Review Article

Point-of-Care Ultrasound in the Diagnostic Evaluation of Acute Dyspnea in the Emergency Department

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Abstract

Acute dyspnea is one of the most frequent and clinically challenging presentations in the emergency department, as it may originate from a broad spectrum of respiratory, cardiovascular, mixed, and systemic conditions with overlapping clinical manifestations. Rapid and accurate identification of the underlying etiology is essential to guide timely and appropriate management. Point-of-care ultrasound has emerged as a valuable diagnostic tool in this context, enabling real-time bedside assessment of cardiopulmonary structures and intravascular volume status. Lung ultrasound allows reliable identification of normal aeration patterns, interstitial syndromes, alveolar consolidation, pleural effusion, and pneumothorax, often demonstrating superior diagnostic performance compared with chest radiography and accuracy comparable to computed tomography for selected conditions. Focused cardiac ultrasound further enhances diagnostic capability by providing immediate evaluation of ventricular function, pulmonary edema, pericardial effusion, and indirect signs of acute pulmonary embolism. Assessment of the inferior vena cava complements cardiac and lung findings by offering insights into volume status and right atrial pressure, supporting differentiation between cardiogenic and non-cardiogenic causes of dyspnea. The integration of these modalities within structured multi-organ ultrasound protocols, such as EMERALD-US, BLUE, eFAST, and FATE, facilitates a systematic and efficient diagnostic approach. Evidence consistently demonstrates that PoCUS reduces time to diagnosis and treatment initiation, increases diagnostic confidence, and improves the likelihood of appropriate, etiology-directed therapy. Although its use has not been associated with significant reductions in mortality or readmission rates, it contributes to improved acute management and shorter intensive care unit stays. Despite these benefits, PoCUS remains limited by operator dependency, technical challenges, and overlapping sonographic findings across different pathologies, which may lead to misinterpretation. These limitations highlight the importance of standardized training, structured diagnostic algorithms, and continuous quality assurance to ensure safe and effective application of PoCUS in the evaluation of acute dyspnea.

Key words

Point-of-care ultrasound, Acute dyspnea, Emergency medicine, Lung ultrasound, Cardiac ultrasound, Diagnostic protocols.

Introduction

Acute dyspnea represents one of the most frequent reasons for presentation to the emergency department and carries important prognostic implications, as it may reflect underlying conditions requiring urgent intervention or advanced levels of care. Its evaluation demands careful clinical judgment to determine both the etiology and the appropriate care setting, since delayed or incorrect decisions may significantly affect outcomes. The clinical relevance of acute dyspnea is further underscored by the intrinsic complexity of its differential diagnosis. Because dyspnea is a nonspecific symptom shared by a wide range of cardiopulmonary and systemic disorders, its initial assessment in the emergency department is particularly challenging. This complexity often necessitates the combined use of clinical examination, laboratory testing, and imaging studies, which can complicate and prolong diagnostic pathways in time-sensitive scenarios [1].

Within this context, conventional diagnostic approaches present several limitations that hinder rapid and accurate decision-making. Standard tools such as chest radiography and laboratory tests may be time-consuming and are frequently associated with delays in obtaining actionable results, thereby postponing critical therapeutic interventions [2]. In addition to these temporal constraints, traditional diagnostic modalities often lack sufficient specificity, particularly in the early stages of disease. This limitation increases the risk of misdiagnosis or delayed diagnosis, which may lead to inappropriate treatment strategies and negatively impact patient outcomes in the emergency setting [3].

