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# POINT-OF-CARE EMERGENCY ULTRASONOGRAPHY IN NON-TRAUMATIC CARDIAC ARREST AND NEAR-ARREST EMERGENCY PATIENTS; A PILOT TRIAL

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## Abstract

**INTRODUCTION:** In this study, we evaluated the applicability and interpretation of point- of- care emergency ultrasound (POCEUS) performed by an emergency physician (EP) in non-traumatic adult cardiac arrest and near-arrest patients at presentation to the Emergency Department (ED).

**METHODS:** POCEUS was performed in 5 steps on 73 adults to assess; 1. Qualitative global cardiac function, cardiac chambers and presence of pericardial effusion; 2. Presence of pleural sliding, B-lines, A-lines or consolidation on anterior-superior; 3. Presence of an abdominal aorta aneurysm and pelvic free fluid; 4. Presence of pleural effusion, consolidation, free fluid on lateral-inferior; 5. Qualitative width and collapsibility of the inferior vena cava. A fulfilled checklist and real-time images of ultrasonography were sent by WhatsApp to the head of the study to generate the evidence and collect the data.
The process of patient care, in-hospital diagnosis and survival were retrieved from digital hospital records. This prospective multicenter sample study was conducted from November 16, 2015, to January 5, 2016.

**RESULTS:** The most common findings of POCEUS were performed and interpreted to have a first prediction of patients' acute clinic problem by EPs were compatible with global systolic dysfunction (n = 16, 22.9%), pulmonary edema (n = 17, 23.3%), pulmonary embolus (n = 6, 8.2%), distributive/hypovolemic shock (n = 12, 16.4%), cardiac tamponade or pericardial effusion (n = 5, 6.8%), and pneumonia (n = 31, 42.5%) at presentation.
The kappa correlation coefficient value of the POCEUS at presentation versus the final, traditional clinical diagnosis of the admitted ward, was 0.773 (95% CI, 0.747–0.892; p = 0.064, McNemar).

**CONCLUSIONS:** POCEUS performed by an EP at presentation had a good agreement between in qualitative prediction of the first differential diagnosis in life-threatened patients and the last diagnosis obtained during hospitalization. Furthermore, this study showed the requirement of evidence in comparison of measurements to the qualitative manner and new descriptive processes in POCEUS for unexplained situations and questions.

**KEY WORDS:** cardiopulmonary arrest, near-arrest, emergency patient, point-of-care emergency ultrasound

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## INTRODUCTION

The history of ultrasonography literature for the emergency patient had been started by Kristensen et al in 1971 including splenic haematoma in trauma [1]. Since then it has been a core application still growing as an independent method performed by emergency medicine in the world [2].

At the present time, emergency ultrasound imaging criteria compendium involves the aorta, cardiac, kidney and bladder, lung and pleura, ocular, pelvic, right upper quadrant, soft tissue/musculoskeletal, trauma, ultrasound-guided procedures and venous thrombosis. For each one primary and extended indications, contraindications, limitations and pitfalls were released and updated by American College of Emergency Physicians [3].

More than, there are many valuable researchers identified the ultrasonographic findings by explaining the relations in algorithms of systems in acute and critical patients [4, 5].

Point of care emergency ultrasound (POCEUS) is generally superior to traditional physical examination alone in the emergency department (ED) and can therefore be highly valuable.

It allows rapid assessment of differential diagnosis of a life-threatening and is performed by emergency physicians (EPs) [6–9].

Evidence-based on real-time ultrasound imaging performed in limited time on cardiac, lungs, abdomen, and inferior vena cava (IVC) is essential to solve the emergency problems on patients in ED. Various protocols for a point-of-care ultrasound with cardiac arrest, shock, and respiratory failure have been reported and improved patient care at the ED [4, 10–12]. Moreover, in stable patients with a new complaint, the ultrasound can also be used to enlighten and prevent the progress of the problem.

In the present study, we aimed to evaluate the applicability and interpretation of POCEUS based on only visual estimation performed by EP on patients with cardiac arrest and near-arrest at presentation to the ED.

We also evaluated the relation predictions obtained by POCEUS and the last diagnosis on hospitalization.

