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# ORIGINAL ARTICLE

## Unveiling the Diagnostic Power of Point-of-Care Ultrasound for Adult Patients Presenting with Dyspnea in Emergency Medicine: A Systematic Review

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**Background** Dyspnea is one of the major reasons patients visit the emergency department (ED). Point-of-Care Ultrasound (POCUS) is a novel approach in diagnosing dyspnea, which is comparable to conventional diagnostic modalities such as chest *X*-Rays.

**Methodology** A comprehensive literature search was conducted until December 2024.

**Results** Our electronic search yielded 510 articles, among which 9 observational studies summarizing data from 3605 patients met our inclusion criteria and were thus included in the review. Our review found that POCUS improved the concordance between ED diagnosis and the final diagnosis from kappa (0.45; 95% CI [0.31, 0.58]) in standard protocol to kappa (0.56; 95% CI [0.43, 0.69] [1] in POCUS based protocols. Furthermore, our review found that the sensitivity of POCUS for the different etiologies for dyspnea ranged from 88% (85.1%–90.6%) to 100.0% (78.2%–100.0%) for congestive heart failure (CHF), 64.7% (38.3–85.8) to 86.8% (84.2%–89.2%) for chronic obstructive pulmonary disease (COPD), and 88.5% (86.4%–90.3%) to 100% (78.2–100) for pneumonia. In terms of specificity, our review found that the specificity of POCUS ranged from 95.2% (83.8%–99.4%) to 96% (95%–96.8%) for diagnosing CHF, 93.3% (77.9%–99.2%) to 96.1% (95.1%–96.9%) for COPD, 74% (64%–82%) to 91.6% (90.1%–92.9%) for pneumonia.

**Conclusions** Our study has found that POCUS is a potential diagnostic modality for acute dyspnea in the emergency department. However, limited research exists on its utility in diagnosing different etiologies of dyspnea.

**Keywords** Diagnostic Modality; Dyspnea; Emergency Medicine; Point-of-Care Ultrasound.
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### INTRODUCTION

Dyspnea is an umbrella term used to describe a myriad of clinical symptoms associated with problems with breathing, including chest tightness, air hunger, and increased work of breathing [2]. The quality and intensity of dyspnea may vary according to the etiology and the underlying pathological mechanism [3]. Furthermore, the presentation of dyspnea is affected by other patient factors, including cultural, psychological, and social characteristics [4]. Acute onset dyspnea (AOD) is one of the main symptoms that cause patients to visit the ED and their subsequent admission. This is because AOD is a symptom that indicates an underlying infectious, oncologic, and cardiorespiratory disease[5–7].

Although a common symptom in the ED, the diagnosis of dyspnea is still challenging. This is partly due to the

various diagnostic categories in which dyspnea falls [8]. Furthermore, the underlying disorders vary in intensity from mild conditions such as anxiety to serious underlying pathologies such as respiratory failure, which need rapid response and management in the ED [8]. Timely assessment, triage, and diagnosis are necessary to initiate management in the emergency department rapidly [9].

Point of care ultrasonography (POCUS) is a term that generally refers to an ultrasound that is performed and interpreted at the bedside by the physician in real time [10]. This enables the physicians to link the patient's presenting symptoms and the findings of POCUS, thus enabling them to initiate immediate management, which is the main objective of ED physicians [11]. In the past decades, the size of POCUS machines has evolved from large portable devices to the current pocket-sized devices [11]. This has increased the use of POCUS in various indications, including in central line placement and the diagnosis of pulmonary embolism, pleural effusion, acute decompensated heart failure, and dyspnea [12–14].

The application of POCUS in diagnosing and managing dyspnea has been increasing in popularity [15]. Empirical evidence has indicated that the diagnostic accuracy of POCUS is similar to that of standard diagnostic methods such as chest *X*-Rays (CXR) in many different respiratory and cardiac pathologies [16]. While having the same diagnostic capabilities as CXR, POCUS had additional advantages to CXR, which include being free from ionizing radiations and its ability to be performed and interpreted in real-time at the bedside [17]. A previous systematic review and meta-analysis (SRMA) found that in different hospital settings, POCUS resulted in significantly shorter time to treatment and length of stay in the intensive care unit of patients with acute onset dyspnoea [18]. Therefore, we aimed to analyze the utility of POCUS in diagnosing various pathologies in patients who come to the ED with a chief complaint of dyspnea.

