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Short communication

Anterior vs lateral symmetric interstitial syndrome in the diagnosis of acute heart failure

Alfonso Sforza [a], Maria Viviana Carlino [a], Mario Guarino [a], Giuseppe Romano [b], Fiorella Paladino [c], Giovanni de Simone [d,*], Costantino Mancusi [d]

[a] Emergency Department, CTO Hospital, Naples, Italy
[b] Emergency Department, Bufalini Hospital, Cesena, Italy
[c] Emergency Department, Cardarelli Hospital, Naples, Italy
[d] Hypertension Research Center, Department of Advanced Biomedical Science, Federico II University Hospital, Naples, Italy

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ABSTRACT

Acute dyspnea due to acute heart failure (AHF) is one of the most common reasons for admission to the Emergency Department (ED). The importance of lung ultrasound (LUS) examination in the diagnostic workup of AHF has been widely established. Limited anterior LUS examination for the diagnosis of AHF is controversial. This study compares the accuracy of LUS examination limited to the anterior or lateral lung zones for the diagnosis of AHF and their accuracy among patients with different levels of hypoxemia according to PO_2/FiO_2 ratio evaluation. We analyzed 170 patients admitted to the ED for acute dyspnea, who underwent multi-organ ultrasound examination of lung, heart and inferior vena cava for differential diagnosis. The thorax was examined following a simplified protocol that provides two scans at each side (anterior and lateral) to sample upper and lower lobes and the presence or the absence of interstitial syndrome (IS) was evaluated. The presence of anterior symmetric IS exhibited lower accuracy than lateral symmetric IS in the diagnosis of AHF in the whole population, but its diagnostic accuracy improves in sub-groups of patients with severe and critical hypoxemia.

1. Introduction

Acute heart failure (AHF) is one of the most common reasons for admission to the Emergency Department (ED) and dyspnea is one of its most frequent clinical presentation [1]. For patients with acute respiratory failure, recognition of AHF is sometimes challenging and requires a complete diagnostic workup including history, physical exam, EKG, chest X-ray, laboratory tests and point-of-care ultrasound [2]. The importance of lung and multi-organ ultrasound examination in the diagnosis of AHF has been established [3–5]. In particular bedside lung ultrasound (LUS) is accurate in diagnosing alveolar-interstitial syndrome [6], even though it requires extensive scanning of both hemi-thorax in anterior and lateral chest wall [7]. Due to the importance of speeding up decision making during acute respiratory failure, simplified protocols for LUS examination are desirable. However, limited anterior lung ultrasound examination for the differential diagnosis of acute respiratory failure is controversial [8,9].

The aim of the present study is to compare the accuracy of LUS examination limited to anterior or lateral lung zones for the diagnosis of AHF and to compare their accuracy among patients with different levels of hypoxemia.

2. Methods

This study is a post-hoc analysis of two observational studies conducted in the ED of "Antonio Cardarelli" hospital in Naples (Italy) from January to April 2017 [10] and in the ED of "Maurizio Bufalini" hospital in Cesena (Italy) from November 2014 to August 2015 [4]. 170 patients admitted to the ED for acute dyspnea or sudden worsening of chronic dyspnea within the previous 48 h were evaluated to test the accuracy of multi-organ ultrasound examination for the diagnosis of dyspnea of cardiac origin. Patients underwent clinical exam, blood gas analysis, chest X-ray, EKG, routine blood tests. Informed consent was obtained from each patient included in the study.

All patients underwent integrated ultrasound examination of lung-heart-inferior vena cava with a pocket ultrasound device (Vscan of General Electric Healthcare) with a single probe (1.7–3.8 MHz), using abdominal preset for lung ultrasound and cardiac preset for heart and inferior vena cava evaluation. All video clips were stored digitally. Integrated ultrasound examination was performed with the patient in semi sitting or supine position by an emergency physician expert in trans-thoracic echocardiography and with good experience of LUS, who was not taking care of the patient. The duration of integrated ultrasound examination was always <3 min (30 s at most for LUS alone) and it was done within 30 min from the arrival of the patients in the ED. The thorax was examined following a simplified protocol that provides two scans at each side, anteriorly on the II intercostal space, mid-clavicular line, and lateral on the V intercostal space, mid-axillary line, to sample upper and lower lung.

* Corresponding author at: Department of Advanced Biomedical Science, Federico II University Hospital, Via Pansini 5, 80131 Naples, Italy.
E-mail address: simogi@unina.it (G. de Simone).