## METHODS

This seven-center of EDs (Baskent University Adana Dr. Turgut Noyan Training and Research Center, Ufuk University, Ege University, Akdeniz University, Gaziantep University, Baskent University Ankara Hospital, and Eskisehir Osmangazi University) prospective random-sample study was performed between November 16, 2015 and January 5, 2016.

The study was carried out in a period where all the centers had at least one working ultrasound in ED continuous and simultaneously at the same time. As the presence of ultrasound machine has not been a formal rule in all EDs in Turkey, yet, as in many developing countries. The study protocol was approved by Baskent University Institutional Review Board (no. KA15/214).

There was only one volunteer researcher in each ED contributed in the study who performed emergency ultrasonography on study cases.

The cases were involved in shifts of volunteer researchers'.

Emergency ultrasonography was performed at once on initial of the presentation of the patient to the ED.

Inclusion criteria were included the age of > 18 years, non-traumatic cardiac arrest or acute, life-threatening, near-arrest cases. Near-arrest cases had at least one of them; Acute; Hypotension/ /hypertension + tachycardia or hypoxia or clinical deterioration at presentation with poor looking with the presence of a significant, intolerable, and unexplained reason to clarify this situation, requiring immediate treatment and management in ED [13].

Performance of POCEUS upon arrival to the ED was realized prior to any blood tests, another imaging methods or any consultation, without any inhibition of advanced life support or emergency treatment/management if required. Real-time ultrasonographic images were recorded by another witnessed healthcare staff member's smartphone and a checklist of ultrasonographic findings in the study with predicted differential diagnosis interpreted was filled by EP who performed POCEUS, sent all via WhatsApp Messenger to the first author of the study to make evidence and collect the data in a file. The findings of the POCEUS were not shared with consultants in order not to affect their final diagnosis for the patient in hospitalization by their traditional way except the emergency staff.

Exclusion criteria included trauma cases, ST-elevation myocardial infarction, gastrointestinal or external hemorrhage, cerebral events and intoxication.

POCEUS was a tool, provided only a prediction in preliminary differential diagnosis on patients by answering the presence or absence of some ultra-

**Table 1. The checklist study form**

| | |
|---|---|
| 1. Cardiac | |
| Ventricle contraction | Left/right: Normal/ /Hypokinetic/Hyperkinetic/ None |
| Chambers | Left/Right: Enlarged/Normal/ /Small |
| Pericardial effusion | -/+/Tamponade |
| 2. Bilateral anterosuperior lungs | |
| Pleural sliding | +/-/Decreased |
| B-lines | < 3/≥ 3/≥ 5 |
| A-lines | +/- |
| Consolidation | +/- |
| 3. Abdomen | |
| Abdominal medial aortic aneurysm ± rupture | +/- |
| Suprapubic free fluid | +/- |
| 4. Inferiolateral lungs and physiological lateral fossas | |
| Pleural sliding | +/-/Decreased |
| B-lines | <3 /≥ 3/≥ 5 |
| A-lines | +/- |
| Consolidation | +/- |
| Bilateral pleural/hepatorenal/ /splenorenal fluid | +/- |
| 5. IVC | |
| Width and Collapsibility | Narrow/Normal/Enlarged and 50%/< 50%/> 50% |
| + If qualitative right ventricle dilatation is present, on 3-point DVT examination: Compressible/Uncompressible | |

sonographic signs in a few minutes. In this sample, it was an independent and the first method performed, prior to the physical examination, advanced examinations, patient care management and plan.

All EPs were emergency medicine fellowship-trained physicians, including at least 2 years experience of emergency ultrasound.

2D-ultrasound with three probes were used. Patients in cardiac arrest were placed in supine, and all other patients were placed in the semi-sitting position.

The parameters were;

1. Qualitative global cardiac function, cardiac chambers, and the presence of pericardial effusion 2. Presence of pleural sliding, B-lines, A-lines, or consolidation in 1 intercostal area (ica) of each side on anterosuperior lungs. 3. Presence of a middle abdominal aorta aneurysm and suprapubic free fluid 4. Pleural sliding, B-lines, A-lines, consolidation, or effusion in 1 ica of each side on inferolateral lungs and free fluid in the physiological lateral abdominal fossas. 5. Qualitative width as narrow, normal, enlarged and IVC collapsibility as $<$, $>$, $\sim$ 50%. The checklist used in the study is shown in Table 1.

