) [7]	Abdomen	Assessment of intra-abdominal free fluid
FATE Protocol (2004) [8]	Cardiac	Rapid assessment of shock states
FEEL protocol (2007) [9]	Cardiac	Echocardiography in cardiac arrest
RUSH Protocol (2008) [10]	Heart, lungs, abdomen	Diagnosing cause of shock
BLUE Protocol (2008) [11]	Lungs	Diagnosis of acute respiratory failure.
C.A.U.S.E. (2008) [12]	Cardiac and lungs	Detect the 4 leading causes of non-arrhythmogenic cardiac arrest (hypovolemia, congestive cardiac failure, cardiac tamponade, Pulmonary Embolism [PE])
PIEPEAR (2008) [13]	Cardiac and lungs	Diagnosis of acute cardiorespiratory failure
ORACLE (2020) [6]	Cardiac and lungs	Cardiac and respiratory evaluation of COVID- 19 patients
ASE POCUS protocol for COVID-19 (2020) [14]	Cardiac, lungs and venous	Outlines structures to be imaged, parameters to assess and measure, and disease associations. May assist in the initial cardiopulmonary assessment of patients with COVID-19.
FUSIC Heart (2012) [15]	Cardiac	Focussed heart ultrasound for adult intensive care.

and left ventricular diastolic function [6]. It was developed during the COVID-19 pandemic to facilitate disease specific assessment and reduce the exposure of trained sonography staff to infection.

Lung ultrasound

Lung ultrasound gained widespread prominence after the work of Daniel Lichtenstein in the 1990s [11]. It has emerged as a highly sensitive and specific tool for detecting pulmonary pathology, demonstrating superiority to chest X-ray in several aspects [16]. Lung ultrasound also has the added advantage compared with chest X-rays and CT scans of the lack of exposure to radiation. It can be used repeatedly without the need to move patients to the radiology department. The use of POCUS for lung ultrasonography has been shown to reduce the use of chest X-rays and CT scans by 26% and 47%, respectively [17].

Lung ultrasound can be used to identify pneumothorax, pleural effusion, pulmonary oedema, lung consolidation, pulmonary embolus, and obstructive airway disease (Fig. 2) [18]. When combined with echocardiography, lung ultrasound improves the diagnostic accuracy of pulmonary oedema (94% vs, 65%; $P = 0.03$) and lung consolidation (83% vs, 66%; $P = 0.016$) [19]. Hence, most POCUS protocols combine echocardiography with lung ultrasound. (Table 1)

Abdominal ultrasound

Abdominal ultrasound in the context of POCUS was initially used for assessment of shock in trauma patients. As a non-invasive alternative to diagnostic peritoneal lavage, and a faster bedside alternative to CT, ultrasound for the assessment of free intraabdominal fluid gained rapid traction. An example of this is the Focused Assessment with Sonography for Trauma (FAST) protocol [7]. FAST evaluates four regions – Pericardial, peri-splenic, perihepatic and pelvic. FAST has a low diagnostic yield in the early post injury phase, in penetrating injuries, and poorly demonstrates retroperitoneal haemorrhage (Fig. 2) [20]. The extended FAST protocol incorporates basic thoracic injury assessment.

In the critical care setting, POCUS incorporates assessment for intraabdominal free fluid, urinary tract obstruction and in some protocols, the abdominal aorta and gall bladder. More advanced techniques involve the assessment of solid organ congestion by assessing the inferior vena cava (IVC), hepatic, portal, and intrarenal veins as part of the Venous Excess Ultrasound (VEXUS) protocol [21].

Evidence for POCUS

The evolution of POCUS in acute care settings has been borne out of the need to increase diagnostic speed and accuracy in a bid to improve clinical outcomes. POCUS is often referred to as the 'stethoscope of the future' to emphasise its adjunctive role in the clinical examination of patients, like the impact of Laennec's device when it was introduced into regular clinical practice in the late 19th century [22].

As stated above, the entry of POCUS into routine medical practice has its origins in emergency medicine and the evaluation of shock, with some of the earliest examples being in the 1970s involving the use of ultrasound for the assessment of intra-abdominal free fluid in trauma patients (Fig. 2) [23]. Contemporary evidence to support its use now exists; a recent prospective study in a single large tertiary hospital evaluated 180 patients presenting with non-traumatic shock. Each patient had two clinical examinations, one with POCUS using the RUSH protocol and the other without. The use of POCUS led to a modification of the treatment plan in 50 of patients while an entirely new plan was devised for 22.3% of patients [24]. In 2017, the ultrasound specialist interest group of the International Federation of Emergency Medicine (IFEM) conducted a modified Delphi process and produced a