These diagnostic challenges have driven the growing interest in integrating point-of-care ultrasound into the evaluation of patients presenting with acute dyspnea. PoCUS has emerged as a rapid and accurate diagnostic alternative, with multiple studies demonstrating high sensitivity and specificity for common etiologies such as acute pulmonary edema, pleural effusion, and pneumothorax [2, 4]. By providing immediate bedside information, PoCUS significantly shortens the time required to establish a working diagnosis and initiate targeted therapy, a factor that is particularly relevant in the management of acute dyspnea, where early intervention is often crucial [5]. Moreover, PoCUS has shown almost perfect agreement with final clinical diagnoses in conditions such as acute heart failure and shock, reinforcing its reliability and supporting its role as an extension of the physical examination rather than merely an ancillary imaging modality [6]. The incorporation of PoCUS into structured diagnostic pathways, including protocols such as the EMERALD-US algorithm, has been associated with improved diagnostic accuracy and more efficient decision-making, without prolonging emergency department length of stay [3].

Beyond its diagnostic advantages, the clinical use of PoCUS has been associated with meaningful benefits in patient management and healthcare utilization. Evidence indicates that PoCUS-guided evaluation leads to shorter times to diagnosis and treatment initiation, as well as reduced lengths of stay in intensive care units. Although its use does not appear to significantly influence 30-day readmission rates or overall mortality, PoCUS-guided management has been linked to higher rates of appropriate therapy and improved alignment between diagnosis and treatment strategies [5]. Furthermore, the ability to perform serial PoCUS examinations allows for dynamic reassessment of patients over time, facilitating ongoing evaluation of treatment response and enabling timely adjustments in management plans, particularly in cases of acute heart failure [7].

The objective of this article is to analyze the role of point-of-care ultrasound in the diagnostic evaluation of acute dyspnea in the emergency department, emphasizing its clinical utility in overcoming the limitations of conventional diagnostic approaches, improving diagnostic accuracy, and facilitating timely decision-making, while examining its impact on patient management and clinical outcomes.

Methodology

For the development of this review on the application of point-of-care ultrasound in the diagnostic evaluation of acute dyspnea in the emergency department, a comprehensive analysis of the scientific literature was conducted with the aim of examining its clinical relevance, diagnostic performance, and impact on decision-making in acute care settings. Emphasis was placed on the role of PoCUS in identifying the main cardiopulmonary etiologies of acute dyspnea, its integration into diagnostic protocols, and its influence on timeliness of diagnosis and patient management.

The review was based on the consultation of well-established scientific databases, including PubMed, Scopus, and Web of Science, selected for their relevance in emergency medicine, critical care, and diagnostic imaging. Strict inclusion and exclusion criteria were applied to ensure the quality and applicability of the selected evidence. Articles published between 2020 and 2025 in English or Spanish were included if they addressed key aspects such as the diagnostic use of PoCUS in acute dyspnea, lung and cardiac ultrasound findings, integrated multi-organ ultrasound protocols, diagnostic accuracy, and clinical outcomes. Studies lacking peer review, presenting incomplete data, or containing duplicated content were excluded. The search strategy incorporated keywords such as: Point-of-care ultrasound, acute dyspnea, emergency medicine, lung ultrasound, cardiac ultrasound, diagnostic protocols.

The initial search identified 33 relevant sources, including original research articles, clinical practice guidelines, systematic reviews, and consensus statements from recognized emergency medicine and critical care societies. These sources were critically analyzed to extract information related to the pathophysiological basis of ultrasound findings, diagnostic accuracy for specific etiologies, comparative performance against conventional imaging modalities, and the clinical impact of PoCUS-guided evaluation.

In addition, artificial intelligence tools were used as complementary support for literature organization, thematic synthesis, and identification of conceptual relationships across studies. These tools facilitated the systematic categorization of findings and contributed to maintaining logical coherence and structural consistency throughout the review.

The analysis followed a qualitative and comparative approach. The extracted data were organized thematically to identify current clinical applications of PoCUS in acute dyspnea, diagnostic strengths and limitations, barriers to implementation in emergency settings, and emerging trends aimed at optimizing ultrasound-based diagnostic strategies. This methodological approach allowed for a structured and evidence-based overview of the current state of knowledge, highlighting the role of PoCUS as a valuable adjunct to clinical assessment and its potential to improve diagnostic efficiency and patient care in the emergency department.

