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Role of lung ultrasound in ICU shocked patients

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Abstract

Introduction: Shock is one of the most frequent concerns and challenges of the intensivist. Lung ultrasound-generated artifacts can be helpful. Lung ultrasound (LUS) is suggested for the management of shock, mainly using lung ultrasound. LUS has the advantages of being safe, non-invasive, rapidly available, and inexpensive.

Aim of the study: Assessment of the role of lung ultrasound in discriminating types of shock in patients admitted to the ICU.

Subjects and Methods: Eighty participants were included in this study. Lung ultrasonography and bedside echocardiography were applied to all patients.

Results: Thirty-two patients who presented with septic shock had an A profile in all of them and an AB profile in six of them, which after fluid therapy transformed to a B profile with 100% sensitivity, 90.5% specificity, 90.5% PPV, and 100% NPV. Thirty hypovolemic shocked patients had a profile when presented to us and after fluid therapy with 100% sensitivity, 94.1% specificity, 88.9% PPV, and 100% NPV. Twelve patients with cardiogenic shock had a B-profile when presented to us, with 100% sensitivity, 95.2% specificity, 80% PPV, and 100% NPV. Four patients with obstructive shock had the same profile when presented to us: 100% sensitivity, 25.5% specificity, 7.9% PPV, and 100% NPV. Two patients with anaphylactic shock had an A profile in all of them when they were presented to us and transformed to a B profile after fluid therapy with 100% sensitivity, 50% specificity, 9.5% PPV, and 100% NPV.

Conclusion: Lung ultrasonography has the privilege of being a dependable, non-invasive, and uncomplicated method with a fast-learning curve that can be used for the discrimination and management of distinctive types of shock. Critical care physicians should greatly consider integrating bedside chest ultrasound into resuscitation pathways, with a possible significant impact on patient diagnosis and management.

1. Introduction

In critical care units, fluids are used to maximize organ perfusion, make up for fluid losses, avoid fluid deficiency, and avoid giving medication, antibiotics, or nutrition. However, when in excess, fluids may induce organ dysfunction, prolong the length of an intensive care unit (ICU) stay, and decrease survival [1].

Recently, LUS has emerged as a new tool to assess overhydration and has been successfully used in patients from various departments [2].

The assessment of shock is a challenge in the absence of a solid gold standard. It is supposed that lung ultrasound can be helpful. Lung ultrasound is a tool proposed for the management of unexplained shock, mainly using lung ultrasound [3].

Lung ultrasound (LUS) may provide a threshold to administer fluid therapy and to optimize volume status [4]. The ultrasonography signs of increased extravascular lung water (EVLW) and overhydration are the artifacts called B-lines. B-lines are hyperechoic, comet-tail artifacts that arise from the level of the pleural line and move simultaneously with lung sliding [5]. A few prospective studies have also used LUS as a prognostic tool in critically ill patients [6].

The current study aimed to assess the role of lung ultrasound in discriminating types of shock in patients admitted to the ICU.

2. Subjects and methods

2.1. Subjects

Our study was conducted to assess the role of lung ultrasound in differentiating types of shock in critically ill patients. The study was conducted in the medical intensive care unit of Fayoum University Hospital. We aimed to enroll 80 adult ICU patients in our study. Close relatives of the patients were required to provide written informed consent. Patients were included in this study if they were expected to stay at least 48 hours in the ICU.

Exclusion criteria

That included patient's refusal, age (18), chest trauma, and post-CPR patients.

2.2. Methods

Our study group patients were subjected to baseline data and meticulous history collection, a full clinical examination, vital sign evaluation, severity score (APACHE II) assessment, and a complete set of routine laboratory tests.

Then, after all the previous points had been accomplished, patients were subjected to the following measures:

Electrocardiogram (ECG).

Echocardiography

Bedside simple cardiac sonography was applied, evaluating mainly the following: cardiac contractility, right side dilatation, and presence of cardiac tamponade.

Lung ultrasound (LUS)

LUS examinations were performed at bedside with the patient in a supine position, using the Philips HD11XE ultrasound system with the convex probe (2.0–5.0 MHz frequency).

Ultrasonography was applied by scanning the lungs from the second to the fourth intercostal space on the left side, and from the second to the fifth intercostal space on the right side at the parasternal, mid-clavicular, anterior-axillary, and mid-axillary lines.