Cardiac and leg vein (if indicated) comprised at first the four-chamber cardiac evaluation that was preferably performed in the apical or parasternal view.

If these views could not be obtained, a subcostal view was done with a phased array or convex probe. Contraction and dilatation of the left and right ventricles and the presence of pericardial effusion were qualitatively evaluated [8, 9].

If there was suspicion of pulmonary thromboembolism (PTE) with a dilated right ventricle, D-shaped left ventricle, or McConnell's sign on the cardiac view, a probe was used to perform the three-point compression technique for evaluation of DVT to determine the presence of uncompressible or limitedly compressible veins [8, 9, 14, 15]. Although, evaluation of D-shaped left ventricle or McConnell's sign were difficult and not considered in emergencies.

For lung views, the anterosuperior and inferolateral areas of the lungs were evaluated with a convex ultrasound probe. Pleural sliding was defined as the movement of the pleural line in an ica with each respiration.

The diffuse interstitial syndrome was defined as 3 or more B-lines, at least in 2 icas in each lung. Focal interstitial parenchymal pathology was considered to be present when 3 or more B-lines were seen in 1 ica on each lung or only in one side. Pneumothorax was predicted as the first probability in differential diagnosis in an acute deteriorated unintubated case while the absence of pleural sliding and B-lines. Lung point is the confirmation, lung pulse is the exclution of pneumothorax, they were not used in this study.

Consolidation was defined as an irregular hypoechoic or tissue-like subpleural area in the parenchyma [5, 12, 16].

In IVC views, IVC collapsibility was qualitatively defined as a diameter change between expansion during expiration and narrowing on the inspiration of approximately 50% within normal conditions are.

If the IVC collapsibility $<$ 50% on inspiration or the diameter of 2.5 cm is measured define that there is sufficient intravascular volume for septic patients in a report [17].

**Table 2. The demographic data and presenting complaint/condition of patients**

| Demographic characteristics | |
|---|---|
| Age in years | 70 ± 13 (29–94) |
| Female sex | 43% (n = 32) |
| The first presenting complaint or condition | |
| Dyspnea | 50.7% (n = 37) |
| Cardiac arrest | 9.6% (n = 7) |
| Chest pain | 9.6% (n = 7) |
| Palpitation | 6.8% (n = 5) |
| General impairment | 5.5% (n = 4) |
| Abdominal pain | 4.1% (n = 3) |
| Emesis | 4.1% (n = 3) |
| Dizziness | 2.7% (n = 2) |
| Syncope | 2.7% (n = 2) |
| Unconsciousness | 2.7% (n = 2) |
| General pain | 1.4% (n = 1) |
| Total | 100% (n = 73) |

Increased collapsibility was defined as a volume deficiency or an increased volume requirement. However, decreased collapsibility was defined as increased preload in volume overload, or indicating cardiac malfunction, tamponade, pulmonary thromboembolism, or acute respiratory distress syndrome (ARDS) [8, 9].

In this study, IVC width and collapsibility was estimated visually as normal or abnormal in a qualitative manner and was not measured. It was a limitation and lack in this study according to the limited time and situations, need further studies in relialibility.

For abdominal aorta aneurysm (AAA) and suprapubic view, abdominal aorta was scanned on the superior umbilical line in the transverse plane. AAA is defined when the diameter greater than 3 cm in literature [18, 19]. In this study, scanning was performed to find a significant visual one.

Suprapubic free fluid was evaluated by examining the medial pelvis in the perpendicular axis using a convex probe [19].

POCEUS on arrest patient was performed only while < 10 seconds of rythm-control intervals not to inhibit or retard the advanced life support guidelines by interrupting chest compressions. This was a protocol ruled for the study.