Pathophysiological Framework of Acute Dyspnea

Acute dyspnea in the emergency department may arise from a broad spectrum of respiratory, cardiovascular, mixed, and systemic conditions, each with distinct pathophysiological mechanisms that can be effectively explored using point-of-care ultrasound. Among respiratory causes, parenchymal disorders such as pneumonia and acute respiratory distress syndrome represent frequent and clinically significant etiologies. These conditions are characterized by inflammatory involvement of the lung parenchyma, leading to impaired gas exchange and acute respiratory distress. Lung ultrasound plays a central role in their evaluation by enabling the detection of B-lines, which reflect interstitial involvement and increased extravascular lung water, thereby supporting the diagnosis of interstitial syndromes in an accurate and timely manner [1, 8].

Pleural disorders constitute another important respiratory cause of acute dyspnea. Pleural effusions contribute to respiratory compromise through mechanical compression of adjacent lung tissue and reduced ventilatory capacity. Ultrasound has proven to be highly effective in identifying pleural effusions, offering superior sensitivity compared with conventional imaging modalities. In addition to its diagnostic value, ultrasound provides real-time guidance for therapeutic interventions such as thoracentesis, enhancing both safety and procedural efficacy [9]. Airway disorders, including asthma and chronic obstructive pulmonary disease exacerbations, also represent common causes of dyspnea in the emergency setting. Although lung ultrasound does not directly visualize airway obstruction, it plays a complementary role by assisting in the differentiation between pulmonary and cardiac causes of dyspnea, particularly in patients with COPD, in whom overlapping clinical features may complicate the diagnostic process [10].

Cardiovascular conditions are among the most frequent and critical causes of acute dyspnea, with acute heart failure representing a leading etiology. In this context, lung ultrasound has demonstrated greater sensitivity and specificity than chest radiography for the detection of pulmonary edema, allowing for rapid identification of cardiogenic causes of respiratory distress and facilitating early initiation of appropriate therapy [4, 11]. Pulmonary embolism constitutes another life-threatening cardiovascular cause of dyspnea, in which PoCUS can support early diagnosis through the identification of indirect signs such as right ventricular dilation and strain. Although not definitive in isolation, these findings are crucial in accelerating diagnostic pathways and guiding urgent management decisions [12]. Similarly, cardiac tamponade represents a critical condition in which ultrasound enables prompt visualization of pericardial effusion and assessment of its hemodynamic impact, thereby expediting life-saving interventions [9].

In many clinical scenarios, dyspnea results from mixed or systemic causes that involve simultaneous respiratory and cardiovascular dysfunction. Conditions associated with increased respiratory and cardiac drive may exacerbate lung injury and compromise cardiopulmonary interactions. In such cases, ultrasound allows for integrated assessment of both lung and cardiac involvement, supporting therapeutic strategies aimed at minimizing secondary injury and optimizing physiological balance [13]. Systemic conditions such as sepsis further exemplify the multifactorial nature of dyspnea, as they may induce respiratory distress through mechanisms including fluid overload, myocardial dysfunction, and respiratory muscle fatigue. Ultrasound contributes to the evaluation of these patients by facilitating assessment of fluid status and cardiac function, thereby informing individualized management strategies [14].

The implications of ultrasound-based assessment in acute dyspnea are substantial. By providing real-time visualization of cardiopulmonary structures, PoCUS enhances diagnostic accuracy and improves differentiation between cardiac and pulmonary etiologies, addressing one of the central challenges in emergency medicine [3]. Furthermore, ultrasound findings directly inform treatment decisions, guiding interventions such as diuretic therapy in acute heart failure or antimicrobial treatment in pneumonia [14]. Beyond diagnosis and treatment guidance, PoCUS offers a non-invasive modality for monitoring disease progression and response to therapy, reducing reliance on more invasive or repetitive diagnostic procedures and supporting dynamic patient reassessment in the emergency department [1].