The following order was followed to apply the lung sonography by scanning the following:

Pericardium

The pericardium was first scanned. No substantial pericardial effusion (it would be here, in a shocked patient, the equivalent of tamponade).

Right ventricle

We then scanned the right ventricle (RV) volume. If there is no RV dilatation, the diagnosis of pulmonary embolism, or any disease generating such a disorder, e.g., pulmonary hypertension, can be ruled out.

Lung to rule out pneumothorax

Then the universal probe was shifted laterally for checking the absence of pneumothorax.

No pericardial tamponade, pulmonary embolism, or pneumothorax. An obstructive shock was likely not the cause of this circulatory failure.

Lungs to look for B-lines

We scanned the lung again, searching for lung rockets (B-lines). If absent, we ruled out hemodynamic pulmonary edema. Therefore, left cardiogenic shock was reasonably ruled out. At this step, the A-profile of pneumothorax and the B-profile of cardiogenic shock have been excluded. Now that obstructive and cardiogenic shock have been ruled out, we considered that both of the only remaining causes (hypovolemic and distributive) require fluids. At this step, a patient with an A-profile can, and mostly should, benefit from fluids.

Fluid therapy

These patients were "fluid responders". The therapeutic part of the LUS could begin. The fluid therapy (30 ml/Kg) should improve the clinical signs of a hypovolemic shock; this is how this diagnosis was done using the Lung ultrasound. If no clinical sign of shock improved, there was no clinical signal for discontinuing the fluid therapy. If fluids began to saturate the lung interstitial compartment, lung rockets (B-lines) would appear.

They would appear all of a sudden. This was the LUS-endpoint, time to discontinue the fluid therapy. If the patient saturated the interstitial compartment of the lung without improving the circulatory status, the diagnosis of hypovolemic shock can just be ruled out. The last remaining cause, distributive shock, should be, by default, considered.

Spinal shock is rarely an issue, anaphylactic shock also occurs in suggestive settings, usually. What remains then, but septic shock? Schematically, in the sequence of the Lung ultrasound protocol, septic shock was defined by the transformation from A-lines to B-lines. At this step, other tools than simple fluid should be used for improving the circulation, mainly vasopressors.

2.3. Statistical analysis

The study was performed using IBM SPSS 26, and a *P-value* of 0.05 or lower was regarded as statistically significant.

3. Results

Our study was conducted in the medical ICU of Fayoum University Hospital from January 2020 to September 2021, and 80 patients who presented with shock were enrolled in this study. The age of patients in our study was 53.7±19.2 years, with 48 (60%) males compared to 32 (40%) female patients.

Hypertension (HTN) and diabetes (DM) were reported in 18 (22.5%) and 20 (or 25%) patients, respectively, and 24 (30%) of them were smokers. There was a statistically significant difference regarding HTN, DM, and smoking among the study population ($P<0.05$) (Table 1). Also, the vital signs revealed that the mean systolic blood pressure (SBP) was 72.2±8 mmHg, the diastolic blood pressure (DBP) was 37.4±8.1 mmHg, the mean arterial pressure (MAP) was 48.98±8.08 mmHg, the mean heart rate (HR) was 118±23.1 pulse/min., the mean Respiratory rate (RR) was 28.7±7.4 breaths/ min., the mean Temperature was 37.6±0.7°C, and the mean Central venous pressure (CVP) was 5.7±8.3 (Table 1). Regarding the echocardiographic findings, the mean ejection fraction (EF) was 57.4±12.1 %, where the mean pulmonary artery systolic pressure (PASP) was 32.4±13.5 mmHg. The blood analysis of the Arterial blood gases was shown in Table 1, as well.

Table 1: Demographic and clinical data of the study group.