## METHODOLOGY

### Protocol and Registration

This systematic review was conducted according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 [19]. The review protocol has not been registered in any electronic database.

### Literature search

The literature search was conducted independently by two reviewers using two approaches.

The reviewers defined a comprehensive search criterion for the electronic databases in the first approach. This criterion and the associated keywords were then used for the electronic searches on four electronic databases, i.e., CENTRAL, PubMed, Science Direct, and Google Scholar. The search strategy for PubMed was as follows: (Ultrasound OR POCUS) AND (Dyspnoea OR Shortness of Breath OR Breathlessness) AND (Emergency physician OR Emergency department OR ED). These keywords were then modified for each of the databases to maximize the number of results. After the electronic search, the reviewers reviewed the lists of references of the obtained studies to find additional studies that would not have been identified in the initial search. Lastly, the reviewers searched for any trial registered in the clinical trial.gov registry for any completed trial with results but lacked available publications.

### Eligibility criteria

After all the articles had been obtained from the databases and registries, the authors then used the eligibility criterion that had been prespecified to analyze each of the articles before their inclusion into the review. The articles that met the inclusion criteria below were then included in the review:

1. Studies that were published in English.
2. Studies that included patients who presented to the ED with complaints of dyspnea, shortness of breath (SOB), or breathlessness.
3. Studies that were conducted only in the emergency department.
4. Studies that reported benefits of incorporating POCUS in diagnosing different underlying pathologies for dyspnea.
5. Studies designed as clinical trials, interventional studies, or observational studies conducted in different settings.

Studies were excluded from the review during the eligibility analysis if they met the following exclusion criteria:

1. Studies that were published in languages other than English.
2. Studies that included patients presenting with dyspnea in other hospital departments, such as the intensive care units.
3. Studies that included patients with other conditions not presenting with dyspnea as the main symptom.
4. Studies that were designed as secondary studies, such as systematic reviews and meta-analyses. Furthermore, case reports and conference abstracts without full articles.

### Data Extraction

The independent reviewers conducted the study selection in different phases. The phases entailed the removal of duplicate articles, screening of abstracts and

titles, and, lastly, screening of available full texts. For inclusion in the review, the independent authors first screened the articles' abstracts obtained after removing duplicates. If the study met the inclusion criteria, it was included in the study; however, if the reviews could not ascertain its eligibility, they proceeded to obtain the full text for screening. After completing the study selection, the reviewers extracted all the data into pilot-tested forms. The data extracted from each study included author identifiers (ID), study design, study setting, the sample size, the examiner's experience in conducting POCUS, the sample characteristics including the sample size, mean/median age, male-to-female ratio, the presence or absence of an ultrasound protocol, the inclusion criteria and the reported outcomes.

### Quality assessment

The methodological quality of the observational studies was assessed using the Newcastle Ottawa Scale (NOS). This scale assesses the quality of the studies using three domains: the selection of participants, the comparability of the study cohorts, and the reporting of the outcomes. The overall quality of the study was then assigned an Agency for Healthcare Research and Quality (AHRQ) standard based on the number of stars in each domain. The qualities assigned were poor, fair, and good.

## RESULT

### Search results

Our electronic search enabled us to retrieve 510 articles from the databases. The duplication assessment led to the removal of 330 duplicates. The remaining 180 publications were assessed based on title and abstract relevance, leading to the removal of 135 irrelevant abstracts. 45 articles were then sought for retrieval, and all were retrieved and evaluated using our eligibility criteria. This led to the inclusion of 9 articles that met the inclusion criteria. The remaining articles were excluded for the following reasons: 6 were not published in the English language, 12 did not include patients presenting with dyspnea, 4 did not report the required outcomes, 8 were secondary studies, and 6 were not conducted in the emergency department. A PRISMA diagram summarizing the search strategy is presented in (Figure 1).