Principles of Point-of-Care Ultrasound in Emergency Medicine

Point-of-care ultrasound is defined as ultrasonography performed and interpreted directly by the treating clinician at the patient’s bedside, allowing for immediate integration of imaging findings into clinical decision-making [15]. This characteristic distinguishes PoCUS from conventional radiologic studies, as it is designed to answer focused clinical questions in real time. Owing to this immediacy and clinical integration, PoCUS is widely regarded as an extension of the physical examination, often compared to a modern stethoscope that enhances bedside assessment by providing direct visualization of internal structures and physiological processes [16].

The advantages of PoCUS are particularly evident in time-critical clinical settings such as the emergency department. By enabling rapid bedside imaging, PoCUS significantly reduces the time to diagnosis when compared with traditional imaging modalities, including computed tomography, which may require patient transport and longer acquisition times. This reduction in diagnostic delay is crucial in acute care scenarios, where early identification of pathology directly influences treatment decisions and outcomes. Furthermore, PoCUS has demonstrated improved diagnostic sensitivity and specificity for several acute conditions, such as small bowel obstruction and abdominal aortic aneurysms, thereby supporting faster and more accurate clinical decision-making in emergent situations [16, 17].

From a technical perspective, PoCUS relies on portable ultrasound equipment designed for use at the bedside, typically incorporating a range of probes to address different anatomical and clinical requirements. Commonly used transducers include curvilinear probes for abdominal and thoracic imaging and linear array probes for superficial structures and vascular access [17]. The fundamental imaging modalities employed in PoCUS include B-mode imaging, which provides grayscale structural visualization, and Doppler techniques, which allow assessment of blood flow and hemodynamic patterns. Together, these imaging modes form the basis of comprehensive point-of-care evaluations across multiple organ systems [18].

Despite its versatility and clinical value, the effectiveness of PoCUS is highly dependent on operator skill. Accurate image acquisition and interpretation require structured training and ongoing practice, as diagnostic performance is closely linked to the clinician's level of proficiency [16]. Training programs typically combine theoretical instruction with supervised hands-on experience, allowing clinicians to progressively develop competence. As experience increases, so does diagnostic accuracy, underscoring the importance of standardized education and continuous skill development to ensure reliable and safe application of PoCUS in clinical practice [17].

Lung Ultrasound in Acute Dyspnea

Normal lung ultrasound patterns are defined by the presence of A-lines, which appear as horizontal, echogenic reverberation artifacts parallel to the pleural line. These lines originate from the pleural interface and indicate preserved lung aeration, reflecting the absence of significant interstitial or alveolar pathology. The visualization of A-lines, together with normal lung sliding, is therefore considered a hallmark of a normally aerated lung on ultrasound examination [19].

In contrast, interstitial syndromes are characterized by the appearance of B-lines, which are vertical, hyperechoic comet-tail artifacts that arise from the pleural line and extend to the bottom of the screen without fading, moving synchronously with lung sliding. The presence of a B-pattern, defined as three or more B-lines within a single intercostal space, is indicative of interstitial involvement and increased extravascular lung water. Lung ultrasound has demonstrated high diagnostic accuracy in identifying interstitial syndromes, with reported sensitivity and specificity values of 90.9% and 91.1%, respectively, supporting its reliability in detecting diffuse interstitial processes in acute care settings [10, 20].

Alveolar consolidation represents a more advanced pathological process and appears on lung ultrasound as a tissue-like or hepatized pattern, reflecting loss of normal aeration and replacement of air by fluid or inflammatory material. This pattern is frequently accompanied by dynamic air bronchograms, which are visualized as hyperechoic linear or punctate structures within the consolidated area that move with respiration. These dynamic features help distinguish consolidation from atelectasis and support the diagnosis of infectious or inflammatory alveolar disease. Lung ultrasound has shown a sensitivity of 76% and a specificity of 92% for the detection of alveolar consolidation, underscoring its value as a diagnostic tool, particularly in intensive care unit settings [21].