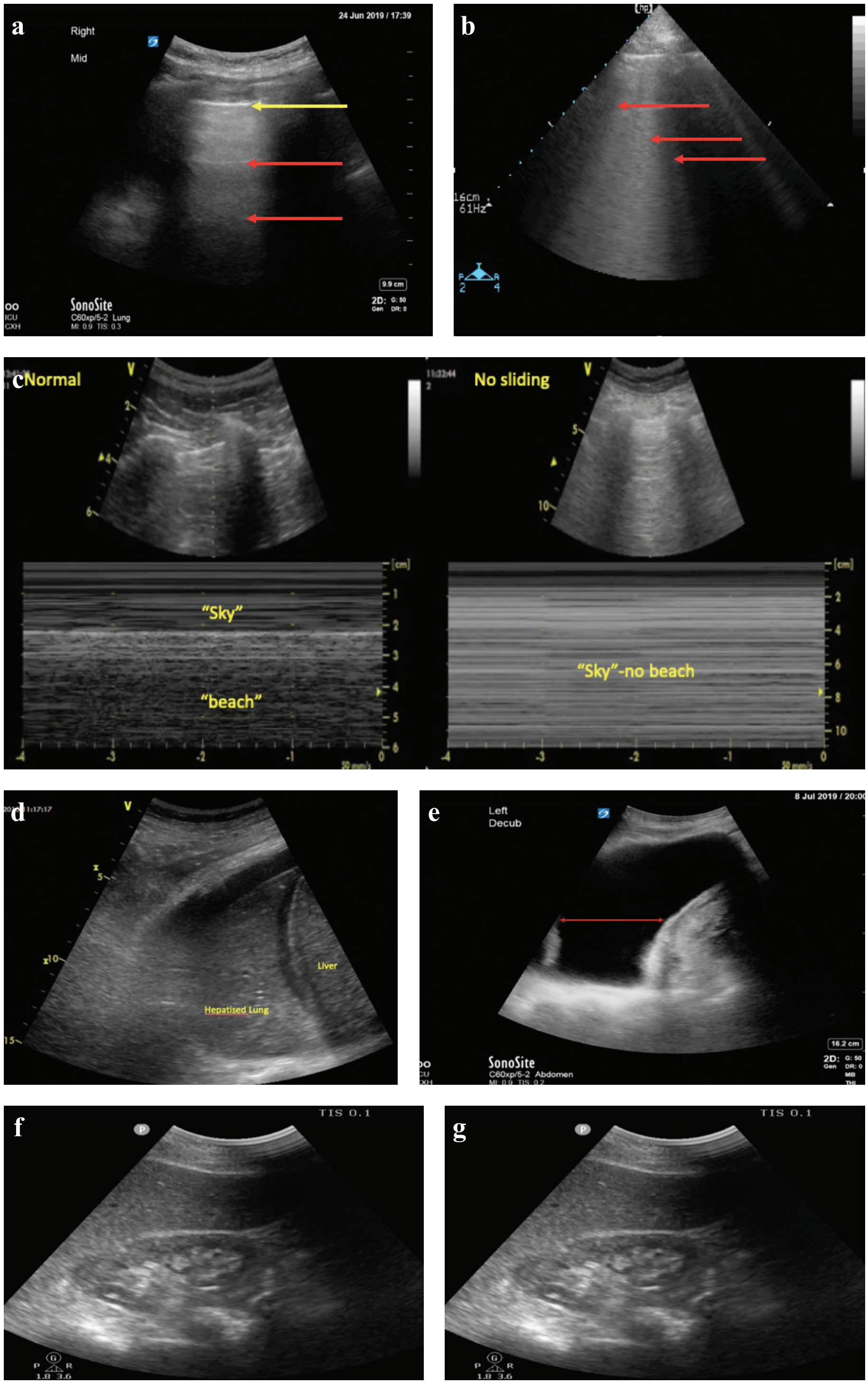

Fig. 2: Lung and Abdominal ultrasound – a) Normal lung ultrasound showing normal a lines, b) Lung ultrasound demonstrating B lines (suggestive of pulmonary oedema, c) Lung ultrasound demonstrating normal lung and pneumothorax on M-mode, d) Lung ultrasound demonstrating a consolidated (hepatised) lung, e) Lung ultrasound demonstrating pleural effusion, f) Abdominal ultrasound demonstrating normal appearance of the hepatorenal recess (Morrison’s pouch), g) Abdominal ultrasound demonstrating the intraabdominal fluid in the hepatorenal recess.

consensus statement on sonography in hypotension and cardiac arrest (SHoC) [25]. The SHoC protocol recommends hypotension core views which consist of cardiac, lung and IVC views. The 2021 resuscitation council UK guidelines for adult advanced life support recommend the use of POCUS in skilled hands to help diagnose treatable causes of cardiac arrest such as cardiac tamponade and tension pneumothorax [26].

In the context of the acutely deteriorating medical patient, a prospective, observational study assessed the effect of POCUS amongst two teams. One used POCUS and the other did not. Adequate immediate diagnosis was made in 94% cases in the POCUS group and 80% in the control group (P = 0.009). Time to first intervention was shorter in the POCUS group 15 [10–25] min versus 34 [15–40] min, P < 0.001). In hospital, mortality rates were 17% in the POCUS group and 35% in the control group (P = 0.007). However, when both groups were matched in a propensity score analysis this difference was not replicated (29% vs, 34%, P = 0.53) [27]. Similarly, in a randomised controlled trial (RCT) evaluating POCUS in patients presenting with chest pain or dyspnoea assessed with the first 24 h of ward admission, time to appropriate treatment was significantly shorter in the POCUS group compared with the POCUS group (median time 5 h [95% CI 0.5-9] vs. 24 h [95% CI 19–29], P = 0.014). However, even though the time to achieve the correct diagnosis was shorter in the POCUS group, it did not reach statistical significance (median time 24 h [95% CI: 18–30] vs. 48 h [95% CI: 20–76], P = 0.12) [28].

A large, RCT was done to evaluate the effect of a standardised POCUS protocol on 30-day or hospital discharge survival in patients presenting to the emergency department with undifferentiated hypotension involving 3 centres in the US and 3 centres in South Africa. The protocol assessed was a modification of the RUSH protocol. The trial failed to show any difference in 30 day or hospital discharge survival between the intervention and standard of care group [29].

During the COVID-19 pandemic, the use of POCUS played a key role in understanding the nature of the disease and helped to identify specific clinical phenotypes which required a different management approach. POCUS protocols such as ORACLE and FUSIC-heart helped bed side clinicians to identify COVID-19 pneumonia [30,31], an increased incidence of right ventricular injury [32], and pulmonary embolism in patients with COVID-19 [6].

A prospective observational study using POCUS to assess the haemodynamic profiles of COVID-19 patients found that 9.6% of patients presented in a low cardiac output state associated with a low ejection fraction. A subset of patients had a low cardiac output with a normal ejection fraction in the context of high positive end expiratory pressure (PEEP) suggesting low preload, and such patients would benefit from careful intravascular volume expansion [33]. This also informed initial guidelines to clinicians warning of a potential risk of the increased incidence of acute kidney injury (AKI) in COVID-19 patients receiving high amounts of PEEP especially if they are underfilled [34].

There is some evidence to support the use of POCUS in the context of acute presentations such as acute heart failure, shock, and acute respiratory failure where there is a signal of benefit by either improving diagnostic accuracy or improving survival by directing physicians to the best management strategy earlier during the presentation [11, 35, 36].

