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Accuracy of point of care ultrasound in evaluation of patients with dyspnea and chest pain in the emergency department

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Abstract
Aim: Dyspnea and chest pain are common principal complaints among individuals who present to the Emergency Department (ED). Point of care ultrasound (POCUS) is more accurate than chest X-Ray (CXR) for the diagnosis of diseases most typically found in patients with chest discomfort and dyspnea. In this study, we aimed to assess the diagnostic accuracy of POCUS in cases presented to the emergency rooms with dyspnea and/or chest discomfort.
Material and Methods: Patients with dyspnea and/or chest pain were submitted to POCUS protocol, which includes lung ultrasound, echocardiography, inferior vena cava (IVC) and deep vein thrombosis (DVT) scans between December 2020 and December 2021. Pre- POCUS diagnoses and POCUS diagnoses were compared to final diagnosis to detect the degree of agreement.
Results: One hundred patients were enrolled in this study. POCUS was 100 % accurate in diagnosing cases of pneumothorax; 99 % accurate in diagnosing pleural effusion; 98 % accurate in diagnosing pulmonary edema; and 95 % accurate in diagnosing pneumonia. It has excellent agreement with cases of acute coronary syndrome (ACS), pulmonary embolism (PE), and pneumothorax (kappa index = 1), as well as a nearly perfect agreement with pulmonary edema (kappa index = 0.842).
Discussion: POCUS is a practical and reliable diagnostic tool that can help in narrowing down the differential diagnoses and shortening the diagnostic time in the assessment of patients with dyspnea and/ or chest pain in the ED.

Keywords
Accuracy, POCUS, Dyspnea, Chest Pain

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Introduction

Dyspnea and chest pain are common principal complaints among individuals who present to the ED [1]. As there are various possible etiologies of dyspnea, it is difficult to come up with a straightforward dyspnea diagnostic algorithm [2]. Chest pain is caused by numerous causes ranging from self-limited to lethal causes, such as ACS, PE, pneumothorax, and aortic dissection [3]. Although CXR and clinical examination are the most widely utilized techniques in the diagnosis of breathing difficulties, they are still inadequate for definitive diagnosis. Computed tomography (CT) scans are considered the gold standard for identifying most lung diseases, but they are time-intensive and require patient transfer to specialized units [4]. Previously, ultrasound was an unacceptable method for lung evaluation due to the fact that air hinders the ultrasound beams. However, recently, pulmonary ultrasound has become an essential diagnostic tool in emergency and pulmonary medicine as it is radiation-free, non-invasive, and a bedside imaging modality that is used in addition to physical and clinical evaluation [5].

Thoracic ultrasonography has been used to diagnose pulmonary edema, pneumonia, pneumothorax, and pleural effusion [6]. Several protocols have been developed to evaluate the role of pulmonary ultrasound in cardiorespiratory conditions; the most widely used is the BLUE protocol (bedside lung ultrasound in emergency) which was developed by Daniel Lichtenstein. The BLUE protocol was accurate in the diagnosis of 90.5% of causes of respiratory failure [7]. FALLS- protocol (fluid administration limited by lung ultrasound) is another protocol used in circulatory failure depending on cardiac and pulmonary ultrasound [8].

According to studies, POCUS is more accurate than CXR for the diseases most typically found in cases with chest pain and dyspnea [1]. POCUS differs from comprehensive ultrasound examination that is used to answer a precise medical problem [9]. POCUS helps in the evaluation of several conditions such as cardiac arrest, trauma, chest pain, and shortness of breath [10]. Gargano et al. have indicated that combining lung ultrasonography with echocardiography could narrow the differential diagnosis of cardiorespiratory problems [11].

The goal of this study is to assess the diagnostic accuracy of POCUS in the evaluation of patients with dyspnea and/or chest pain in the emergency rooms.

Material and Methods

This cross-sectional study was carried out at the ED of Alexandria Main University Hospital, Egypt, from December 2020 to December 2021. Ethical approval was obtained from Alexandria University Ethical Committee (Reference number 0201345). Informed consent was taken from all patients or their legally acceptable representatives.

Population

Patients were included into the study if they matched the following criteria: age >18 years with a primary complaint of dyspnea and/or chest pain. Patients were excluded if they had an unstable tachyarrhythmia or bradyarrhythmia that leads to a shock state and patients with a known diagnosis were referred from another hospital. The attending clinician made a preliminary diagnosis and treatment plan.