Pleural effusions are readily identified on ultrasound as anechoic or hypoechoic fluid collections located between the parietal and visceral pleura, often demonstrating a characteristic meniscus sign. Lung ultrasound has demonstrated good diagnostic performance in detecting pleural effusions, with reported sensitivity and specificity of 85% and 77%, respectively [21]. Pneumothorax, on the other hand, is diagnosed by the absence of lung sliding and the identification of the lung point sign, which represents the transition between aerated lung and pneumothorax. In this context, lung ultrasound has shown superior diagnostic performance compared with chest radiography, achieving a sensitivity of 83% and a specificity of 99% for pneumothorax detection [22].

When compared with conventional imaging modalities, lung ultrasound demonstrates notable advantages in diagnostic performance for several acute conditions. In cases of acute decompensated heart failure, lung ultrasound has been shown to be more sensitive and specific than chest radiography, with sensitivity and specificity values of 91.8% and 92.3%, respectively, compared with 76.5% and 87.0% for chest X-ray [4]. Furthermore, in intensive care unit settings, lung ultrasound provides diagnostic accuracy comparable to computed tomography for conditions such as acute respiratory distress syndrome. Pooled analyses have reported a sensitivity of 63.1% and a specificity of 94.2% for lung ultrasound in the diagnosis of ARDS, while the LUS-ARDS score has demonstrated a high area under the receiver operating characteristic curve of 0.90, indicating strong overall diagnostic performance [21, 23].

Cardiac Ultrasound in the Dyspneic Patient

Focused cardiac ultrasound performed at the point of care plays a central role in the evaluation of patients with acute dyspnea in emergency settings, as it enables rapid assessment of cardiac structure and function directly at the bedside. Through standardized cardiac views, PoCUS allows clinicians to evaluate both left and right ventricular function, which is essential for distinguishing cardiac from non-cardiac causes of respiratory distress and for guiding early management decisions [24]. The feasibility and clinical utility of this approach have been demonstrated in structured diagnostic pathways such as the EMERALD-US protocol, which highlights the value of focused ultrasound in rapidly identifying the underlying causes of dyspnea in the emergency department and supporting timely clinical decision-making [3].

Assessment of ventricular function constitutes a cornerstone of focused cardiac PoCUS. The technique is effective in evaluating left ventricular systolic performance as well as estimating right atrial pressure, both of which are critical parameters in the diagnosis and management of heart failure. By providing immediate insight into cardiac filling and contractility, PoCUS supports early identification of hemodynamic compromise and facilitates targeted therapeutic interventions [24]. In this context, PoCUS has demonstrated high sensitivity and specificity for the detection of cardiogenic pulmonary edema, surpassing the diagnostic performance of traditional chest radiography and reinforcing its role as a frontline diagnostic tool in acute care settings [4].

The identification of acute heart failure and cardiogenic pulmonary edema is further enhanced through the integration of lung ultrasound as a complementary component of PoCUS. Lung ultrasound has been shown to be more sensitive and specific than chest X-ray in diagnosing acute decompensated heart failure, primarily through the detection of sonographic B-lines, which serve as a key indicator of pulmonary edema and increased extravascular lung water [4].

In addition to ventricular assessment, PoCUS is highly valuable for the detection of pericardial effusion and the evaluation of tamponade physiology. Focused cardiac ultrasound enables prompt visualization of pericardial fluid accumulation and assessment of its hemodynamic impact, providing critical information in patients presenting with hemodynamic instability and suspected cardiac tamponade [2, 24].

Although PoCUS is not considered a definitive diagnostic modality for acute pulmonary embolism, it contributes important supportive information through the identification of indirect signs. Findings such as right ventricular dilation and dysfunction may raise suspicion for pulmonary embolism and prompt further diagnostic evaluation or early therapeutic considerations in appropriate clinical contexts [9].