FAST protocol

The FAST protocol is widely recognised in acute settings due to its efficacy and reliability in detecting internal haemorrhage in critically unwell patients [37–39]. While it is not a substitute for other imaging modalities, it is a valuable tool in the initial trauma management as it allows for rapid assessment and aid interventions which are paramount in these patients. The FAST scan has been integrated into trauma protocols and guidelines worldwide which highlights that POCUS has the potential to contribute to more evidence-based tools in the future and improve outcomes for acutely unwell patients.

The greatest impact of POCUS is in the evaluation and treatment of the acute problems presenting in an acutely ill patient; however, it is difficult to demonstrate how this benefit translates into a mortality benefit. The use of POCUS is best placed in a process of care that includes other evidence based diagnostic and therapeutic management strategies delivered as a care bundle towards a specific acute presentation.

Pitfalls of POCUS

Cross-transmission of organisms

A soiled ultrasound probe can serve as a medium of transmission of microbes between patients. This risk is reduced but not eliminated by regular decontamination of the probes after each use. The coupling gel used during scanning has been shown to permit bacterial growth and it does not have any bactericidal or bacteriostatic properties [40,41]. In order to minimise the risk of cross-infection, it is recommended that after each patient use the gel is wiped off the transducer probes and cables with absorbent cloth. Additional cleaning with a low to medium level disinfectant is required daily. Frequent use of alcohol wipes after every patient use may degrade the rubber seal of the probe of some transducers [42]. The use of probe covers for the transducer and single use sterile gel may help to reduce the risk of cross-infection. Ultrasonic cleaning devices have been shown to be effective in dis-infecting ultrasound probes while preserving the integrity of the transducers [43].

Bias and interpretation

The use of ultrasound in the critical care setting is prone to inter- and intra-observer variability in the interpretation of findings. This is more common in situations where structured POCUS protocols are not used. It is important that departments where POCUS is performed routinely have a robust clinical governance process in place to guide the use of POCUS and reduce variability. The Royal College of Radiologists and the British Medical Ultrasound Society have published recommendations to guide the safety, governance, and education of POCUS used outside radiology departments [44].

Retention of POCUS skills

The widespread use of POCUS and its increased applicability in different clinical settings has led to an exponential increase in the training opportunities available with varying content and structure. Some are integrated as part of a clinical training programme while others are standalone programmes [45]. The paucity of appropriately trained supervisors has led to a proliferation of short (1–3 day) courses, usually containing a mix of hands-on training and workshops [15]. A few studies have shown that long term retention of POCUS skills with short training programmes is poor, necessitating the need for re-training [46,47]. Some POCUS training systems emphasise the need for Continuous Professional Development (CPD) and re-accreditation, such as the Australian Certificate of Clinician Performed Ultrasound (CCPU) [48].

POCUS in Resource Poor Settings

The utility of POCUS has increased recently as ultrasound machines have become cheaper and more portable. This has increased the potential diagnostic yield in acute settings where other diagnostic modalities might be inaccessible due to cost or lack of infrastructure required. In 1985, the World Health Organization (WHO) noted that the use of ultrasound has the potential to improve patient management in developing countries where ultrasound may represent the sole useful radiology service [49]. Another core challenge is the lack of a specialised healthcare workforce. The use of POCUS combined with 'task shifting'– where specific tasks are moved from highly qualified health workers to less qualified health workers, in order to increase efficiency of available human resources – has been identified as a strategy to overcoming inequitable access and poor health outcomes in Resource Poor Settings (RPS) [50, 51]. Despite this, there is considerable variability in the use of POCUS in RPS due to the inequitable distribution of resources and infrastructure, and difficulties in accessing appropriate training and support. Consequently, most of the ultrasound assessments are carried out by radiologists/radiographers [52].

A recent study looked at the use of a lung ultrasound protocol to assess pregnant women admitted to a high dependency unit in Sierra Leone. Patients were assessed at 6, 24 and 48 hours after admission. Features examined for included pleural effusion, atelectasis, consolidation, and adult respiratory distress syndrome (ARDS). The study found abnormal lung ultrasound features in 21% of patients, and found that patients who were clinically in respiratory distress but with a normal lung ultrasound the aetiology was usually linked to anaemia or metabolic acidosis. Patients with respiratory distress and abnormal lung ultrasound features had a higher mortality [53]. Despite the limitations of this study, this demonstrates the applicability of POCUS to direct appropriate management and facilitate severity stratification in critically ill patients in a resource limited setting.

There are multiple indications for POCUS in RPS, including infectious diseases, trauma, and cardiology/cardiac surgery especially congenital heart disease [54]. In a study from Iraq, certain sonographic changes such as hepatosplenomegaly and bowel thickening increased the diagnostic likelihood of typhoid fever in atypical cases where serology may be negative [55]. In another study from Tanzania, POCUS was used to identify prognostic factors for mortality in patients who presented with bowel perforation secondary to typhoid fever [56]. Similarly, there is evidence of use of POCUS in the assessment of patient with malaria to aid diagnosis and assess severity, by assessing hepatosplenomegaly and optic nerve sheath diameter in cases of cerebral malaria [57]. POCUS has also been used in the diagnosis and management of echinococcus, tuberculosis (including extra-pulmonary tuberculosis) and human immunodeficiency virus (HIV) disease [58–61].

In RPS, where financial considerations greatly influence decision-making, the role of POCUS is promising due to its cost-effectiveness. It offers an affordable imaging solution that can aid more rapid diagnosis and management of patients, which is crucial in areas where expensive imaging modalities or clinicians with specialised skills are lacking. Wider introduction of POCUS in these settings, can facilitate faster diagnostic and treatment decisions, which in turn can have a favourable impact on patient outcomes. Furthermore, its cost-effectiveness can have a positive contribution to the healthcare system by potentially reducing unnecessary referrals and thus optimising resource allocation.

The Future

Artificial intelligence

While the concept of artificial intelligence (AI) has been around for decades, its use in the medical field has however, accelerated recently. AI is a technology that 'self-learns' from the data it is provided to reach a conclusion [62] and so far, it has proven to have multiple uses in imaging analysis, diagnostic assistance, treatment optimisation, drug development, and many more [63].

