THE EVOLVING ROLE OF POINT-OF-CARE ULTRASOUND (POCUS) IN ICU AND EMERGENCY ANAESTHESIA

Abstract: Point-of-care ultrasound (POCUS) has rapidly become anessential tool in emergency anaesthesia and critical care, offering real-time, non-invasive imaging at thebedside to support rapid and informed clinical decisions in critically ill patients. It significantly enhances the diagnosis and management of life-threatening conditions such as shock, pneumothorax, and cardiac tamponade by improving the evaluation of cardiac function, intravascular volume, and pulmonary abnormalities. Standardised protocols includingfocused cardiac ultrasound, Lung ultrasound,the Focused Assessment with Sonography in Trauma, extended FASTstreamline diagnosis and facilitate precise and targeted interventions.POCUS is widely applied in evaluating cardiovascular, respiratory, abdominal, and vascular assessments, as well as for guiding procedures such as vascular access and regional anaesthesia. Within anaesthetic practice, it serves critical roles in airway assessment, gastric content assessment, and haemodynamic monitoring. As advancements in ultrasound technology continue, structured training programs and education becomes more prevalent, POCUS is increasingly recognised as a core competency in emergency anaesthesia and critical care anaesthesia.

''Evolving Role of POCUS in ICU and Emergency Anaesthesia''

Keywords: E-FAST, emergency anaesthesia, FAST, ICU, POCUS, ultrasound

Introduction: Point-of-care ultrasound (POCUS) involves the use of portable ultrasound devices at the bedside to aid in the real-time diagnosis, monitoring, and treatment of patients. Over the last twenty years, it has evolved from a supportive imaging technique into a crucial clinical tool in Intensive care units (ICUs) and emergency anaesthesia[1,2] Its ability to provide rapid, non-invasive, and repeatable assessments of physiological status has made it essential in the care of critically ill and hemodynamically unstable patients. In emergency and ICU settings, POCUS significantly improves the evaluation of cardiac function, volume status, and lung pathology, enabling clinicians to make timely and accurate clinical decisions.[3] Protocols such as focused cardiac ultrasound, lung ultrasound, and extended focused assessment with sonography for trauma are now widely used to assess conditions like shock, cardiac tamponade, pneumothorax, pleural effusion, pulmonaryedema, and intra-abdominal haemorrhage.[4,5,6] These standardized, goal-directed protocols provide a structured approach to diagnosis and directly influence patient management and resuscitation strategies.

POCUS plays a vital role in guiding a range of bedside procedures. When used for vascular access, ultrasound guidance significantly lowers the risk of complications compared to traditional landmark-based techniques, while also improving first-attempt success rates and overall patient safety. [7–8] Furthermore, POCUS increases the precision and safety of

procedures such as thoracentesis, paracentesis, pericardiocentesis, and regional anaesthesia, enabling more efficient and effective clinical interventions. [9]

In the domain of anaesthesia, particularly in emergency and perioperative settings POCUS is being increasingly utilized for airway assessment, evaluation of gastric contents, and intraoperative hemodynamic monitoring. It enables anaesthesiologists to anticipate difficult airways, evaluate aspiration risk, and assess cardiac function and fluid status during complex surgical procedures. [10–11]Forexample, gastric ultrasonographyprovides real-time visualization of stomach contents and volume.aiding in the assessment of aspiration risk before induction of anaesthesia. [12]

Technological advancements have further driven the adoption of POCUS by enhancing image quality and clarity, device portability, and battery performance. Additionally, the establishment of formal training programs and standardized guidelines by organizations such as the American Society of Echocardiography and the Society of Critical Care Medicine has made POCUS training more structured and accessible for non-radiologist clinicians.[13–14] Its incorporation into critical care and anaesthesia curricula reflects the growing recognition of POCUS as a fundamental clinical skill.[15] With accumulating evidence supporting its diagnostic accuracy, clinical utility, and procedural safety, POCUS is now increasingly regarded as a standard of care in intensive care units and emergency anaesthesia practice. This review outlines its expanding clinical applications, key benefits, and future potential within critical care environments.

Materials and Methods

The data for this review were compiled from a wide range of articles published between 2000 and 2021, sourced from multiple academic journals. These papers were carefully selected and reviewed to extract relevant information applicable to the focus of this study.