Inferior Vena Cava and Volume Status Assessment

Evaluation of the inferior vena cava using point-of-care ultrasound represents a commonly employed technique for estimating intravascular volume status and right atrial pressure in acute care settings. The assessment is typically performed by measuring the IVC diameter and its respiratory variation, expressed as the collapsibility index. Standardized measurements are obtained approximately 1 to 2 cm distal to the hepatic vein confluence or alternatively 3 to 4 cm distal to the junction of the right atrium and the inferior vena cava, ensuring consistency and reproducibility of the examination. The collapsibility index is calculated using the formula (IVC maximum diameter minus IVC minimum diameter divided by IVC maximum diameter), providing a quantitative estimate of venous compliance and volume status [25].

Interpretation of IVC size and respiratory variation allows clinicians to infer right atrial pressure and overall fluid status. An IVC diameter of less than 2.1 cm combined with greater than 50% collapsibility during inspiration is generally associated with normal right atrial pressure, whereas a diameter exceeding 2.1 cm with less than 50% collapsibility suggests elevated right atrial pressure [26]. These sonographic parameters are particularly useful in the emergency department, where rapid assessment of volume status can guide immediate therapeutic decisions, including fluid resuscitation or diuretic administration [24, 26].

In the context of acute dyspnea, IVC ultrasound contributes to the differentiation between cardiogenic and non-cardiogenic etiologies. Volume overload is a hallmark feature of heart failure, and evaluation of IVC size and collapsibility can support the identification of this condition when integrated with clinical findings and other ultrasound assessments. Studies have shown that the collapsibility index demonstrates moderate sensitivity and specificity for the diagnosis of heart failure, indicating that while it is a useful diagnostic adjunct, it should be interpreted as part of a broader, multi-parameter diagnostic algorithm rather than as a standalone test [27].

Despite its clinical utility, IVC ultrasound is subject to several limitations and potential confounding factors. Patient-related variables such as body habitus, elevated intra-abdominal pressure, and variations in respiratory effort can significantly influence IVC measurements and lead to misinterpretation. Additionally, the technique is highly operator-dependent, requiring adequate training and experience to ensure accurate image acquisition and reliable interpretation. Population-specific variability further complicates the use of fixed cut-off values, as differences in average IVC diameter have been reported among different ethnic groups, including smaller baseline measurements observed in certain populations such as Filipinos, underscoring the need for context-specific interpretation of findings [24, 25].

Integrated Ultrasound Protocols for Acute Dyspnea

The rationale for adopting multi-organ ultrasound approaches in the evaluation of acute dyspnea lies in the complex and often overlapping clinical manifestations of cardiac and pulmonary diseases. Patients presenting with dyspnea frequently exhibit nonspecific signs and symptoms that may originate from the heart, lungs, or a combination of both systems. Multi-organ ultrasound protocols address this diagnostic challenge by enabling a comprehensive and simultaneous assessment of cardiac, pulmonary, and venous structures, thereby providing a more integrated understanding of the underlying pathophysiology. This comprehensive approach is particularly valuable in the emergency department, where rapid differentiation between conditions such as acute heart failure, pneumonia, and chronic obstructive pulmonary disease exacerbations is essential, given that each entity requires distinct and often time-sensitive management strategies [3, 28].

Several structured multi-organ ultrasound protocols have been developed to standardize and optimize the diagnostic evaluation of dyspnea. Among these, the EMERALD-US protocol is specifically designed for use in emergency departments and incorporates systematic lung, cardiac, and venous ultrasound examinations to identify the etiology of acute dyspnea [3]. Other established protocols, including BLUE, eFAST, and FATE, have also demonstrated clinical utility, particularly when used in combination. Their integrated application has been shown to enhance pre-hospital and early in-hospital diagnosis of conditions such as pleural effusion and other cardiopulmonary abnormalities, resulting in improved diagnostic accuracy and greater concordance with definitive hospital-based diagnoses [28].

These protocols are typically applied through step-by-step diagnostic algorithms that guide clinicians through a structured sequence of ultrasound assessments. The evaluation often begins with lung ultrasound to identify signs of interstitial syndrome, consolidation, pleural effusion, or pneumothorax, followed by focused cardiac ultrasound to assess ventricular function, volume status, and pericardial pathology, and complemented by venous ultrasound when indicated. This systematic approach allows for the progressive exclusion or confirmation of potential causes of dyspnea, thereby reducing diagnostic uncertainty and minimizing reliance on extensive laboratory testing and conventional radiological imaging [2, 3].