In recent years, AI has been developed to assist in real time interpretation of data during bedside POCUS examination, and it has produced promising outcomes. AI can help with the analysis of images, identification of structures, and in measuring certain organ abnormalities and function [64]. One study looking at cardiac POCUS has demonstrated a high agreement (0.498; $P < 0.001$) in measured left ventricle (LV) ejection fraction between AI automated algorithm and a professional in cardiac POCUS [65]. In the same study, different parameters, including an IVC measuring tool, and an automatic velocity time integral tool were also analysed, which also showed the same trend in the results. However, the study was limited by a relatively small sample size as well as not including cases with moderate and severe LV dysfunction or poor image quality.

Another study looking at artifacts known as 'B-lines' on lung ultrasound (Fig. 2) in acute settings showed 93% sensitivity and 96% specificity, which was higher than an expert's interpretation. However, it was less accurate at assessing severity of B-lines [66]. Similarly, one study looking at the diagnosis of paediatric pneumonia has used an AI neural network to identify pneumonia infiltrates with 90.9% sensitivity and 100% specificity [67].

Apart from cardiac and pulmonary POCUS, AI has also been applied to other acute POCUS scans, including foetal [68], DVT [69], and renal [70] scans with similarly optimistic results. The overall impression is that AI automated measurements are just as reliable while being faster than humans at interpretation and calculation – allowing for a quicker diagnosis and better patient outcomes [71]. It is also worth remembering that AI is still in its early stages [72]. It is predicted that AI will become even more powerful with more advanced algorithms and capabilities, which could lead to much more accurate and faster POCUS interpretation.

Integration of AI in POCUS could result in a more user-friendly and less user dependent experience. This could require less training and knowledge from the user, meaning that more novice users would be able to confidently use POCUS and use the AI analysed data to aid clinical judgement. A small study looking at paediatric lung POCUS found that novice users, with limited POCUS exposure and knowledge, were able to identify pneumonia with a help of AI-augmented interpretation systems with 93.7% accuracy (95% CI 79.1–99.2) [73].

The implementation of AI in POCUS is both intriguing and endless. However, one of the reasons that could decelerate the application of AI in POCUS is the current lack of standardised protocols and algorithms as opposed to other imagining modalities such as X-ray, CT, and MRI [74]. Static imaging modalities, like X-rays, are easier for AI to process and give a more accurate result as opposed to live imaging like POCUS [64].

Apart from AI being utilised in practice, it also has a potential role in POCUS training and education. AI generated resources could simulate ultrasound scenarios that might be used for training purposes in a controlled environment [75]. A small study has shown that an AI training tool has helped radiology residents achieve higher sensitivity, specificity, and accuracy at chest X-ray interpretation with the AI tool [76]. However, their performance went back to their baseline without the AI aid, suggesting that they did not learn or retain the information when using the AI tools.

Currently, there are not many clear guidelines on how to utilise AI in medical education [77]. However, AI has potential to identify gaps in an individual's knowledge and personalise the teaching material in the most beneficial and efficient way to create an individualised learning experience [78].

Accessibility

We have seen a massive progression in technological advancement in all sectors, and POCUS has followed the same trend. POCUS devices are now smaller, faster, and more multifunctional [79]. This enables easier transportation and use in various locations, including resource-limited and remote environments [80]. In the future, it is likely to gain more advanced features and customisation with integrated AI, which promises even more usability.

Advancing software is also likely to revolutionise POCUS. It has the potential to increase the image quality not just by improved image collection, but also by post-acquisition improvements including more advanced processing algorithms with better artifact recognition [81] and even more complex post-imaging features like 3D reconstruction [82,83]. Furthermore, as previously discussed, AI implementation in software development has the potential to enhance images, provide automatically calculated measurements and even automatically interpret the data. We can also expect further speciality-oriented automated features. For instance, an increasing number of POCUS machines have a built-in cardiac feature which automatically estimates ejection fraction [84]. More automatic measurements will follow as the software evolves. Advancing software development also has the potential for more personalised interpretation by considering patient-specific factors, like gender, weight, and age. All these reasons promise a more user-friendly and less user-dependent software with more accurate data analysis.

While the cost of POCUS devices is dropping, they can still be comparatively high, with starting prices at around \$2000, and the average cost being around \$8000 [85] depending on the varying functionality of the device. As the technology advances and the manufacturing process improves, we can expect that the cost will progressively reduce. So far, the increased affordability has widened the audience of POCUS users to clinics, smaller hospitals, and even individual healthcare professionals [79]. If prices for the device continue to fall, we can expect that number of operators in these settings will significantly increase. And as the number of users increase, the number of individuals able to provide training is also expected to increase, which translates to more accessible training. Furthermore, with the current trends in computer and internet speed, it is predicted that more people will have access to online resources, teaching programmes, and simulation tools which could make access to training easier. More advanced technology will also allow for larger databases and faster analysis of data, which could be used for training and education purposes.

The use of real-time, remotely supervised ultrasound (Tele-POCUS) has been proven to be effective in recent years. Some studies show that the use of this teaching strategy to remotely supervise clinicians, who have basic POCUS training, has improved the quality of POCUS scans as opposed to un-supervised clinicians [86–88]. We can expect that the role of remote supervision and teaching will exponentially increase in the upcoming years.

While mandatory ultrasound training during undergraduate education is not yet widely adopted, it has slowly made its way into the curriculum at some medical schools due to its growing uses [89]. We can anticipate it being implemented by more medical schools in the future and this will further promote early exposure to ultrasound and build confidence in the next generation of users.

The demand of POCUS is constantly increasing due to its benefits of portability, quick diagnosis, cost-effectiveness, and better patient outcomes [85]. POCUS is also becoming more accessible due to advancing technology, AI, reducing costs, and easier access to training. And if that trend continues, POCUS has a potential to eventually replace the stethoscope as it will provide more diagnostic opportunities with higher accuracy and at a much faster rate.

Conclusion

POCUS has become an established assessment modality in the acute setting. The use of POCUS is increasing and extending to non-traditional indications. While we highlighted the promising future of POCUS, it is worth noting that its purpose is not to replace other specialist imaging modalities (e.g., CT scan and MRI) but rather serve as a cost-effective adjunct to guide initial management of the patient alongside specialist input (e.g., cardiologists, radiologists).