### Characteristics of the included studies

This systematic review included 9 observational studies summarizing data from 3605 patients presenting with dyspnea in the emergency department [1,20–27]. The studies were conducted in different settings, including the United States of America (USA), Italy, India, and Rwanda. Most of the included studies had protocols that specified how the POCUS was conducted. In most cases, the comparator was either the baseline investigations without the POCUS or an alternative diagnosis used with conventional diagnosis. The characteristics of the included studies are presented in Table (1).

### Methodological quality

All the included studies had good methodological quality in both the selection of the study participants and the reporting of outcomes. Table (1) summarizes the methodological quality of the included studies.

Table (2) summarizes the characteristics and outcomes of the included studies.

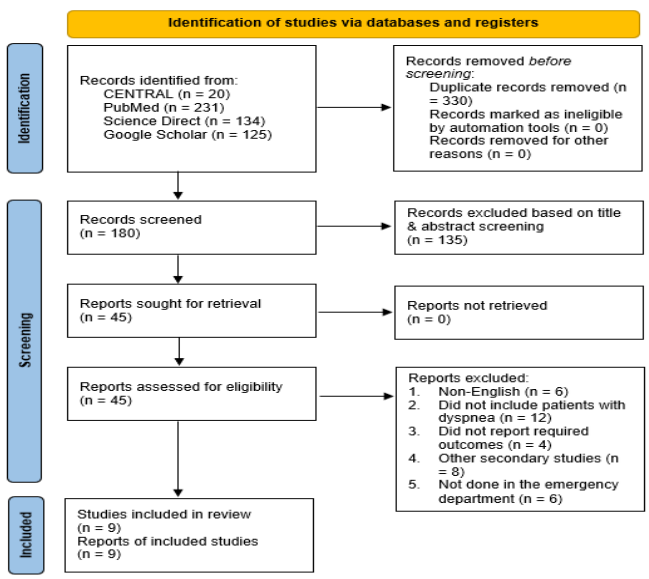


**Figure 1:** A PRISMA flow diagram summarizing the search strategy.

**Narrative synthesis**

**POCUS examiners**

Among the included studies, the experience of the physicians varied widely. Some studies, such as Liteplo *et al*., included medical students with minimal didactic training and experience conducting and interpreting at least five scans [25]. However, in most of the studies, the investigators were either residents or attending physicians in emergency medicine who had training in ultrasound conduction and then developed and performed POCUS according to the various study protocols [1,20–25,27]. Furthermore, in other studies, the examiners were highly qualified, either fellows with specialist training in ultrasonography OR attending physicians with fellowship training [21,24].

**Concordance between pre-pocus diagnosis and post-POCUS diagnosis**

The concordance between the pre-POCUS diagnosis was only reported in the study, which indicated that without the POCUS, the concordance between the ED diagnosis and the final diagnosis was kappa (0.45; 95% CI [0.31, 0.58]). When POCUS was incorporated into the diagnosis, the concordance between POCUS bases diagnosis improved to kappa (0.56; 95% CI [0.43, 0.69] [1]. In the study done by Zanobetti *et al*., the correlation between POCUS diagnosis and the final diagnosis was (Kappa 0.711) [20]. In another study, the correlation between POCUS diagnosis and final diagnosis was (0.668).

**Changes in diagnosis**

Different studies assessed the changes in the primary diagnosis even after incorporating POCUS. Beyer *et al*. reported an incidence of changes in physicians of two different teams performing the POCUS. The incidence of change in the diagnosis in 32% (95% CI; 22.2 -41.4%) of the cases when the POCUS was done by a US team and 40% (95% CI [28.1, 51.9]) when a primary team performed the ultrasound (US) [27]. This shed insight into the impact of the experience and expertise of the sonographers on the observed POCUS findings.