The last diagnosis in hospitalization is formed a combination of whole traditional reported results

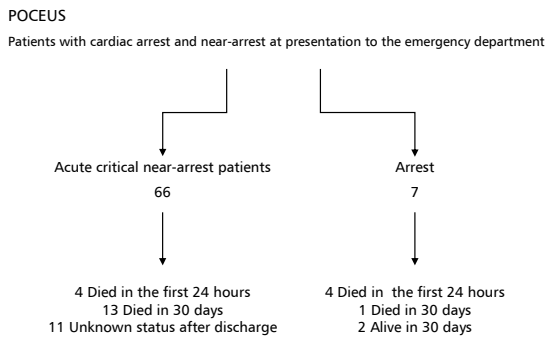



**FIGURE 1.** The patient flow

of all examinations including of X-ray, echocardiography, computed tomography, and other examinations, planned by other physicians, consultants. Only the decision in diagnosis of them who hospitalized the patient were studied prospectively from the records of patients.

Statistical analyses were performed with SPSS 17.0 statistical analysis software (SPSS Inc., Chicago, IL, USA). Categorical data are presented as number and percentage, and continuous data are presented as mean and standard deviation. Relations were evaluated with the inter-rater correlation method, and statistical differences were tested with the McNemar test. Good agreement between the POCEUS and the clinical diagnosis was defined as a p value of $< 0.05$ using the McNemar test and a kappa correlation coefficient of $> 0.70$.

## RESULTS

In total, 73 patients were evaluated.

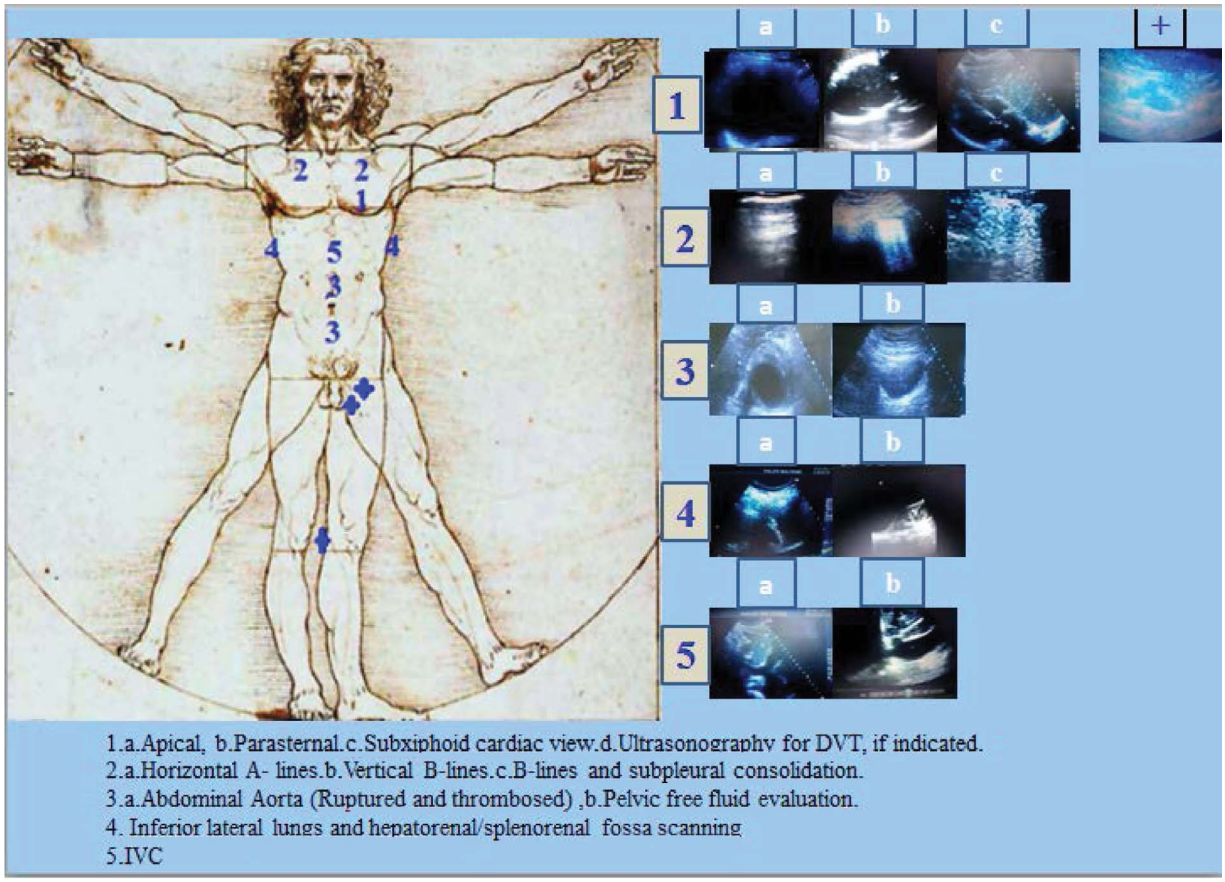
Four patients were excluded according to the exclusion criteria (Gastrointestinal hemorrhage began after the first evaluation at ED in 1 patient, a cerebral event was confirmed without any lateralization at presentation in one patient, and incomplete data forms were obtained for two patients.