Clinical assessment

Vital signs, general examination and patient's clinical history were all documented by the emergency clinician. All patients received routine testing electrocardiography (ECG), CXR, and laboratory investigations, such as arterial blood gases, blood assessment, and cardiac enzymes, as part of the hospital's procedure.

Point-of-care ultrasound

All patients were submitted to an ultrasonography approach after the first examination, which included pulmonary ultrasonography, echocardiography, inferior vena cava evaluation (IVC), and a deep vein thrombosis (DVT) test.

Lung scan was carried out using one of two ultrasound devices: Mind ray DC-30, and DP-20 (Mind ray, Shenzhen, China) with a curvilinear probe (2-5 MHz) and a high-frequency linear probe (5-10 MHz). Ultrasound examinations were performed immediately after the initial assessment in the ED with the patient in the supine or semi-setting position. Lung ultrasound was done for the detection of lung consolidation, pneumothorax, pulmonary edema, and pleural effusion.

POCUS diagnosis of different lung pathologies:

1. Pneumonia was diagnosed by the detection of consolidation or shred sign, with or without effusion.
2. Pulmonary edema was diagnosed by the presence of multiple bilateral B-lines equal or more than three with or without pleural effusion.
3. Pneumothorax was considered in case of absence of lung sliding and the presence of lung point that is pathognomonic for pneumothorax.
4. Pleural effusion was defined as a hypoechoic area between visceral and parietal pleura that may be bilateral.

More than one diagnosis could be present in the same patient.

Echocardiography was carried out using a Vivid machine (General Electric, Boston, USA) with a 2.8-4 MHz phased array probe. The heart contractility, presence or absence of effusion around the heart, equalization of the heart chambers, aortic root diameter, condition of the valves, signs of pericardial tamponade, and regional wall motion abnormalities were examined.

Ultrasound was also used to assess the IVC diameter. Measurement of the maximum diameter at the end of expiration and the minimum diameter at the end of inspiration were obtained.

Finally, ultrasound two-point compression test was used to diagnose DVT in this study [12]. Area of the femoral vein as well as area of the popliteal vein were examined for compressibility; if the vein was not collapsible, a positive test was reported.

The ultrasound protocol was carried out by the emergency physician with four years of experience in the field of emergency ultrasound. All scans were performed without interruption of the patient's medical care and the duration of ultrasound examination was recorded.

The patient's age, gender, and comorbidities were all gathered as part of the demographic data. Vital signs at the time of presentation, admission diagnoses, ECG and laboratory investigations such as cardiac biomarkers, and complete blood count, were obtained in the emergency rooms. There are no gold standard tests for all etiologies, thus we used a gold

standard test for each etiology: echocardiography performed bycardiologists for cardiac heart failure; CT pulmonary angiography for PE; CT chest for pneumonia, pneumothorax, and pleural effusion and echocardiography and cardiac enzymes investigations for the ACS.

Statistical analysis

Statistical Package for the Social Sciences (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp) was used to analyze the data. Categorical data were represented as numbers and percentages. Quantitative data were expressed as mean and standard deviation. The sensitivity, specificity, positive predictive value, and negative predictive value were calculated for lung ultrasound and chest radiography, using CT chest as the gold standard test. The agreement between pre- POCUS diagnosis and POCUS diagnosis was calculated using Cohen's kappa coefficient. The Kappa values were classified as follows: equal or less than 0.20 as poor agreement; 0.21 to 0.40 as fair agreement; 0.41 to 0.60 as moderate agreement; 0.61 to 0.80 as good agreement; above 0.80 as very good agreement.

Results

This study was conducted on 100 patients with dyspnea and/or chest pain in the ED. Fifty-nine of the studied cases were males (59.0%) and 41 were females (41.0%). The median age was 55 years. Dyspnea was the most reported complaint (60%), followed by chest pain (26%). Eighty percent of the subjects had comorbidities, which included ACS (16%), hypertension (HTN) (38%), COPD/Asthma (20%), heart failure (13%), renal impairment (6%) and liver disease (9%) (Table 1).

The ejection fraction of the left ventricular (LVEF) was decreased in 30% of cases and hyper dynamic in 9% of cases.