**Diagnostic accuracy**

Diagnostic accuracy was measured using different metrics, including sensitivities, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV). The sensitivity of POCUS for the different etiologies for dyspnea ranged from 88% (85.1%-90.6%) to 100.0% (78.2%-100.0%) for congestive heart failure, 64.7% (38.3-85.8) to 86.8% (84.2%-89.2%) for chronic obstructive pulmonary disease (COPD), and 88.5% (86.4%-90.3%) to 100% (78.2-100) for pneumonia. On the other hand, the specificity of POCUS ranged from 95.2% (83.8%-99.4%) to 96% (95%-96.8%) for diagnosing CHF, 93.3% (77.9%-99.2%) to 96.1% (95.1%-96.9%) for COPD, 74% (64%-82%) to 91.6% (90.1%-92.9%) for pneumonia. Only one study, Umuhire *et al*., reported the accuracy of POCUS, which was 100% for both CHF and COPD [23]. For pneumonia, the accuracy of POCUS was 85.7% [23]. (Table 3) provides a detailed description of the various diagnostic parameters included in the multiple studies for the three symptoms.

**DISCUSSION**

To our knowledge, this is the first study to summarize the utility of POCUS in the ED for diagnosing the etiologies of dyspnea. We found that using POCUS in the diagnosis of dyspnea improved the concordance between ED diagnosis and the final diagnosis in patients presenting with dyspnea. Furthermore, we found that incorporating POCUS in the ED improved the diagnostic accuracy of ED physicians compared to conventional diagnostic methods.

**Use of POCUS in the emergency department (ED)**

The use of POCUS has been increasing in popularity over the past decades. Various studies have investigated its utility across multiple hospital departments [28,29]. Popat *et al*. provided a summary of the utilization of POCUS in diagnosing multiple pathologies in the ED [28]. The study, which summarized all the current evidence until 2023, found that POCUS had high sensitivity and specificity for various conditions presented in the emergency department, including hydronephrosis, small bowel obstruction (SBO), and pleural effusion, among other conditions [28].

Our study expounded on the current evidence but focused on the efficacy of POCUS in diagnosing acute dyspnea. Most included studies were not comparative studies; thus, most reported outcomes were not compared to other studies. One of the studies that compared POCUS to chest *X*-Ray (CXR) reported that for various pathologies of dyspnea, POCUS had similar sensitivity to CXR in the diagnosis of pneumothorax and pleural effusion in patients presenting with dyspnea (100% versus 100%) [21]. However, for specificity, POCUS had lower specificity for some of the etiologies, such as pleural effusion, compared to CXR (71% versus 80%) [21]. However, these results were inconsistent across all the etiologies since the specificity for POCUS was superior to CXR in diagnosing pulmonary edema (93% versus 92%) [21].

Incorporating POCUS into clinical practice may require the examiners to have the skills to operate the POCUS systems. Our study found that most studies included highly skilled physicians as either one of the investigators or the principal investigators. The study by Bayer *et al*., illustrated the importance of clinicians' experience conducting POCUS. They found that the rate of change in primary diagnosis was lower (32%) when the