There are several POCUS protocols, and it is important to standardise its training and implementation. POCUS has the potential play a big part in the delivery of healthcare in resource limited settings, with further future developments promising more tailored approaches to the unique needs of these areas.

Acknowledgements

Conflict of interest and funding

HY is a member of the advisory board and receives honorarium for education from AOP Orphan Limited not related to this work.

None declared. The authors have not received any funding or benefits from industry or elsewhere to conduct this study.

Authors' contributions

All authors contributed equally to the production of this manuscript.

References

1. Moore CL, Copel JA. Point-of-care ultrasonography. N Engl J Med 2023; 364(8): 749–757. doi: 10.1056/nejmra0909487
2. Barjaktarevic I, Kenny JÉS, Berlin D, Cannesson, M. The evolution of ultrasound in critical care: from procedural guidance to hemodynamic monitor. J Ultrasound Med 2021; 40(2): 401–405. doi: 10.1002/jum.15403
3. Seif D, Perera P, Mailhot T, Riley D, Mandavia, D. Bedside ultrasound in resuscitation and the rapid ultrasound in shock protocol. Crit Care Res Pract 2012; 2012: 503254. doi: 10.1155/2012/503254
4. Winters B, Custer J, Galvagno SM, Colantuoni E, Kapoor SG, Lee HW, et al. Diagnostic errors in the intensive care unit: a systematic review of autopsy studies. BMJ Qual Saf 2012; 21(11): 894–902. doi: 10.1136/bmjqs-2012-000803
5. Lau YH, See KC. Point-of-care ultrasound for critically-ill patients: a mini-review of key diagnostic features and protocols. World J Crit Care Med 2022; 11(2): 70. doi: 10.5492/wjccm.v11.i2.70
6. García-Cruz E, Manzur-Sandoval D, Rascón-Sabido R, Gopar-Nieto R, Barajas-Campos RL, Jordán-Ríos A, et al. Critical care ultrasonography during COVID-19 pandemic: the ORACLE protocol. Echocardiography 2020; 37(9):1353–61. doi: 10.1111/echo.14837
7. Rozycki GS, Ochsner MG, Schmidt JA, Frankel HL, Davis TP, Wang D, et al. A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. J Trauma 1995; 39(3): 492–500. doi: 10.1097/00005373-199509000-00016
8. Jensen MB, Sloth E, Larsen KM, Schmidt MB. Transthoracic echocardiography for cardiopulmonary monitoring in intensive care. Eur J Anaesthesiol 2004; 21(9): 700–7. doi: 10.1017/S0265021504009068
9. Breitkreutz R, Price S, Steiger HV, Seeger FH, Ilper H, Ackermann H, et al. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: a prospective trial. Resuscitation 2010; 81(11): 1527–33. doi: 10.1016/j.resuscitation.2010.07.013
10. Perera P, Mailhot T, Riley D, Mandavia D. The RUSH exam: rapid ultrasound in SHock in the evaluation of the critically lll. Emerg Med Clin North Am 2010; 28(1): 29–56, 2010. doi: 10.1016/j.emc.2009.09.010
11. Lichtenstein DA, Mezière GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure*: the BLUE Protocol. Chest 2008; 134(1): 117–25. doi: 10.1378/chest.07-2800
12. Hernandez C, Shuler K, Hannan H, Sonyika C, Likourezos A, Marshall J. C.A.U.S.E.: cardiac arrest ultra-sound exam—A

better approach to managing patients in primary non-arrhythmogenic cardiac arrest. Resuscitation 2008; 76(2): 198–206. doi: 10.1016/j.resuscitation.2007.06.033