The clinical impact of these integrated ultrasound protocols is reflected in improvements in both diagnostic efficiency and timeliness of care. The use of point-of-care ultrasound has been shown to significantly reduce the time required to establish a diagnosis and initiate appropriate treatment when compared with conventional diagnostic methods. Evidence indicates a mean reduction of approximately 63 minutes in diagnostic time, highlighting the value of PoCUS in accelerating clinical decision-making in acute settings. Additionally, the implementation of PoCUS-based protocols increases the likelihood of patients receiving appropriate, etiology-directed therapy. Although these benefits have not been associated with significant reductions in 30-day readmission rates or mortality, they underscore the role of multi-organ ultrasound as an effective tool for improving diagnostic accuracy and optimizing early management in patients presenting with acute dyspnea [5].

Clinical Impact and Evidence Base

The use of point-of-care ultrasound has a significant impact on diagnostic confidence and clinical decision-making in patients presenting with acute dyspnea. Evidence demonstrates that PoCUS markedly reduces the time required to establish a diagnosis and initiate treatment when compared with conventional diagnostic pathways. Specifically, studies have reported a mean reduction of 63 minutes in time to diagnosis and 27 minutes in time to treatment initiation, highlighting the ability of ultrasound to accelerate critical clinical decisions in emergency settings [5]. In the prehospital environment, lung ultrasound has shown high diagnostic accuracy for acute decompensated heart failure, with sensitivity and specificity values of approximately 87%, supporting its use for early identification of cardiogenic dyspnea and prompt initiation of targeted therapy before hospital arrival [29]. Beyond emergency and prehospital care, diaphragm and lung ultrasound have also been shown to influence clinical decision-making in respiratory physiotherapy, with significant changes observed in diagnostic impressions and management strategies following ultrasound assessment, further underscoring its broader clinical impact [30].

The influence of PoCUS extends beyond diagnostic confidence to the selection and implementation of therapeutic interventions. Patients evaluated with PoCUS are more likely to receive appropriate, etiology-directed therapy compared with those assessed using conventional diagnostic methods alone, reflecting improved alignment between diagnosis and treatment. Although the use of PoCUS has not been associated with significant reductions in 30-day readmission rates or overall mortality, its contribution to shorter intensive care unit stays suggests more effective acute management and improved resource utilization in the early phases of care [5]. Additionally, ultrasound-guided assessment supports the use of non-invasive respiratory support strategies in patients with acute dyspnea, enabling effective symptom control and physiological stabilization without the need for invasive mechanical ventilation in selected cases [1].

The clinical relevance of these findings is supported by multiple high-quality studies, including systematic reviews and meta-analyses. A comprehensive systematic review and meta-analysis evaluating the role of PoCUS in acute dyspnea highlighted its benefits in reducing diagnostic and treatment delays while increasing the likelihood of appropriate therapeutic interventions [5]. Similarly, another review focusing on prehospital lung ultrasound emphasized its high diagnostic accuracy for acute decompensated heart failure, reinforcing its value in facilitating early intervention and continuity of care from the prehospital to the in-hospital setting [29]. In recognition of this growing body of evidence, the American College of Physicians recommends the use of PoCUS as an adjunct to standard diagnostic pathways, particularly in situations characterized by diagnostic uncertainty [9].

From a health systems perspective, considerations regarding cost-effectiveness further support the integration of PoCUS into routine clinical practice, despite the limited availability of direct economic analyses. The demonstrated reductions in diagnostic and treatment times, combined with improved appropriateness of therapy and shorter intensive care unit stays, suggest potential cost savings through more efficient use of healthcare resources and optimization of patient flow in acute care settings [5, 9].