**Table 1:** Characteristics of the included studies:

| AUTHOR ID | DESIGN | COUNTRY | Sample size | Examiner POCUS experience | Mean/Median age | Male to female ratio | PROTOCOL | | INCLUSION CRITERIA | REPORTED OUTCOMES |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | POCUS | REFERENCE | | |
| Beyer *et al*., 2021 [27] | Prospective cohort study (PCS) | USA | 156 encounters | Mixed | 61(51-73) | 57:68 | No specific protocol, routine care adhered to. | No particular protocol, routine care adhered to. | Adult patients with undifferentiated dyspnea | Change in differential diagnosis and management of the patients. |
| Papanagnou *et al*., 2016 [1]. | PCS | USA | 119 patients | Senior emergency medicine residents, fellows, and attending physicians. | 69.5(66.5–72.5) | 61:58 | The protocol was standardized for the study, and each physician did a supervised cardiopulmonary | The reference was the baseline findings. In which assessment and history taking were done based on the hospital's routine practice. | Patients with chief complains of dyspnea or objective parameters indicating dyspnea. | The percentage of post-US diagnoses matching the final diagnosis, the change in time to the final diagnosis, and the change in physicians' confidence level after POCUS. |
| Zanobetti *et al*., 2017 [20]. | PCS | Italy | 2683 patients | Emergency physicians with at least two years of experience after a professional course in lung ultrasound and cardiac echocardiography in the ED. | 71.2±18.6 | 1367:1316 | The lung ultrasound was done per the standard practice and a study protocol. | The reference standard was baseline evaluations as per the hospital protocol. | Patients presented to the ED with chief complaints of dyspnea, which was ruled out to be of non-traumatic origin. | Concordance between pre-ultrasound diagnosis and post-ultrasound diagnosis and diagnostic accuracy of POCUS. |
| Buhunaid *et al*., 2018 [21]. | PCS | USA | 128 patients | Fellows or attending physicians with fellowship training in ultrasound use. | 64 | 71:57 | A lung ultrasound was performed according to a standard protocol | The reference standard was baseline evaluations as per the hospital protocol. | Patients with chief complaints of chest pain and | The sensitivity of POCUS and chest X-rays in diagnosing causes of dyspnea. |
| Baid *et al*., 2022 [22]. | PCS | India | 237 patients | Emergency medicine residents with 2 months-POCUS training. | 53(18-82) | 142:95 | The POCUS was performed according to a prespecified protocol, e.g., lung US, echocardiogram, and then an inferior vena cava (IVC) evaluation. | The reference standard was the baseline evaluation done on admission | Patients with acute onset dyspnea. | Lung and cardiac ultrasound findings. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Umuhire *et al*., 2019 [23]. | PCS | Rwanda | 100 patients | Emergency medicine physician with focused ultrasound training. | 45±21.9 | 57:43 | There was a pre-specified protocol for each system, including the lungs, IVC, and heart, deep venous thrombosis (DVT) evaluation, and a FAST scan. | A separate clinical team did the baseline clinical exam and history taking. | Patients with complaints of breathlessness of different severity. | Ultrasound findings and diagnostic accuracy of pre- and post-POCUS diagnosis. |
| Mantuani *et al*., 2016 [24] | PCS | USA | 57 patients | Fellowship-trained sonographers. | 58.2 | 36:21 | No separate protocol since ultrasound was part of resuscitation care for dyspneic patients. | No separate protocols. | Patients with complaints of dyspnea and in need of immediate medical attention. | Ultrasound findings and diagnostic sensitivity and specificity. |
| Liteplo *et al*., 2009 [25]. | PCS | USA | 100 patients. | Emergency physicians who were specialists in US or medical students with US training. | 74±14 | 55:45 | POCUS was conducted according to a study protocol. | No specified protocol, baseline investigations according to hospital guidelines. | Patients with dyspnea aged 18 years and above. | Sensitivity and positivity. |
| Cibinel *et al*., 2012 [26]. | PCS | Italy | 56 patients. | Emergency physicians: No specifications on the qualifications. | 82.1±13.7 | 35:21 | POCUS was performed according to a study protocol. | Not specified. | Patients with complaints of shortness of breath (SOB). | Sensitivity and positivity. |

POCUS: Point of care ultrasound; ID: Identifier; USA: United States of America; PCS: Prospective cohort study; ED: Emergency department; US: Ultrasound; IVC: Inferior vena cava; DVT: Deep venous thrombosis; FAST: Focused Assessment with Sonography in Trauma; SOB: shortness of breath.

**Table 2:** The characteristics of the included studies

| AUTHOR ID | SELECTION | COMPARABILITY | OUTCOMES | AHRQ standard |
|---|---|---|---|---|
| Bayer *et al*., 2021 [27] | 3 | 2 | 3 | Good |
| Papanagnou *et al*., 2016 [1]. | 3 | 2 | 3 | Good |
| Zanobetti *et al*., 2017 [20] | 3 | 2 | 3 | Good |
| Buhunaid *et al*., 2018 [21] | 3 | 2 | 3 | Good |
| Baid *et al*., 2022 [22] | 3 | 2 | 3 | Good |
| Umuhire *et al*., 2019 [23] | 3 | 2 | 3 | Good |
| Mantuani *et al*., 2016 [24]. | 3 | 2 | 3 | Good |
| Liteplo *et al*., 2009 [25]. | 3 | 2 | 3 | Good |
| Cibinel *et al*., 2012 [26]. | 3 | 2 | 3 | Good |

ID: Identifier; HRQ: Agency for Healthcare Research and Quality.