13. Yin W, Li Y, Wang S, Zeng X, Qin Y, Wang X, et al. The PIEPEAR workflow: a critical care ultrasound based 7-step approach as a standard procedure to manage patients with acute cardiorespiratory compromise, with two example cases presented. Biomed Res Int 2018; 2018: 4687346. doi: 10.1155/2018/4687346
14. Johri AM, Galen B, Kirkpatrick JN, Lanspa M, Mulvagh S, Thamman R. ASE statement on Point-of-Care ultrasound during the 2019 novel coronavirus pandemic. J Am Soc Echocardiog 2020; 33(6): 670–3. doi: 10.1016/j.echo.2020.04.017
15. FUSIC Heart. Available from https://ics.ac.uk/product/heart.html. [cited 10 January 2024]
16. Vignon P, Chastagner C, Berkane V, Chardac V, François B, Normand S, et al. Quantitative assessment of pleural effusion in critically ill patients by means of ultrasonography. Crit Care Med 2005; 33(8): 1757–63. doi: 10.1097/01.CCM.0000171532.02639.08
17. Peris A, Tutino L, Zagli G, Batacchi S, Cianchi G, Spina R, et al. The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computed tomography scans in critically ill patients. Anesth Analg 2010; 111(3): 687–92. doi: 10.1213/ANE.0b013e3181e7cc42
18. Lichtenstein DA. Lung ultrasound in the critically ill. Ann Intensive Care 2014; 4: 1–12. doi: 10.1186/2110-5820-4-1
19. Bataille B, Riu B, Ferre F, Moussot PE, Mari A, Brunel E, et al. Integrated use of bedside lung ultrasound and echocardiography in acute respiratory failure: a prospective observational study in ICU. Chest 2014; 146(6): 1586–93. doi: 10.1378/chest.14-0681
20. Montoya J, Stawicki SP, Evans DC, Bahner DP, Sparks S, Sharpe RP, et al. From FAST to E-FAST: an overview of the evolution of ultrasound-based traumatic injury assessment. Eur J Trauma Emerg Surg 2016; 42: 119–26. doi: 10.1007/s00068-015-0512-1
21. Beaubien-Souligny W, Rola P, Haycock K, Bouchard J, Lamarche Y, Spiegel, R, et al. Quantifying systemic congestion with Point-Of-Care ultrasound: development of the venous excess ultrasound grading system. Ultrasound J 2020; 12: 16. doi: 10.1186/s13089-020-00163-w
22. Roguin A. Rene Theophile Hyacinthe Laënnec (1781–1826): the man behind the stethoscope. Clin Med Res 2006; 4(3): 230. doi: 10.3121/cmr.4.3.230
23. Savoia P, Jayanthi S, Chammas M. Focused Assessment with Sonography for Trauma (FAST). J Med Ultrasound 2023; 31(2): 101. doi: 10.4103/jmu.jmu_12_23
24. Sasmaz MI, Gungor F, Guven R, Akyol KC, Kozaci N, Kesapli M. Effect of focused bedside ultrasonography in hypotensive patients on the clinical decision of emergency physicians. Emerg Med Int 2017; 2017: 1–8. doi: 10.1155/2017/6248687
25. Atkinson P, Bowra J, Milne J, Lewis D, Lambert M, Jarman B. et al. International Federation for Emergency Medicine Consensus statement: sonography in hypotension and cardiac arrest (SHoC): an international consensus on the use of point of care ultrasound for undifferentiated hypotension and during cardiac arrest. CJEM 2017; 19(6): 459–70. doi: 10.1017/cem.2016.394
26. Advanced life support guidelines (2021).Available from https://www.resus.org.uk/library/2021-resuscitation-guidelines/adult-advanced-life-support-guidelines. [cited 10 January 2024]
27. Zieleskiewicz L, Lopez A, Hraiech S, Baumstarck K, Pastene B, Bisceglie MD, et al. Bedside POCUS during ward emergencies is associated with improved diagnosis and outcome: an observational, prospective, controlled study. Crit Care 2021; 25: 1–12. doi: 10.1186/s13054-021-03466-z
28. Ben-Baruch Golan Y, Sadeh R, Mizrakli Y, Shafat T, Sagy, I, Slutsky T. et al. Early Point-of-Care ultrasound assessment for medical patients reduces time to appropriate treatment: a pilot randomized controlled trial. Ultrasound Med Biol 2020; 46(8): 1908–15. doi: 10.1016/j.ultrasmedbio.2020.03.023
29. Atkinson PR, Milne J, Diegelmann L, Lamprecht H, Stander M, Lussier D. et al. Does Point-of-Care ultrasonography improve clinical outcomes in emergency department patients with undifferentiated hypotension? An international randomized controlled trial from the SHoC-ED investigators. Ann Emerg Med 2018; 72(4): 478–89. doi: 10.1016/j.annemergmed.2018.04.002
30. Buonsenso D, Pata D, Chiaretti A. COVID-19 outbreak: less stethoscope, more ultrasound. Lancet Respir Med 2020; 8(5): e27. doi: 10.1016/S2213-2600(20)30120-X
31. Volpicelli G, Gargani L, Perlini S, Spinelli S, Barbieri G, Lanotte A, et al. Lung ultrasound for the early diagnosis of COVID-19 pneumonia: an international multicenter study. Intensive Care Med 2021; 47(4):444–54. doi: 10.1007/s00134-021-06373-7
32. Lan Y, Liu W, Zhou Y. Right Ventricular Damage in COVID-19: association between myocardial injury and COVID-19. Front Cardiovasc Med 2021; 8: 606318. doi: 10.3389/fcvm.2021.606318
33. Hollenberg SM, Safi L, Parrillo JE, Fata M, Klinkhammer B, Gayed N, et al. Hemodynamic profiles of shock in patients with COVID-19. Am J Cardiol 2021; 153: 135–9. 10.1016/j.amjcard.2021.05.029
34. Ottolina D, Zazzeron L, Trevisi L, Agarossi A, Colombo R, Fossali T, et al. Acute kidney injury (AKI) in patients with Covid-19 infection is associated with ventilatory management with elevated positive end-expiratory pressure (PEEP). J Nephrol 2022: 35: 99–111. doi: 10.1007/s40620-021-01100-3
35. Pivetta E, Goffi A, Nazerian P, Castagno D, Tozzetti C, Tizzani M, et al. Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial. Eur J Heart Fail 2019; 21(6): 754–66. doi: 10.1002/ejhf.1379
36. Kanji HD, McCallum J, Sirounis D, MacRedmond R, Moss R, Boyd JH. Limited echocardiography–guided therapy in subacute shock is associated with change in management and improved outcomes. J Crit Care 2014; 29(5): 700–5. doi: 10.1016/j.jcrc.2014.04.008
37. Lee C, Balk D, Schafer J, Welwarth J, Hardin J, Yarza, et al. Accuracy of Focused Assessment with Sonography for Trauma (FAST) in disaster settings: a meta-analysis and systematic review. Disaster Med Public Health Prep 2019; 13(5–6): 1059–64. doi: 10.1017/dmp.2019.23
38. Qi X, Tian J, Sun R, Zhang H, Han J, Jin H, et al. Focused assessment with sonography in trauma for assessing the injury in the military settings: a meta-analysis. Balkan Med J 2019; 37: 3–8. doi: 10.4274/balkanmedj.galenos.2019.2019.8.79
39. Lin K-T, Lin Z-Y, Huang C-C, Yu S-Y, Lin J-H, Lin Y-R. Prehospital ultrasound scanning for abdominal free fluid detection in trauma patients: a systematic review and meta-analysis. BMC Emerg Med 2024; 24: 7. doi: 10.1186/s12873-023-00919-2
40. Muradali D, Gold WL, Phillips A, Wilson S. Can ultrasound probes and coupling gel be a source of nosocomial infection in patients undergoing sonography? An in vivo and in vitro study.

