POINT OF CARE ULTRASOUND IN CRITICAL CARE AND EMERGENCY MEDICINE: REVIEW ARTICLE

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Abstract

Background: Point-of-care ultrasound (POCUS) has emerged as a valuable diagnostic tool in critical care and emergency medicine, offering real-time clinical information at the patient's bedside. Unlike comprehensive ultrasound examinations, POCUS is focused and goal-directed, providing rapid insights into specific clinical questions. The integration of POCUS into clinical practice has gained traction due to its ability to enhance diagnostic accuracy, reduce uncertainty, and improve patient outcomes. With advancements in technology leading to the development of portable and affordable ultrasound devices, POCUS has become more accessible to healthcare providers across various practice settings. **Objective:** This study aims to evaluate the effectiveness of POCUS in improving diagnostic accuracy, its impact on patient outcomes such as hospital stay and mortality rates, the feasibility of incorporating POCUS into routine clinical practice, and the identification of potential barriers to its implementation in critical care and emergency medicine settings. **Conclusion:** The utilization of POCUS in critical care and emergency medicine has shown promise in enhancing diagnostic accuracy, improving patient outcomes, and streamlining clinical decision-making processes. Despite challenges such as limitations in certain cardiac conditions and the need for ongoing training, the benefits of POCUS outweigh the concerns. Further research is needed to explore the impact of various POCUS modalities on patient-centered outcomes, address implementation barriers, and optimize training requirements for healthcare professionals. By ensuring appropriate utilization and documentation of POCUS findings, healthcare providers can maximize the benefits of this valuable diagnostic tool in critical care and emergency medicine, ultimately enhancing patient care and clinical outcomes.

Keywords: Point-of-care systems, Ultrasonography, Emergencies, Critical care.

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Introduction:

Point-of-care ultrasound (POCUS) refers to an ultrasound examination conducted and interpreted by the clinician at the patient's bedside to gather specific clinical information [1]. Unlike a comprehensive ultrasound, which is typically performed by radiologists or cardiologists and involves a thorough evaluation of the entire anatomical region, POCUS is designed to address a specific clinical question through a focused, goal-directed assessment. The primary aim of POCUS is to either confirm or rule out specific conditions or provide a definitive answer to a binary clinical query.

While comprehensive ultrasound examinations can take hours or days to order, execute, interpret, and report, POCUS offers real-time clinical information within minutes [1]. Recent research has demonstrated that POCUS can enhance diagnostic accuracy and reduce physicians' diagnostic uncertainty. Furthermore, studies have indicated that most patients undergoing POCUS of the heart, lungs, and deep veins in an emergency department experience minimal discomfort [2].

Medical professionals have expressed support for the integration of POCUS into clinical practice. Moreover, medical students exposed to POCUS during their undergraduate education have exhibited a better grasp of its clinical utility. The utilization of POCUS has gained popularity in emergency medicine, leading to an increased emphasis on POCUS education in residency programs [3].

The rising adoption of ultrasound in emergency and critical care settings has prompted some countries to extend health insurance coverage for POCUS in these areas. The implementation of standardized scopes and recommended indications for ultrasound use by individual countries has facilitated ultrasound practice in emergency and critical care settings [4]. Despite the rapid growth of POCUS in emergency, trauma, and critical care medicine, concerns have been raised regarding patient safety, including issues such as overuse, inaccurate diagnoses, inappropriate utilization, and excessive reliance on POCUS. To enhance patient care and avoid unnecessary strain on healthcare budgets, it is essential to ensure appropriate prescription, application, and documentation of POCUS findings [5].

Objectives:

The main objectives of this review are:

1. to assess the effectiveness of point of care ultrasound in improving diagnostic accuracy in critical care and emergency medicine settings.
2. to evaluate the impact of point of care ultrasound on patient outcomes, such as length of hospital stay and mortality rates.
3. to investigate the feasibility and practicality of incorporating point of care ultrasound into routine clinical practice.
4. to identify potential barriers and challenges to the implementation of point of care ultrasound in critical care and emergency medicine.

Equipment and instrumentation:

The advancement in technology, specifically the miniaturization of ultrasound machines and the enhancement of computing capabilities, has significantly contributed to the evolution of portable ultrasound devices. This progress has led to a wide array of ultrasound devices now available in the Point-of-Care Ultrasound (POCUS) market. Thanks to improvements in signal computational capacity, even the smallest mobile devices can now deliver high-quality imaging results. Furthermore, the cost of POCUS has seen a substantial decrease, rendering this technique more accessible to healthcare providers [6].

Various types of ultrasound machines are utilized for POCUS, falling into categories such as "compact cart-based," "handcarried," and "handheld or pocket-sized." The compact cart-based devices are designed to be transported to the patient's bedside, boasting advanced features with powerful processors, large screen sizes, and ample memory. However, they come with drawbacks such as their bulkiness, limited maneuverability, indoor use restriction, short battery life, and high cost. On the other hand, hand-carried ultrasound machines feature a clamshell laptop or miniature television design, with modern versions incorporating touchscreen displays [7]. These devices are relatively lightweight, facilitating easy hand-carrying, and offer an extended battery life along with high-quality imaging capabilities. Nonetheless, they may lack some advanced features and storage capacity compared to cart-based models. Pocket-sized machines, being the most portable, are characterized by their lightweight construction, longest battery life, and affordability. Yet, they tend to produce lower quality images and offer fewer features or workflow processes. Despite the nascent stage of this market, it is rapidly evolving, with new devices introducing a mobile application-based system that transforms a tablet or smartphone into a portable ultrasound by connecting a probe directly or wirelessly [8].