The patients' demographic data (age and sex) and presenting complaint/condition are shown in Table 2.

Figure 1 shows the patient flow.

Figure 2 demonstrates the places of a probe used in the study and the sample of the ultrasound views.

Comparison of the emergency ultrasound interpretation versus blind traditional clinical diagnoses during hospitalization revealed a kappa correlation coefficient of 0.773 (95% CI, 0.747–0.892; p = 0.064, McNemar test) (Tab. 3).




*Respectfully to Leonardo Da Vinci for science and art in Vitrivius*

**FIGURE 2.** Demonstrates the places of a probe used in the study and the sample of the ultrasound views

Figure 3 compared the prediction of differential diagnosis by POCEUS at presentation to the last diagnosis on hospitalization on a chart.

## DISCUSSION

Differential diagnosis in emergency patients presenting to the ED with cardiac arrest or near-arrest is a complex problem to be solved within limited time. Physical examination alone ensures neither an accurate preliminary prediction of the clinical problem nor optimal treatment of the patient's condition. X-ray examination is generally insufficient in the interpretation of findings and cannot demonstrate additive systematic clues [16]. Computed tomography is not the first diagnostic option in the management of these patients, just suitable after the patient's vital signs have been stabilized and thus controlled.

POCEUS is used by EPs only to answer the essential questions and prioritizing the treatment. Algorithms manage this process in a shorter time and provide real-time findings based on confirmation or exclusion [7–9].

Clattenburg reported a CPR pauses with POCUS performed lasted a mean 19.3 s with versus a mean 14.2 s without it. It was longer of 6.1 s by the same physician both active in resuscitation and POCUS. While there was not any association between ROSC, the number of CPR pauses or POCUS duration [20]. Ideally, it should be performed by another EP independently, unfortunately, there was not a time counter used alone in our study. This could be controlled and prevented by another commissioned staff in CPR.

Some studies have described algorithms for arrest, shock, and respiratory failure [4, 5, 10–12, 16, 21–22]. The Fluid Administration Limited by Lung Sonography (FALLS) protocol has been used to identify circulatory collapse, using cardiac and lung ultrasonography [4]. In addition to the FALLS protocol, fluid management is essential in patient care. In the SESAME protocol, 1. Anterior lungs for pneumothorax, 2. DVT for pulmonary embolus, or 3. Abdomen for hypovolemia were evaluated.