AJR Am J Roentgenol 1995; 164: 1521–4. doi: 10.2214/ajr.164.6.7754907
41. Tesch C, Froschle G. Sonography machines as a source of infection. AJR Am J Roentgenol 1997; 168(2): 567–8. doi: 10.2214/ajr.168.2.9016251
42. Koibuchi H, Fujii Y, Kotani K, Konno K, Matsunaga, H, Miyamoto M, et al. Degradation of ultrasound probes caused by disinfection with alcohol. J Med Ultrason 2011; 38: 97–100. doi: 10.1007/s10396-010-0296-1
43. Pineau L, Radix C, Weber DJ. Comparison of the sporicidal activity of a UV disinfection process with three FDA cleared sterilants. Am J Infect Control 2022; 50: 1316–21. doi: 10.1016/j.ajic.2022.02.027
44. Recommendations for specialists practising ultra- sound independently of radiology departments Safety, governance and education. Available from https://www.rcr.ac.uk/news-policy/latest-updates/recommendations-for-specialists-practising-ultrasound-independently-of-radiology-departments-safety-governance-and-education/. [cited 13 November 2023]
45. Wang A, McCabe M, Gow-Lee E, James S, Austin B, Wailes D, et al. Evaluation of a survey for acute care programme directors on the utilisation of point-of-care ultrasound. Postgrad Med J 2022; 98(1163): 694–9. doi: 10.1136/postgradmedj-2021-140127
46. Kimura BJ, Sliman SM, Waalen J, Amundson SA, Shaw DJ. Retention of ultrasound skills and training in 'Point-of-Care' cardiac ultrasound. J Am Soc Echocardiogr 2016; 29: 992–7. doi: 10.1016/j.echo.2016.05.013
47. Schott CK, LoPresti CM, Boyd JS, Core M, Haro EK, Mader MJ, et al. Retention of Point-of-Care ultrasound skills among practicing physicians: findings of the VA National POCUS training program. Am J Med 2021; 134(3): 391–9. doi: 10.1016/j.amjmed.2020.08.008
48. Certificate in Clinician Performed Ultrasound. Available from https://www.asum.com.au/education/ccpu-course/. [cited 15 December 2023]
49. Future use of new imaging technologies in developing countries. Report of a WHO Scientific Group. World Health Organ Tech Rep Ser 1985; 723: 1–67.
50. Abrokwa SK, Ruby LC, Heuvelings CC, Bélard S. Task shifting for point of care ultrasound in primary healthcare in low- and middle-income countries-a systematic review. EClinical Medicine 2022; 45: 101333. doi: 10.1016/j.eclinm.2022.101333
51. Task shifting global recommendations and guidelines HIV/AIDS. Geneva: World Health Organisation (WHO) Press; 2008.
52. Sidi M, Sani GM, Ya'u A, Zira JD, Loshugno SS, Luntsi G. The current status of ultrasound practice in Kano metropolis, Nigeria. Egypt J Radiol Nucl Med 2021; 52: 1–8, 2021. doi: 10.1186/s43055-021-00509-x
53. Pisani L, De Nicolo A, Schiavone M, Adeniji AO, Palma AD, Gennaro FD, et al. Lung ultrasound for detection of pulmonary complications in critically ill obstetric patients in a resource-limited setting. Am J Trop Med Hyg 2020; 104(2): 478–86. doi: 10.4269/ajtmh.20-0996
54. Tran TT, Hlaing M, Krause M. Point-of-Care ultrasound: applications in low- and middle-income countries. Curr Anesthesiol Rep 2021; 11: 69–75. doi: 10.1007/s40140-020-00429-y
55. Younis SN. The role of abdominal ultrasound in the diagnosis of typhoid fever: an observational study. Travel Med Infect Dis 2014; 12: 179–82. doi: 10.1016/j.tmaid.2013.09.004
56. Chalya PL, Mabula JB, Koy M, Kataraihya JB, Jaka H, MshanaSE, et al. Typhoid intestinal perforations at a University teaching hospital in Northwestern Tanzania: a surgical experience of 104 cases in a resource-limited setting. World J Emerg Surg 2012; 7: 4. doi: 10.1186/1749-7922-7-4
57. Murphy S, Cserti-Gazdewich C, Dhabangi A, Musoke C, Nabukeera-Barungi N, Price D, et al. Ultrasound findings in Plasmodium falciparum malaria: a pilot study. Pediatr Crit Care Med 2011; 12(2): e58–63. doi: 10.1097/PCC.0b013e3181e89992
58. Del Carpio M, Mercapide CH, Salvitti JC, Uchiumi L, Sustercic, J, Panomarenko H, et al. Early diagnosis, treatment and follow-up of cystic echinococcosis in remote rural areas in Patagonia: impact of ultrasound training of non-specialists. PLoS Negl Trop Dis 2012; 6(1): e1444. doi: 10.1371/journal.pntd.0001444
59. Heller T, Wallrauch C, Goblirsch S, Brunetti E. Focused assessment with sonography for HIV-associated tuberculosis (FASH): a short protocol and a pictorial review. Crit Ultrasound J 2012; 4: 21. doi: 10.1186/2036-7902-4-21
60. Orlowski HLP, McWilliams S, Mellnick VM, Bhalla S, Lubner MG, Pickhardt PJ, et al. Imaging spectrum of invasive fungal and fungal-like infections. Radiographics 2017; 37(4): 1119–34. doi: 10.1148/rg.2017160110
61. Giordani MT, Tamarozzi F, Kaminstein D, Brunetti E, Heller T. Point-of-care lung ultrasound for diagnosis of Pneumocystis jirovecii pneumonia: notes from the field. Crit Ultrasound J 2018; 10: 8. doi: 10.1186/s13089-018-0089-0
62. Gore JC. Artificial intelligence in medical imaging. Magn Reson Imaging 2020; 68: A1–4. doi: 10.1016/j.mri.2019.12.006
63. Liu P, Lu L, Zhang J, Huo T, Liu S, Ye Z. Application of artificial intelligence in medicine: an overview. Curr Med Sci 2012; 41: 1105–15. doi: 10.1007/s11596-021-2474-3
64. Sonko ML, Arnold TC, Kuznetsov IA. Machine learning in Point of Care ultrasound. POCUS J 2022; 7: 78–87. doi: 10.24908/pocus.v7iKidney.15345
65. Gohar E, Herling A, Mazuz M, Tsaban G, Gat T, Kobal S, et al. Artificial Intelligence (AI) versus POCUS expert: a validation study of three automatic AI-based, real-time, hemodynamic echocardiographic assessment tools. J Clin Med 2023; 12(4): 1352. doi: 10.3390/jcm12041352
66. Baloescu C, Toporek G, Kim S, McNamara K, Liu R, Shaw MM, et al. Automated lung ultrasound B-line assessment using a deep learning algorithm. IEEE Trans Ultrason Ferroelectr Freq Control 2020; 67(11): 2312–20. doi: 10.1109/TUFFC.2020.3002249
67. Correa M, Zimic M, Barrientos F, Barrientos R, Román-Gonzalez A, Pajuelo MJ, et al. Automatic classification of pediatric pneumonia based on lung ultrasound pattern recognition. PLoS One 2018; 13(12): e0206410. doi: 10.1371/journal.pone.0206410
68. Jang J, Park Y, Kim B, Lee SM, Kwon J-Y, Seo JK, et al. Automatic estimation of fetal abdominal circumference from ultrasound images. IEEE J Biomed Health Inform 2018; 22(5): 1512–20. doi: 10.1109/JBHI.2017.2776116
69. Nafee T, Gibson CM, Travis R, Yee MK, Kerneis M, Chi G, et al. Machine learning to predict venous thrombosis in acutely ill medical patients. Res Pract Thromb Haemost 2020; 4(2): 230–7. doi: 10.1002/rth2.12292
70. Ravishankar H, Annangi P, Washburn M, Lanning J. Automated kidney morphology measurements from ultrasound images using texture and edge analysis. InMedical Imaging 2016: Ultrasonic Imaging and Tomography 2016 Apr 1 (Vol. 9790, pp. 359–365).