**Table 3:** The diagnostic accuracy of POCUS for various etiologies for dyspnea.

| STUDY ID | Zanobetti *et al.*, 2017 [20] | | | Buhunaid *et al.*, 2018 [21] | Mantuani *et al.*, 2016 [24]. | | | Umuhire *et al.*, 2019 [23] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Symptom | CHF | COPD | Pneumonia | Pneumonia | CHF | COPD | Pneumonia | CHF | COPD | Pneumonia |
| Sensitivity | 88% (85.1-90.6) | 86.8% (84.2-89.2) | 88.5% (86.4-90.3) | 0.89 (0.54-1.00) | 100.0 (78.2-100.0) | 64.7 (38.3-85.8) | 100.0 (78.2-100) | NR | NR | NR |
| Specificity | 96% (95-96.8) | 96.1% (95.1-96.9) | 91.6% (90.1-92.9) | 0.74 (0.64-0.82) | 95.2 (83.8-99.4) | 93.3 (77.9-99.2) | 82.9 (67.9-92.8) | NR | NR | NR |
| Accuracy | NR | NR | NR | NR | NR | NR | NR | 100 | 100 | 85.7 |
| Positive predictive value | 85.8% (82.8-88.5) | 89.7% (87.2-91.8) | 87.7% (85.6-89.6) | NR | NR | NR | NR | NR | NR | NR |
| Negative predictive value | 96.6% (95.8-97.4) | 94,9 (93.8-95.8) | 92.1% (90.7-93.4) | NR | NR | NR | NR | NR | NR | NR |

ID: Identifiers; CHF: Congestive heart failure; COPD: Chronic obstructive pulmonary disease; NR: Not reported.

ultrasound was conducted by an experienced US team and higher (40%) when the US was conducted by primary care physicians in the hospitals [27]. These findings indicated that more of the clinical staff should be trained in the use of POCUS either during their study or as continuous professional development courses for it to be successfully implemented in the clinical area.

### Limitations of the study

This review presented the first preliminary results we found on the current evidence of the utility of POCUS in diagnosing dyspnea in the emergency department. Despite our robust methodological approach, this review had some limitations. First, we could not pool the quantitative results of the included studies since the reported outcomes were highly variable and limited results of the reported outcomes. Second, although POCUS is a novel approach to diagnosing various conditions in the ED, its feasibility will depend on its comparative advantage over standard diagnostic methods such as computed tomography scans (CT scans) and CXR. However, since most of the studies used POCUS as standard care, without controls using CXR, we could not determine the comparative diagnostic capabilities of POCUS compared to these other diagnostic methods.

## CONCLUSION AND RECOMMENDATIONS

Our study has indicated that POCUS is a feasible and alternative method for diagnosing various etiologies for dyspnea in the ED. While the sensitivity of POCUS is comparable to that of standard diagnostic imaging such as CXR, it has been shown to have better specificity in diagnosing various pathologies for dyspnea. However, there is limited evidence on POCUS, and its comparative advantage is inconsistent across different pathologies. We, therefore, make the following recommendations for further research on the utility of POCUS in the emergency department. More studies need to be conducted to determine the utility of POCUS in detecting acute dyspnea in the ED. Future studies should include controls to assess the comparative advantage of POCUS to standard diagnostic methods such as CXR. However, such trials may not be feasible in some settings since POCUS has been made as part of the initial diagnostic criteria for patients presenting with acute dyspnea in the ED. Therefore, the feasibility of indirect comparison between the various diagnostic methods should be investigated in future reviews.

## CONFLICT OF INTERESTS

There are no conflicts of interest.

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