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The presence or the absence of interstitial syndrome (IS, defined as presence of at least 3 B lines for lung field) and the presence or the absence of pleural effusion (defined as hypo-anechoic space between the parietal and visceral pleura) was evaluated (Fig. 1) [11]. Positive anterior LUS was defined by the presence of IS and/or effusion bilaterally on the 2nd intercostal space. Positive lateral LUS was defined by the presence of IS and/or effusion bilaterally on the 5th intercostal space. Based on review of entire medical records, patients were classified into two groups: AHF or non AHF according to current guidelines [12].

As a measure of severity of hypoxia, we calculated P/F as the ratio between arterial partial pressure of oxygen by blood gas analysis (in mmHg) and fraction of inspired oxygen expressed.

2.1. Statistical analysis

Data were analyzed using SPSS version 21.0 (SPSS, Chicago, Illinois, USA). Continuous data are expressed as mean ± 1 standard deviation and categorical variables as percentages. Quantitative variables were compared by using Student's *t*-test while χ^2 distribution was used to compare categorical variables. The performance of anterior and lateral symmetrical IS and/or effusion in addressing the diagnosis of AHF was analyzed and comparisons were made among them, using sensitivity, specificity, positive predictive value, negative predictive value and the accuracy defined by the proportion of true results. Confidence intervals (CI) at 95% were calculated for sensitivity, specificity, positive predictive value and negative predictive value. Areas under (AUC) receiver operating characteristic (ROC) curves were used to compare the accuracy of combined lateral and anterior LUS, anterior LUS and lateral LUS alone for the final diagnosis of AHF using DeLong method [13]. The accuracy of anterior and lateral LUS was also evaluated in two sub-groups of patients with severe and critical hypoxemia defined as a PO_2/FiO_2 (P/F) ratio below 200 and 150 respectively.

A *p*-value <0.05 was considered statistical significant.

3. Results

According to the adjudicated diagnosis, 64 patients (38%) had AHF and 106 patients (62%) had non-AHF (Table 1).

Patients with AHF had higher systolic blood pressure and creatinine levels than patients with non-AHF (Table 1, all $p < 0.05$). In contrast, patients with non-AHF had higher white blood cell count and lower oxygen saturation than those with AHF (Table 2, all $p < 0.05$).

Performance of combined lateral and anterior LUS was identical to that of lateral LUS alone (AUC 0.91 for both methods).

Table 3 shows the performance of lateral and anterior LUS in the diagnosis of AHF in the total study population. Positive lateral LUS exhibited excellent sensitivity, good specificity and accuracy for the diagnosis of AHF, while anterior LUS, despite similar specificity, was less accurate in the identification of AHF than lateral LUS (Fig. 2, $p < 0.0001$). Figs. 3 and 4 show performance of lateral and anterior LUS for the diagnosis of AHF in subgroups of patients with severe ($n = 41$) and critical ($n = 18$) hypoxemia respectively. Accuracy of anterior LUS in the diagnosis of AHF progressively increase with worsening of hypoxemia, becoming comparable with lateral LUS ($p = 0.16$ for P/F ≤ 200 and $p = 0.57$ for P/F ≤ 150).

Table 1
Baseline characteristics and clinical findings detected at the time of patient presentation in the emergency department.

	Acute heart failure (AHF) ($n = 64$)	Non-acute heart failure (non-AHF) ($n = 106$)	*p*-Value
Age (years)	75.8 ± 11.1	73.5 ± 13.3	0.21
Women (%)	44	41	0.68
Medical history of chronic obstructive pulmonary disease (%)	23	49	0.001
Medical history of heart failure and/or ischemic heart disease (%)	41	18	0.01
Heart rate (bpm)	90.5 ± 25.5	94.2 ± 21.4	0.62
Systolic BP (mmHg)	141.2 ± 30.7	132.8 ± 22.2	0.01
Diastolic BP (mmHg)	79.7 ± 15.6	73.7 ± 12.7	0.09
Serum creatinine (mg/dL)	1.6 ± 1.7	1.1 ± 0.5	0.000
White blood cell count ($\times 10^3$/μL)	9.5 ± 4.5	11.9 ± 6.1	0.002
Oxygen saturation (%)	91.8 ± 5.0	89.8 ± 9.0	0.005
PaO_2/FiO_2	276.2 ± 88.7	250.4 ± 85.5	0.84
pH	7.42 ± 0.09	7.41 ± 0.09	0.67
Lactate level (mmol/L)	1.94 ± 2.19	1.68 ± 1.13	0.09
NT-pro BNP (pg/dl)	9350 ± 11,450	2984 ± 7034	0.007
Ejection fraction (%)	42 ± 14	57 ± 8	0.0001
Dilated left atrium (%)	87	25	0.0001

BP: blood pressure.