71. Wang H, Uraco AM, Hughes J. Artificial intelligence application on Point-of-Care ultrasound. J Cardiothorac Vasc Anesth 2021; 35(11): 3451–2. doi: 10.1053/j.jvca.2021.02.064
72. Xu Y, Liu X, Cao X, Huang C, Liu E, Qian S, et al. Artificial intelligence: a powerful paradigm for scientific research. The Innovation 2021; 2(4): 100179. doi: 10.1016/j.xinn.2021.100179
73. Nti B, Lehmann AS, Haddad A, et al: Artificial intelligence-augmented pediatric lung POCUS: a pilot study of novice learners. J Ultrasound Med 2022; 41(12): 2965–72. doi: 10.1002/jum.15992
74. Cheikh A Ben, Gorincour G, Nivet H, May J, Seux M, Calame P, et al. How artificial intelligence improves radiological interpretation in suspected pulmonary embolism. Eur Radiol 2022; 32(9): 5831–42. doi: 10.1007/s00330-022-08645-2
75. van de Venter R, Skelton E, Matthew J, Woznitza N, Tarroni G, Hirani SP, et al. Artificial intelligence education for radiographers, an evaluation of a UK postgraduate educational intervention using participatory action research: a pilot study. Insights Imaging 2023; 14: 25. doi: 10.1186/s13244-023-01372-2
76. de Margerie-Mellon C. Leveraging artificial intelligence in radiology education: challenges and opportunities. Eur Radiol 2023; 33: 8239–40. https://doi.org/10.1007/s00330-023-10112-5
77. Lee J, Wu AS, Li D, Kulasegaram K. Artificial intelligence in undergraduate medical education: a scoping review. Acad Med 2021; 96(11s): S62–70. doi: 10.1097/ACM.0000000000004291
78. Kundu S. How will artificial intelligence change medical training? Commun Med 2021; 1: 8. doi: 10.1038/s43856-021-00003-5
79. Lee L, DeCara JM. Point-of-Care ultrasound. Curr Cardiol Rep 2020; 22: 149. doi: 10.1007/s11886-020-01394-y
80. Bukhman AK, Nsengimana VJP, Lipsitz MC, Henwood PC, Tefera E, Rouhani SA, et al. Diagnosis and management of acute heart failure in Sub-Saharan Africa. Curr Cardiol Rep 2019; 21: 120. doi: 10.1007/s11886-019-1200-2
81. Bitker L, Talmor D, Richard J-C. Imaging the acute respiratory distress syndrome: past, present and future. Intensive Care Med 2022; 48: 995–1008. doi: 10.1007/s00134-022-06809-8
82. Ramanujam V, Tian L, Chow C, Kendall MC. Three-Dimensional Imaging of Commonly Performed Peripheral Blocks: Using a Handheld Point-of-Care Ultrasound System. Anesth Pain Med. 2023;13(2):e134797.
83. Ibrahim A, Zhang S, Angiolini F, Arditi M, Kimura S, Goto S, et al. Towards ultrasound everywhere: a portable 3D digital back-end capable of zone and compound imaging. IEEE Trans Biomed Circuits Syst 2018; 12(5): 968–81. doi: 10.1109/TBCAS.2018.2828382
84. Baribeau Y, Sharkey A, Chaudhary O, Krumm S, Fatima H, Mahmood F, et al. Handheld Point-of-Care ultrasound probes: the new generation of POCUS. J Cardiothorac Vasc Anesth 2020; 34(11): 3139–45. doi: 10.1053/j.jvca.2020.07.004
85. Carrera KG, Hassen G, Camacho-Leon GP, Rossitto F, Martinez F, Debele TK. The benefits and barriers of using Point-of-Care ultrasound in primary healthcare in the United States. Cureus 2022; 14(8): e28373. doi: 10.7759/cureus.28373
86. Lam J, Wong S, Grubic N, Nihal S, Herr JE, Belliveau DJ, et al. Accelerated Remote Consultation Tele-POCUS in Cardiopulmonary Assessment (ARCTICA). POCUS J 2020; 5(2): 55–8. doi: 10.24908/pocus.v5i2.14452
87. Evangelista A, Galuppo V, Méndez J, Evangelista L, Arpal L, Rubio C, et al. Hand-held cardiac ultrasound screening performed by family doctors with remote expert support interpretation. Heart 2016; 102(5): 376–82. doi: 10.1136/heartjnl-2015-308421
88. Jensen SH, Weile J, Aagaard R, Hansen KM, Jensen TB, Petersen MC, et al. Remote real-time supervision via tele-ultrasound in focused cardiac ultrasound: A single-blinded cluster randomized controlled trial. Acta Anaesthesiol Scand 2019; 63(3): 403–9. doi: 10.1111/aas.13276
89. Gilbertson EA, Hatton ND, Ryan JJ. Point of care ultrasound: the next evolution of medical education. Ann Transl Med 2020; 8(14): 846. doi: 10.21037/atm.2020.04.41

*** Hakeem Yusuff**
Department of Anaesthesia and Intensive Care Medicine
Glenfield Hospital
Groby Road
Glenfield
Leicester
LE3 9QP
UK
Email: hakeem.yusuff1@nhs.net