**Table 3. Comparison of POCEUS diagnosis at presentation with last clinical diagnosis during hospitalization**

| Diagnosis | POCEUS prediction/ The last diagnosis in hospitalization (n/n) | Kappa coefficient (95% CI), p |
|---|---|---|
| Systolic heart failure<br>Depressed global cardiac contraction | 16/15 | 0.877 (95% CI, 0.812–0.921), 1 |
| Pulmonary edema<br>1) Systolic heart failure and pulmonary edema<br>Depressed cardiac contractiliy + ≥ 3 common B-lines + IVC collapsibility of < 50%, qualitative diameter normal or dilated<br>2) Non-cardiac pulmonary edema<br>Normal/hyperkinetic cardiac contractiliy + ≥ 3 common B lines + IVC collapsibility of < 50% or ≥ 50% , qualitative diameter narrow, normal or dilated | 5/8 | 0.748 (95% CI, 0.637–0.839), 0.25 |
| | 12/10 | 0.893 (95% CI, 0.839–0.933), 0.50 |
| Pulmonary thrombus<br>Dilated right ventricle, D-shaped left ventricle, McConnell's sign, ± DVT | 6/5 | 0.706 (95% CI, 0.569–0.805), 1 |
| Distributive/septic/ hypovolemic shock<br>Hyperkinetic/normal cardiac function ± small left ventricle + IVC collapsibility of > 50% | 12/13 | 0.759 (95% CI, 0.642–0.842), 1 |
| Tamponade or pericardial effusion<br>Incomplete right ventricle diastole + pericardial effusion | 4/5 | 0.786 (95% CI, 0.678–0.860), 1 |
| Pneumonia<br>Consolidation/local, ≥ 3 one-sided B-lines/pleural effusion | 31/22 | 0.682 (95% CI, 0.564–0.802), 0.012 |
| Pneumothorax<br>No pleural sliding, no B-lines | 2/2 | 0.486 (95% CI, 0.289–0.643), 1 |
| Chronic lung diseases<br>Common A-pattern<br>Normal cardiac contractility and IVC collapsibility | 7/10 | 0.537 (95% CI, 0.356–0.684), 0.453 |

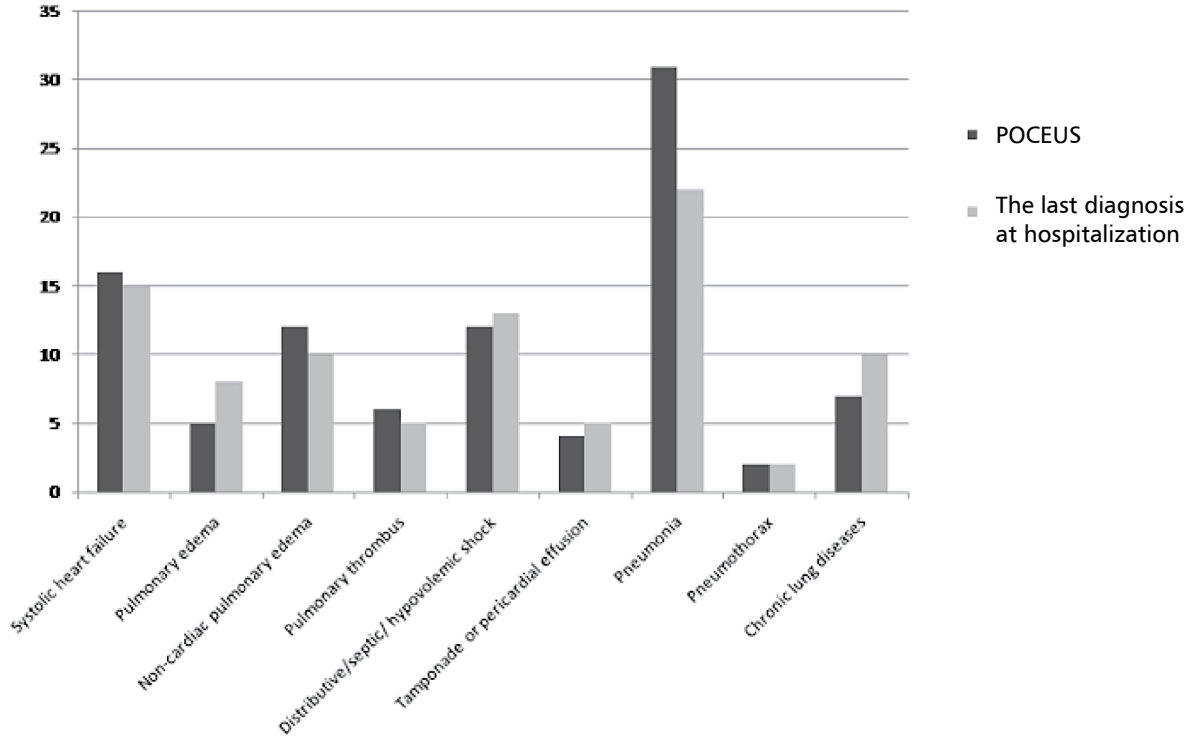



**FIGURE 3.** Compared the prediction of differential diagnosis by POCEUS at presentation to the last diagnosis on hospitalization on a chart

If a B-profile is present, differentiation between ARDS and a cardiac etiology is required. The cardiac view for pericard is suggested in the last step [11]. However, the cardiac view was the first step in our study in accordance with life support guidelines [22, 23].