Table 1. Demographic, clinical data, and POCUS findings in the studied cases

	n=100	%
Age (years; mean ± SD)		53.04 ± 14.25
Gender		
Males	59	59%
Females	41	41%
Complaints		
Dyspnea	60	60%
Chest pain	26	26%
Dyspnea and chest pain	14	14%
Comorbidities		
CAD	16	16%
HTN	38	38%
Asthma/COPD	20	20%
HF	13	13%
Renal disease	6	6%
Liver disease	9	9%
Pocus findings		
Reduced LVEF	30	30%
Hyper dynamic LVEF	9	9%
Pericardial effusion	7	7%
Pericardial tamponade	-	-
McConnell sign	1	1%
Wall motion abnormality	21	21%
Pulmonary edema	24	24%
Pleural effusion	24	24%
Pneumothorax	4	4%
Pneumonia	14	14%
Fat IVC	35	35%
Flat IVC	65	65%

CAD; coronary artery disease, HTN; hypertension, HF; heart failure, COPD; chronic obstructive lung disease, POCUS; point of care ultrasound, LVEF; left ventricular ejection fraction, IVC; inferior vena cava

Table 2. Chest X-Ray accuracy in the diagnosis of different lung pathologies

	CT chest				Sensitivity	Specificity	PPV	NPV	Accuracy
	Negative		Positive						
	No.	%	No.	%					
X-ray chest									
Plural effusion	(n = 75)		(n = 25)						
Negative	75	100.0	7	28.0	72.0	100.0	100.0	91.46	93.0
Positive	0	0.0	18	72.0					
Pneumothorax	(n = 96)		(n = 4)						
Negative	96	100.0	1	25.0	75.0	100.0	100.0	98.97	99.0
Positive	0	0.0	3	75.0					
Pneumonia	(n = 81)		(n = 19)						
Negative	81	100.0	8	42.1	57.9	100.0	100.0	91.01	92.0
Positive	0	0.0	11	57.9					
Pulmonary edema	(n = 76)		(n = 24)						
Negative	76	100.0	13	54.2	45.8	100.0	100.0	85.39	87.0
Positive	0	0.0	11	45.8					
Lung ultrasound									
Plural effusion	(n = 75)		(n = 25)						
Negative	75	100.0	1	4.0	96.0	100.0	100.0	98.68	99.0
Positive	0	0.0	24	96.0					
Pneumothorax	(n = 96)		(n = 4)						
Negative	96	100.0	0	0.0	100.0	100.0	100.0	100.0	100.0
Positive	0	0.0	4	100.0					
Pneumonia	(n = 81)		(n = 19)						
Negative	81	100.0	5	26.3	73.7	100.0	100.0	94.19	95.0
Positive	0	0.0	14	73.7					
Pulmonary edema	(n = 76)		(n = 24)						
Negative	75	98.7	1	4.2	95.8	98.7	95.83	98.68	98.0
Positive	1	1.3	23	95.8					

CT; computed tomography

Table 3. Agreement of diagnoses before and after pocus

Final diagnosis	Pre POCUS diagnosis		Post POCUS diagnosis	
	Kappa	P	Kappa	P
Acute coronary syndrome	1.000	<0.001*	1.000	<0.001*
Pneumonia	0.641	<0.001*	0.777	<0.001*
Pulmonary edema	0.675	<0.001*	0.945	<0.001*
Musculoskeletal pain	1.000	<0.001*	1.000	<0.001*
Pericardial effusion	0.713	<0.001*	1.000	<0.001*
Pleural effusion	0.794	<0.001*	0.973	<0.001*
Pulmonary embolism	0.823	<0.001*	1.000	<0.001*
Pneumothorax	0.852	<0.001*	1.000	<0.001*
Asthma/COPD	0.828	<0.001*	0.736	<0.001*
Pericarditis	1.000	<0.001*	1.000	<0.001*

κ: Kappa test p: p-value for agreement *: Statistically significant at p ≤ 0.05
POCUS;point of care ultrasound, COPD; chronic obstructive pulmonary disease

The most common sonographic findings in the studied patients were bilateral B lines, pleural effusion, and lung consolidation. The size of the IVC was scanned to test volume responsiveness; 35% of patients were volume responsive (flat IVC), whereas 65 % were not (fat IVC). Scans for DVT were positive in 7 cases (Table 1).

The accuracy of CXR and POCUS revealed that the sensitivity and specificity of CXR and POCUS were respectively: 72% and 100% versus 96% and 100% for pleural effusion; 75% and 100% versus 100% and 100% for pneumothorax; 57.9% and 100% versus 73.7% and 100 % for pneumonia; 45.8% and 100% versus 95.8% and 98.7% for pulmonary edema (Table 2). In this study, the most common final diagnoses were ACS (25 patients, 25%), pleural effusion (25 patients, 25%) and pulmonary edema (24 patients, 24%). The emergency physician was able to correctly diagnose pleural effusion in 18 patients (18%) pre-POCUS compared to 25 patients (100%) post-POCUS (Kappa index = 1). Pulmonary edema was diagnosed in 19 patients (19.0%) pre- POCUS diagnosis and in 24 patients (24%) post- POCUS diagnosis (kappa index = 0.945) (Table 3).