Clinical applications in ICU and Emergency anaesthesia

POCUS has transformed bedside evaluation and significantly improved procedural safety in intensive care units and emergency anaesthesia settings. Its strength lies in offering real-time, non-invasive, and dynamic assessments, which are crucial for timely and accurate decision-making in critically ill or hemodynamically unstable patients.The broad integration of POCUS into clinical practice highlights its effectiveness in enhancing diagnostic accuracy, reducing complication rates, and optimizing the overall delivery of patient care.[1,2]

- **Rapid Diagnosis at Bedside:** Enables immediate identification of life-threatening conditions such as pneumothorax, cardiac tamponade, massive pleural effusion, or hypovolemia without the need to transport unstable patients.
- **Minimization of Procedural Risks:** Enhances safety during invasive procedures like central venous catheterization, thoracentesis, pericardiocentesis, and nerve blocks by providing visual guidance.
- **Tailored Hemodynamic Management:** Facilitates personalized therapy through dynamic assessment of fluid responsiveness, cardiac function, and vascular tone guiding fluid administration or inotropic support.
- **Reduced Dependence on Delayed Imaging:** Decreases the need for radiographic or CT imaging, which may be logistically challenging or risky in unstable patients.

- **Enhanced Patient Safety and Outcomes:** Early intervention guided by POCUS has been shown to reduce ICU stay, minimize complications, and improve overall outcomes in critically ill populations**.**

- **Cardiovascular Assessment:** Focused cardiac ultrasound is widely used in ICU and emergency settings to evaluate cardiac function, identify pericardial effusion and tamponade, detect left and right ventricular dysfunction, and assist in managing patients with shock states.[3]It enables rapid assessment of volume status and myocardial contractility, often providing more reliable information than physical exams or central venous pressure measurements.[16]

- **Pulmonary Evaluation:** Lung ultrasound is highly sensitive in identifying conditions such as pneumothorax, pleural effusion, pulmonary edema, and interstitial syndrome.[5,17] Owing to its superior accuracy and rapid results, it has largely replaced chest X-rays in many intensive care units. The BLUE (Bedside Lung Ultrasound in Emergency) protocol provides a systematic method for diagnosing acute respiratory failure through the use of LUS.[5]

- **Abdominal and Trauma Evaluation:** In emergency and trauma care, POCUS through the FAST (Focused Assessment with Sonography in Trauma), extended FAST, protocol enables the detectionof free fluid within the abdomen or chest, suggesting internal bleeding or organ damage.[6]It facilitates prompt surgical decision-making and is now an integral part of standard trauma management protocols.

- **Hemodynamic Monitoring:** POCUS aids in evaluating intravascular volume status by assessing the diameter and collapsibility of the inferior vena cava (IVC), along with left ventricular filling and stroke volume variation using Doppler methods.[18]These

assessments are crucial for guiding fluid management, particularly in conditions like sepsis, shock, and during fluid resuscitation.

- **Vascular Access:** Ultrasound-guided vascular access is now considered the standard practice for placing central venous catheters, significantly reducing complications such as arterial puncture, haematoma, and pneumothorax.[7] It also enhances first-attempt success rates for peripheral IV insertion, particularly in patients with difficult venous access.[19]

- **Airway and Gastric Evaluation:** POCUS can evaluate difficult airway It is especially useful for identifying the cricothyroid membrane in emergency situations and can confirm endotracheal tube placement more quickly than capnography. Additionally, gastric ultrasound enables evaluation of stomach content and volume, to determine aspiration riskparticularly important in emergency surgeries or trauma patients with unknown fasting status .[10]

- **Regional Anaesthesia and Nerve Blocks:** POCUS has revolutionized regional anaesthesia by enabling real-time visualization of nerves, blood vessels, and fascial planes, leading to greater precision and safety in nerve blocks. It has significantly reduced the incidence of vascular puncture, nerve injury, and local anaesthetic systemic toxicity.[12]

- **Detection of Deep Vein Thrombosis (DVT):** Bedside compression ultrasound is a valuable tool for identifying proximal deep vein thrombosis in critically ill patients, enabling timely anticoagulation or further assessment for pulmonary embolism.[20] This approach accelerates both diagnosis and the initiation of treatment in the ICU.

- **Assessment of Volume Status and Fluid Responsiveness:** POCUS enables real-time evaluation of fluid responsiveness through measurements such as inferior vena cava (IVC) collapsibility, left ventricular outflow tract (LVOT) velocity time integral (VTI), and the presence of B-lines on lung ultrasound.[21] This precise guidance is essential in critically ill patients, where inadequate or excessive fluid resuscitation can result in adverse outcomes.

- **Diaphragmatic Ultrasound:** Evaluation of diaphragmatic function in ventilated patients, assists in predicting weaning outcomes from mechanical ventilation.Identifiesdiaphragmatic dysfunction contributing to respiratory failure.

- **FAST and E-FAST in trauma:**The Focused Assessment with Sonography in Trauma FAST and extended FAST, protocols are essential for identifying hemoperitoneum, haemothorax, and pneumothorax, pericardial effusion in trauma and emergency situations. They play a vital role in detecting internal bleeding, enabling rapid triage and surgical decision-making, while also minimizing the need for CT scans in hemodynamically unstable patients.