Limitations, Pitfalls, and Sources of Error

Despite its widespread adoption and demonstrated clinical value, the use of point-of-care ultrasound is subject to important technical and operator-related limitations that may affect diagnostic accuracy and reliability. Incomplete or technically limited examinations represent a significant challenge, as a substantial proportion of ultrasound studies may be inadequately performed or insufficiently documented. For example, up to 29.8% of extended focused assessment with sonography for trauma examinations have been reported as undocumented or incomplete, a limitation that can contribute to diagnostic uncertainty and increase the risk of error in acute care settings [31].

Operator experience and training play a critical role in determining the diagnostic performance of PoCUS. Inexperienced users may demonstrate reduced accuracy in image acquisition and interpretation, particularly when using hand-held ultrasound devices equipped with decision-support software. Although these technologies are designed to facilitate bedside imaging, they do not eliminate the need for adequate training and clinical judgment. Studies have shown that operator variability remains a significant factor influencing diagnostic outcomes, even with the assistance of automated or semi-automated interpretation tools [32].

Another important limitation arises from the overlap of ultrasound findings across different pathologies. Certain conditions may share similar sonographic features, complicating interpretation and increasing the risk of misdiagnosis. For instance, both bullous emphysema and pneumothorax may present with absent lung sliding on ultrasound, making differentiation challenging without careful correlation with clinical findings and additional sonographic signs [33]. Although structured protocols such as EMERALD-US are designed to aid in distinguishing among common causes of acute dyspnea, overlapping signs between conditions such as heart failure and pneumonia may still complicate diagnostic reasoning and require cautious interpretation [3].

The risk of misinterpretation is further compounded by diagnostic anchoring, a cognitive bias in which clinicians place excessive weight on initial ultrasound findings and fail to adequately consider alternative diagnoses. Such anchoring can lead to inappropriate interventions, including unnecessary chest tube placement in cases where bullous emphysema is misidentified as pneumothorax, with potentially serious consequences for patient safety [3]. This risk highlights the necessity of integrating ultrasound findings within a broader clinical context rather than relying on isolated imaging signs [9].

To mitigate these limitations and improve the reliability of PoCUS, several strategies have been proposed. Comprehensive training programs and formal certification processes for ultrasound operators are essential to enhance diagnostic accuracy and reduce operator-dependent errors [33]. The implementation of structured diagnostic algorithms, such as the EMERALD-US protocol, supports a systematic and standardized approach to image acquisition and interpretation, thereby improving diagnostic consistency across providers and settings [3]. Additionally, the use of decision-support software and telemedicine-based supervision can provide real-time feedback and expert guidance, potentially improving diagnostic performance. However, despite these technological advances, operator variability remains a concern, reinforcing the need for ongoing education, quality assurance initiatives, and critical clinical judgment in the application of point-of-care ultrasound [32].

Conclusion

Acute dyspnea in the emergency department arises from a wide and complex range of respiratory, cardiovascular, mixed, and systemic pathophysiological mechanisms, which often overlap and limit the diagnostic accuracy of isolated clinical assessment or conventional imaging. Point-of-care ultrasound enables real-time, bedside evaluation of lung, cardiac, and venous structures, allowing a more precise pathophysiological characterization of dyspnea and improving differentiation between cardiogenic and non-cardiogenic etiologies.

The integration of lung, cardiac, and inferior vena cava ultrasound within structured multi-organ protocols enhances diagnostic efficiency and clinical decision-making in acute dyspnea. PoCUS demonstrates high diagnostic accuracy for key conditions such as pulmonary edema, pneumonia, pleural effusion, pneumothorax, and acute heart failure, significantly reducing time to diagnosis and treatment initiation while facilitating timely, etiology-directed therapeutic interventions.

Despite its proven clinical impact, the effective use of PoCUS is limited by operator dependency, technical challenges, and overlapping ultrasound findings across different pathologies, which may lead to misinterpretation and diagnostic anchoring. These limitations underscore the need for standardized training, structured diagnostic algorithms, and continuous quality assurance to ensure safe, reliable, and clinically integrated application of point-of-care ultrasound in the evaluation of acute dyspnea.

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