In the study of Volpicelli et al., incorporation of a lung examination in multiorgan ultrasonographic protocol was decisive for a definite diagnosis in 24 cases (22%) in undifferentiated hypotension patients in ED. An ultrasound definite diagnosis was reached in the majority of patients, excluding only 7 patients out of 108 enrolled [5].

In another study included patients with cardiac arrest and undifferentiated hypotension, as well as cardiac contraction, valvular, pericardial, IVC, pleural, and abdominal abnormalities were identified with POCUS [21] Only for 2 patients of cardiac arrest cases were not obtained any initial specific ultrasonographic clue by POCEUS. Aortic dissection, aortic aneurysm rupture, and ileus were the other diagnoses obtained by POCEUS and were compatible with the findings in the literature [24, 26].

The BLUE protocol was created as a diagnostic protocol for critically ill patients with acute respiratory failure by Lichtenstein, finalized to diagnose all the main causes, that are, cardiogenic edema, pneumonia, pulmonary embolism, exacerbation of COPD/asthma, pneumothorax [4, 11, 12]. Another study revealed that multiple B-lines on at least two scans per side were present in patients with a diffuse interstitial syndrome called the 'B pattern' by Volpicelli. This condition was explained with relation to cardiogenic pulmonary congestion or ARDS but was also present in pulmonary fibrosis, interstitial or multiple bilateral pneumonia, and tuberculosis miliarisis [16]. In a study, the sensitivity and specificity of lung ultrasound for pneumonia were 0.985 and 0.649, respectively [27]. In the present study, 31 patients were interpreted (42.5%) as pneumonia by POCEUS; As EPs were interpreted consolidation or local B-pattern as only pneumonia for the first possibility without considering other reasons. Only 22 (71%) of these had a diagnosis of pneumonia in the patients' final clinical records at hospitalization. However, not all patients had undergone computed tomography for confirmation or exclusion. In another one detected pulmonary consolidation by lung ultrasonography in 30 patients, 18 patients also showed air bronchograms [5], while it was not studied in our cases.

Six patients were interpreted as pulmonary embolism, however, five were confirmed to have pulmonary embolism based on pulmonary angiography computed tomography (PACT). One of 5 patients had an uncompressible main femoral vein with a thrombus image. The misdiagnosed one had interstitial lung disease, reported on PACT.

As another POCEUS algorithm indicator, the IVC is used to estimate the patient's volume status and preload by only the qualitative estimation of collapsibility because of the limited time. In patients with pericardial tamponade, massive pulmonary embolus, and cardiac failure, the IVC collapsibility decreases and the expiration diameter increases along with an increased preload pressure and duration without intubation [16]. On the other hand, pulmonary embolism (PE) with a pulmonary A pattern and without IVC congestion has been reported [5].

In our study, 2 cases were unexplained in non-arrest group, they were finalized as acute renal failure and diastolic failure.

Limitations were that the diameter of IVC was not measured. Qualitative manner needs to be proven in further studies for reliability. The diameter of right ventricle on suspected of dilatation was not measured. The abdominal aorta was not measured. There was not a plan to identify bronchograms. There were no video recordings studied in all along with the patient management. There was only one performer in each center participated voluntarily in this study.

Near-arrest was a clinical situation intuitive decided with inspection foresight of the patient by physician.

Three or more B-lines in two zones of each lung with normal cardiac contraction could be present in both pulmonary edema caused in diastolic failure and other etiologies besides ARDS. Diastolic failure parameters were not studied.

## CONCLUSION

POCEUS is an applicable method performed in ED. The first interpretation of findings at presentation had a relation within the last diagnosis obtained during hospitalization. Development of evidence-based algorithms including unexplained cases would enlighten and contribute in the first emergency differential diagnosis and ensure the survival of patients.

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## Statement of competing interests

There are no competing interests including financial or others that may have affected the research or the conclusions drawn from the study.

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