- **Neurological Assessment:**POCUS allows for non-invasive bedside evaluation of elevated intracranial pressure by measuring the optic nerve sheath diameter and utilizing transcranial Doppler to assess cerebral blood flow. This is particularly valuable in trauma and neurocritical care settings, providing early detection of intracranial hypertension when CT imaging is not readily accessible.

- **Procedural Guidance:** Procedures such as thoracentesis, paracentesis, pericardiocentesis, and abscess drainage are performed more safely and efficiently under ultrasound guidance.[22]

- **Critical Care Protocols:** Various ICU-specific POCUS protocols, including RUSH (Rapid Ultrasound for Shock and Hypotension) and FALLS (Fluid Administration Limited by Lung Sonography), have been designed to quickly identify the underlying causes of undifferentiated shock and respiratory failure.[9,23]

Ongoing advancements in handheld, high-resolution ultrasound devices, along with the introduction of structured training programs, have significantly increased the accessibility of POCUS for intensivists and anaesthesiologists. With a growing body of evidence highlighting its diagnostic and procedural benefits, POCUS has evolved from a supplementary tool to a fundamental skill in contemporary critical care and emergency anaesthesia practice.[24]

Educational Integration and Training

The integration of POCUS into ICU and emergency anaesthesia practice requires well-structured educational frameworks.Effective training should combine theoretical instruction, simulation-based learning, and hands-on supervised clinical experience to ensure both competence and patient safety.Several anaesthesia societies have advocated for integrating POCUS skills into postgraduate training curricula. [25,26] Competency-based education featuring objective structured clinical examinations and digital learning platforms is increasingly recognized as a scalable response to rising demand.[27] Furthermore, ongoing mentorship programs play a crucial role in maintaining skill proficiency and building clinical confidence.[28]

Challenges and Barriers

Despite its advantages, several barriers hinder the widespread adoption of POCUS in critical care:

- Time limitations in high-demand ICU and emergency environments often restrict both training and routine application.[3]
- Financial constraints, including the cost of ultrasound equipment and ongoing maintenance, present significant hurdles, particularly in resource-limited settings.[29]
- The technique's operator dependence and variability between observers can compromise diagnostic consistency and reliability.
- Legal and regulatory issues such as, those concerning image storage, formal documentation, and integration with electronic medical record systems remain unresolved in many institutions.
- The steep learning curve, especially in the absence of structured feedback, makes skill acquisition difficult.
- Absence of unified global certification standards. [30,31,32]

Technological Advancements and Future Directions

Recent technological advancements are rapidly expanding POCUS capabilities:

- Handheld, wireless devices have become more affordable and user-friendly
- AI-assisted image interpretation, using deep learning algorithms, is emerging as a powerful tool to support novice users
- 3D ultrasound and fusion imaging with CT or MRI are pushing the boundaries of bedside diagnostics

- Integration with tele-ultrasound platforms allows remote guidance and expert review in real-time, critical during pandemics or rural deployments.[33,34,35]
- **Miniaturization and Portability**: Today's compact, pocket-sized ultrasound devices often connected to smartphones have greatly enhanced accessibility. Additionally, tele-ultrasound systems support remote supervision and training, expanding their utility in diverse clinical settings.
- **Sensor Integration and ICU Monitoring**: Studies by Davoudi et al. and Nerella et al. highlight advancements in integrating POCUS with continuous ICU monitoring systems, paving the way for AI-driven, comprehensive critical care.[36,37]

Conclusion

POCUS has firmly established itself as a vital diagnostic and procedural tool in critical care and emergency anaesthesia. Its ability to deliver rapid, real-time, and repeatable bedside assessments has transformed patient management in high-acuity settings, improving diagnostic accuracy, procedural safety, and clinical outcomes. Standardized protocols for cardiac, pulmonary, abdominal, and vascular evaluation have enabled structured and goal-directed approaches to complex clinical scenarios.The growing integration of POCUS into airway management, hemodynamic monitoring, trauma assessment, and regional anaesthesia reflects its expanding utility across a wide range of clinical domains. Educational efforts, competency-based training programs, and support from leading anaesthesia societies have firmly established POCUS as an essential skill in ICU and perioperative care. However, its global adoption still faces obstacles such as limited time, financial constraints,

operator variability, and the absence of standardized international certification. Overcoming these challenges will require structured mentorship, the expansion of digital learning platforms, and the development of robust regulatory frameworks.

Looking ahead, emerging technologies such as AI-assisted image interpretation, compact wireless ultrasound devices, tele-ultrasound capabilities, and integration with ICU monitoring systems are set to transform the practice of POCUS. These advancements are expected to enhance accessibility, improve diagnostic accuracy, and further embed ultrasound into real-time clinical decision-making. As critical care continues to advance, POCUS is increasingly recognized as a cornerstone of precision medicine, offering clinicians a versatile, reliable, and indispensable tool for managing critically ill patients.

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