4. Discussion

Our study demonstrates that the accuracy of anterior and lateral LUS in diagnosing AHF differs significantly among patients presenting to the ED with acute dyspnea. Scanning both anterior and lateral zones can help to identify virtually all cases of AHF. Limited scanning to the anterior lung zones is accurate in diagnosing AHF in a sub-setting of patients presenting with severe/critical hypoxemia.

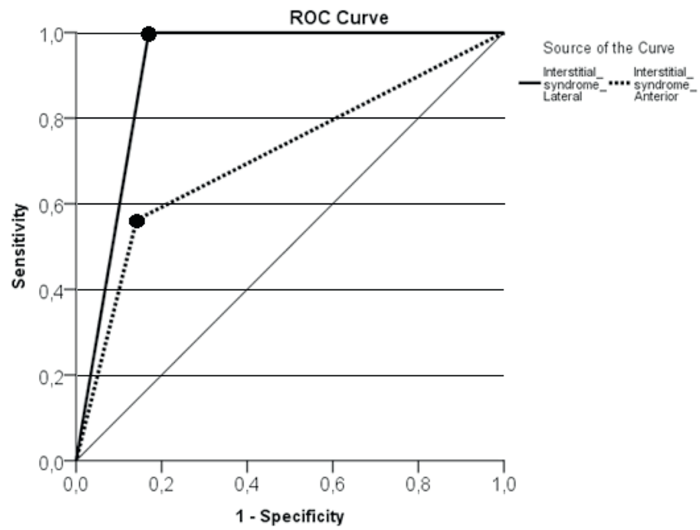
AHF is defined as gradual or rapid change in heart failure signs and symptoms resulting in a need for urgent therapy. These symptoms are primarily the result of pulmonary congestion due to elevated left ventricular filling pressures with or without reduced left ventricular systolic function [14]. The acute elevation of pulmonary wedge pressure finally results in interstitial and alveolar edema [1]. The LUS visualization of vertical reverberation artifacts, the B-lines, is diagnostic of this IS, as the expression of high impedance discontinuities due to the close apposition between alveolar air and the increased interstitial fluids [15]. Thus, LUS represents a valid tool to estimate pulmonary extra-vascular lung water [16]. In our study the presence of a symmetrical IS/effusion in the lateral fields has very high sensitivity and positive predictive value and excellent accuracy for the diagnosis of AHF in the total study population, while anterior LUS positivity shows less accuracy for the diagnosis of AHF because of poor sensitivity. This finding supports the idea that, during AHF, congestion and edema follow a gravitational pattern initially involving the inferior lobes [17]. Considering that our method of lung scanning on the V inter-costal space, mid-axillary line, allows to sample lower lobes [18], ultrasound examination of the lateral chest areas seems to be mandatory to diagnose the majority of the cases of AHF.

Others found the anterior LUS was diagnostic. Lichtenstein and colleagues demonstrated that symmetrical anterior IS/effusion was present in 97% of their patients with acute respiratory failure due to AHF [8]. This finding is probably due to the critical clinical conditions of these patients requiring admission in intensive care unit because of severe respiratory impairment [19]. Recently Russel and colleagues suggested that a simplified protocol (using only anterior lung examination + cardiac focus ultrasound) is useful and time saving in ED to identify AHF among dyspneic patients [20]. Even in this case, the clinical conditions of the admitted patients can explain the difference from our findings.

In sub-groups of patients with severe and critical hypoxemia (P/F ≤ 200 and 150 respectively), the accuracy of anterior symmetrical IS/effusion dramatically improves correct identification of AHF, by sharply improving sensitivity and negative predictive value making our finding comparable with those quoted above. Our findings suggest that anterior B lines are present in acute pulmonary edema with severe hypoxemia when both lower and upper lobes are involved in the alveolar/interstitial syndrome. However, it should be underlined that lateral LUS is inclusive also of these patients with very severe hypoxemia and, therefore, we think that should be put first in a point of care ultrasound protocol.

5. Conclusion

Diagnostic accuracy of lateral LUS for diagnosis of AHF is excellent independently of hypoxemia. In contrast, LUS limited to anterior lung zones exhibits suboptimal accuracy except in patients with severe/critical hypoxemia.



Test Result Variable(s)	AUC	Std. Error	Asymptotic 95% Confidence Interval Lower	Asymptotic 95% Confidence Interval Upper	p
Lateral LUS positive	0.915	0.023	0.871	0.959	
Anterior LUS positive	0.710	0.043	0.626	0.795	0.0001

Fig. 2. ROC curve analysis for the diagnosis of AHF using lateral or anterior LUS positivity in the total study population.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2019.01.013.

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