Choosing the appropriate ultrasound device depends on the practice environment. Cart-based

devices may excel in emergency departments or ICUs but may not be as suitable for use outside hospital settings. Conversely, pocket-sized devices, while convenient and user-friendly, may lack the advanced features necessary for in-hospital scenarios. The future trajectory of technology development aims to deliver a more cost-effective POCUS device [9].

Different modalities of POCUS:

In the intensive care unit (ICU), there are various other modalities of Point-of-Care Ultrasound (POCUS) that, although less frequently utilized, can offer valuable insights. These modalities encompass airway ultrasound, screening for deep vein thrombosis (DVT), diaphragm ultrasound, and ultrasound assessment of the optic nerve sheath diameter. For instance, conducting pre-procedural airway ultrasound has been shown to enhance safety prior to a percutaneous tracheostomy [10]. Moreover, diaphragm ultrasound has demonstrated exceptional accuracy in detecting diaphragm dysfunction. Furthermore, ultrasound evaluation of the optic nerve sheath diameter enables the bedside detection of elevated intracranial pressure and can aid in prognostication following cardiac arrest. Despite these potential benefits, the evidence supporting the impact of these POCUS modalities on patient-centered outcomes remains limited. Furthermore, there is a need for further exploration and research into the training requirements and learning curve associated with these modalities [11].

Clinical uses of POCUS in critical care and emergency medicine:

Focused cardiac ultrasound: Focused cardiac ultrasound (FoCUS) serves as a valuable tool for promptly evaluating cardiac structure and function in critically ill patients at the bedside. The FoCUS examination comprises five essential views: the parasternal long axis, parasternal short axis, apical four chamber, subcostal four chamber, and subcostal inferior vena cava (IVC) views [12]. Utilizing grayscale ultrasound allows for a detailed assessment of cardiac anatomy, with adjustments in depth and gain settings crucial for optimal visualization. Furthermore, incorporating color Doppler analysis of the mitral and aortic valves to detect regurgitation forms a vital part of the assessment [13]. The timely use of FoCUS can pinpoint various underlying issues in urgent cardiorespiratory conditions. Challenges associated with FoCUS in patients may stem from factors like body size, surgical attire, chest tubes, or subcutaneous air, all of which can hinder obtaining clear images. Misinterpretations, either false positives or false negatives, might arise from improper scanning angles that compromise image quality. Moreover, FoCUS has its limitations in detecting certain cardiac conditions such as pericardial fat pads, cysts, minimal pericardial effusion, diastolic dysfunction, valve disorders, and pulmonary hypertension [14]. For cases where uncertainty persists or complex clinical scenarios arise, a more extensive echocardiographic evaluation or alternative imaging modalities should be considered. Achieving accuracy and efficiency in performing FoCUS necessitates thorough education and training. Typically, FoCUS training involves a blend of theoretical learning, practical hands-on experience, and supervised clinical practice [15]. Competent healthcare professionals ought to demonstrate proficiency in acquiring and interpreting FoCUS images before conducting independent examinations. Sustained efforts in continuous education and quality enhancement play a pivotal role in upholding and enhancing the precision and dependability of FoCUS outcomes [16].

Thoracic ultrasound: Thoracic ultrasound has witnessed a growing utilization in the management of individuals presenting with acute dyspnea and respiratory failure in the emergency department. This increasing usage can be attributed to its efficacy in facilitating decision-making processes for both differential diagnosis and treatment strategies. In comparison to conventional imaging modalities like simple radiography and computed tomography (CT), thoracic ultrasound stands out for its ability to be swiftly and safely administered to patients, rendering it a valuable option for early imaging assessments [17].

POCUS emerges as a valuable tool in diagnosing interstitial syndrome, characterized by the presence of more than three B-lines in the intercostal space, exhibiting high sensitivity (94%) and specificity (92%). While pulmonary edema resulting from heart failure represents the most prevalent clinical cause of interstitial syndrome, it is crucial to recognize that various cardiac and pulmonary conditions can manifest similarly. Furthermore, thoracic ultrasound proves to be superior to radiography and CT in the accurate identification of pleural effusion, enabling precise measurement and prediction of effusion properties. Additionally, real-time ultrasound guidance enhances procedural safety, facilitating interventions like thoracentesis [18].