There was a very good agreement between pre-POCUS diagnosis and post- POCUS diagnosis regarding ACS, pericarditis, and musculoskeletal pain (kappa index = 1). There was perfect agreement between POCUS diagnosis and final diagnosis for PE (kappa index = 1). The duration of our echo-ultrasound protocol ranged from 12 minutes to 17 minutes with a median duration of 15 minutes.

Discussion

Focused echocardiography was first used to assess dyspnea in the emergency room in 2001 [13]. It is critical to start rapid focused therapy for pulmonary edema, COPD, pneumonia, and other causes of respiratory distress, however, determining the etiology of dyspnea in unstable patients can be difficult and challenging [14].

There was perfect agreement between POCUS diagnosis and final diagnosis (kappa =1.00) in PE, ACS, and pericarditis, and kappa = 0.945 for pulmonary edema. This is consistent with the findings of Mantuani et al. [14] who discovered that multi-organ POCUS has 100% sensitivity for decompensated heart failure, and Nazerian et al. [15], who emphasized the utility of multi-organ ultrasound in patients with suspected PE.

Our study compared the sensitivities and specificities for CXR and POCUS and discovered that the sensitivity and specificity of CXR and pulmonary ultrasound were: 72% and 100% versus 96% and 100% for pleural effusion; 75% and 100% versus 100% and 100% for pneumothorax; 57.9% and 100% versus 73.7% and 100 % for pneumonia; 45.8% and 100% versus 95.8% and 98.7% for pulmonary edema, respectively. These findings were slightly higher than those of Bekagos et al. who found that chest ultrasound was more accurate than routine CXR in the diagnosis of causes of shortness of breath with sensitivities and specificities of 87.6% and 96.2 % for pulmonary edema; 85.7 %, and 99.0% for pneumonia; 98.2%, and 67.3% for asthma/COPD, 46.2% and 100% for PE, and 71.4% and 100% for pneumothorax, respectively [2]. This could be because our study only looked at a small number of cases.

On the other hand, the sensitivity of pre-POCUS diagnosis was superior to POCUS diagnosis of COPD/asthma with kappa index = 0.828 for pre- POCUS diagnosis and kappa index =0.736 for POCUS diagnosis. Zanobetti et al. had reported the same findings [16]. PE showed kappa index =1, which was superior to the study by Ahn et al., which showed kappa index =0.95. The higher agreement in our study could be due to the integration of lower limb DVT ultrasound in our protocol [17].

An interesting finding was that our protocol identified all cases of ACS, PE, pericardial effusion, and pneumothorax accuracy 100% and Kappa index = 1. This may be due to the integration of focused echocardiography, IVC scan, and DVT scan to lung ultrasound elucidating that merely lung ultrasound is not enough in diagnosing different etiologies of dyspnea.

The duration of our echo-ultrasound protocol ranged from 12 minutes to 17 minutes with a median duration of 15 minutes, this is longer than the scan duration (SD) in research by Russel et al. with an average total time of 12 minutes (SD 4 minutes) to complete [18]. This may be due to the additional parameters being included in our study.

Conclusion

According to the results of this study, POCUS revealed high sensitivity and specificity, therefore it is considered a bedside, dependable, quick, and non-invasive technique. The results imply that it could have a major role in the diagnostic workup of dyspnea and chest pain in the ED, alongside comprehensive echocardiography and CT in difficult scenarios. The use of POCUS by emergency physicians in the detection of different causes of dyspnea and chest pain is feasible, time saving, and avoids unnecessary radiological investigations.

Study limitations

The current study had several limitations. It was a single-center study with small sample size that may hamper some of our findings. Only one physician provided all sonographic tests, hence, the findings may not be applicable to other emergency departments or physicians that perform POCUS as it is user dependent. Patients could not be included consecutively, while the POCUS investigator was not present in the ED, which could have resulted in selection bias. Examiner was not fully blind to the patient's clinical characteristics, which may also have led to performance bias. One of the study's limitations is that we did not discriminate between systolic and diastolic heart failure. These limitations should be balanced against the benefits of point-of-care ultrasonography in narrowing the differential diagnosis of dyspnea and chest pain in the ED.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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