Abdominal POCUS: is a valuable tool that can be utilized in patients presenting with abdominal symptoms such as abdominal pain, flank pain, and a distended abdomen. POCUS offers several advantages including its rapid performance,

avoidance of unnecessary radiation and contrast exposure, quick diagnosis, and potential reduction in hospitalization length and costs [19]. Specifically, POCUS for right upper quadrant (RUQ) pain is beneficial for evaluating acute cholecystitis, with key positive findings including the sonographic Murphy sign, presence of cholelithiasis, gallbladder wall thickening, and pericholecystic fluid collection. Additionally, dilatation of the common bile duct can be identified in the RUQ areas. Recent studies have shown that both Emergency Medicine (EM) physicians and radiologists exhibit similar accuracy in detecting acute cholecystitis through POCUS [20].

In the case of renal colic patients, Renal POCUS assists EM physicians in detecting hydronephrosis, while bladder ultrasound aids in identifying ureterovesical junction or bladder stones, as well as the absence of ureteral jet in patients suspected to have obstructive uropathy [21]. Aortic POCUS involves measuring the diameter of the abdominal aorta and examining for the presence of an intimal flap in cases of aortic dissection using both transverse and longitudinal ultrasound planes. Furthermore, aortic ultrasound can assist emergency physicians in identifying a ruptured abdominal aortic aneurysm (AAA) with high sensitivity and specificity [22].

Ultrasound guided procedures: Ultrasound guidelines, as outlined by various organizations such as the American College of Emergency Physicians (ACEP), are advised to encompass detailed recommendations on procedures due to the crucial role these procedures play in patient care, thereby enhancing the safety and effectiveness of medical interventions [23]. The evolution of ultrasound technology has broadened the scope of these guidelines, extending beyond mere disease diagnosis and management to encompass procedural guidance aimed at ensuring the delivery of optimal patient care across diverse healthcare settings. Particularly in critically ill patients, bedside needle procedures like central venous catheter insertion, thoracentesis, and pericardiocentesis are frequently necessary. It is well-established that ultrasound-guided procedures offer notable advantages over traditional landmark-based approaches [24]. The increasing accessibility of ultrasound machines and portable devices, coupled with the ongoing emphasis on patient safety in critical care environments, has led to a notable surge in the utilization of ultrasound-guided procedures.

POCUS in critical care: where assessments are aimed at being comprehensive rather than urgent. While POCUS examinations may not encompass the complete functional and structural status of patients, comprehensive ultrasound has become a common practice within the ICU setting. The complexity of mastering specialized skills across various domains can pose a challenge for ICU clinicians. Comprehensive echocardiography, for instance, demands a higher level of expertise in image acquisition, proficiency, and experience compared to POCUS [25]. Consequently, ICU clinicians are tasked with determining the necessity of ultrasound evaluations and establishing connections with experts from different clinical departments.

Many ICU clinicians undergo rigorous training to conduct specialized ultrasound studies effectively. In the ICU, certain intensivists specializing in coronary care are proficient in performing comprehensive echocardiography, while others focusing on respiratory care may specialize in lung ultrasound. This enables ICU clinicians to promptly and accurately diagnose critically ill patients based on their acquired skills. The efficacy of a POCUS study in the ICU heavily relies on the skill and experience of the clinician conducting the examination, leading to variations in the scope of the assessment depending on both the clinician and the patient's condition upon admission.

Despite the utilization of comprehensive ultrasound studies, common conditions such as pleural effusion, pneumothorax, ascites, and deep vein thrombosis are frequently identified using POCUS [26]. Furthermore, patients in intensive care may encounter sudden exacerbations of existing illnesses or complications, necessitating ICU clinicians to promptly assess and manage hemodynamic and respiratory deteriorations through POCUS. Irrespective of the specific ICU setting or the underlying disease, POCUS plays a vital role in evaluating cardiac function, detecting cardiac tamponade, significant valvular dysfunction, and assessing the fluid responsiveness of patients in shock. The continuous pumping and beating of the heart present a challenge in evaluating its function via ultrasound, requiring a substantial investment of time and effort to attain proficiency in echocardiography [27].

Conclusion:

The integration of POCUS in critical care and emergency medicine settings has shown significant promise in enhancing diagnostic accuracy, improving patient outcomes, and streamlining clinical decision-making processes. The real-time nature of POCUS provides rapid access to crucial clinical information, aiding clinicians in confirming or ruling out specific conditions promptly. The evolution of portable ultrasound devices, with advancements in technology and

increased affordability, has made POCUS more accessible to healthcare providers in various practice environments.

The clinical uses of POCUS, including focused cardiac ultrasound, thoracic ultrasound, abdominal ultrasound, and ultrasound-guided procedures, have demonstrated utility in diagnosing a wide range of conditions and guiding therapeutic interventions. While challenges such as limitations in certain cardiac conditions and the need for ongoing training persist, the benefits of incorporating POCUS into routine clinical practice outweigh these concerns.

Moving forward, further research is needed to explore the impact of various POCUS modalities on patient-centered outcomes, address potential barriers to implementation, and optimize the training requirements for healthcare professionals. By ensuring appropriate prescription, application, and documentation of POCUS findings, healthcare providers can maximize the benefits of this valuable diagnostic tool in critical care and emergency medicine settings. The continued evolution of POCUS technology and guidelines will undoubtedly play a pivotal role in enhancing patient care and clinical outcomes in the future.

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