Variables		**Values**	**Range**	***P-value***
Age (years)		53.7 ± 19.2	19-90	
Sex	Female	32 (40%)		
	Male	48 (60%)		
Risk factors				
HTN	Yes	18 (22.5%)		<0.05*
	No	62 (77.5%)		
DM	Yes	20 (25%)		<0.05*
	No	60 (75%)		
Smoking	Yes	24 (30%)		<0.05*
	No	56 (70%)		
Vital signs				
SBP		72.2±8	60-80	
DBP		37.4±8.1	30-50	
HR		118±23.1	55-170	
RR		28.7±7.4	16-45	
Temperature		37.6±0.7	36.6-39.5	
CVP		5.7±8.3	-6-25	
MAP		48.98±8.08	40.9-57.06	
Echocardiographic findings				
EF%		57.4±12.1	21-71	
PASP (mmHg)		32.4±13.5	18-88	
ABG (arterial blood gases)				
PH		7.3±0.2	6.8-7.6	
PCO2		32.1±11.2	12-81	
HCO3		13.9±5	3-20	
Lactate		14.5±9.5	5-24	

*Significant.

In the current study the lung rockets (B-lines) were investigated by detecting of the A- and B- profiles (Figure 1). The results revealed that A-profile was found in 76 (76%) and 32 (32%) of patients before and after resuscitation, respectively. B-profile was found in 20 (20%) and 42 (42%) of patients before and after resuscitation, respectively. AB-profile was found in 6 (22%) patients before and after resuscitation. Finally, C-profile was found in 4 (4%) patients before and after resuscitation (Table 2).

Table 2: LUS findings.

Variables		N	%
Before fluid resuscitation	A profile	76	76.0%
	B profile	20	20.0%
	AB profile	6	6.0%
	C profile	4	4.0%
After fluid resuscitation	A profile	32	32.0%
	B profile	42	42.0%
	AB profile	6	6.0%
	C profile	4	4.0%

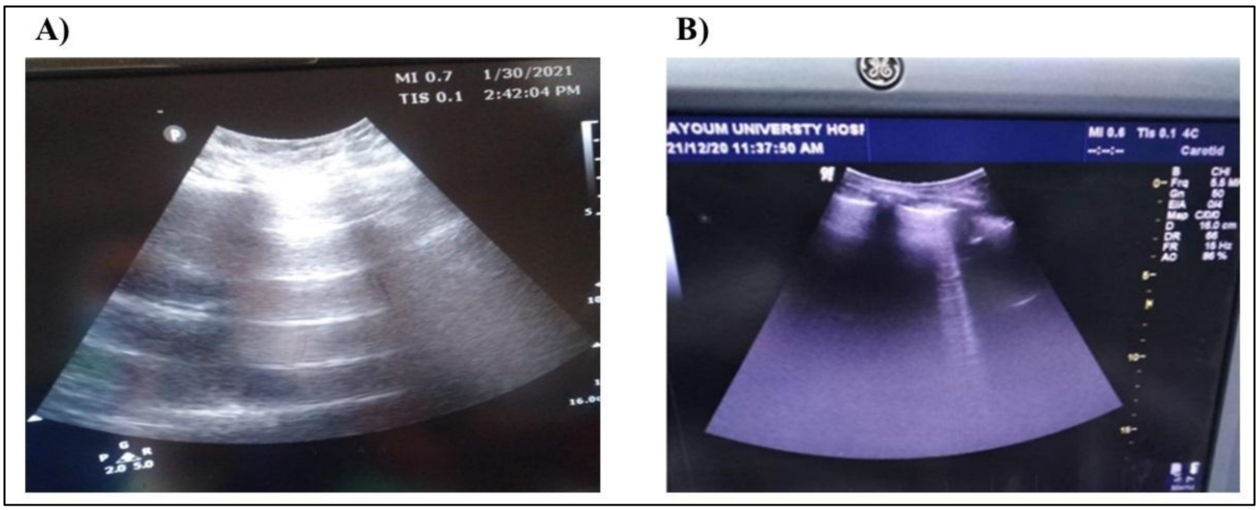

Figure 1: Example of the LUS findings. A) A-profile, B) B-profile.

Before resuscitation, it was found that there were 12 patients (15%) in cardiogenic shock, 4 patients (5%) in obstructive shock, and 64 patients (80%) in other types of shock. After resuscitation, it was found that there were 32 patients (40%) in septic shock, 30 patients (37.5%) in hypovolemic shock, 12 patients (15%) in cardiogenic shock, 4 patients (5%) in obstructive shock, and 2 patients (2.5%) in anaphylactic shock. as shown in table 3.

Table 3: Type of shock according to primitive diagnosis by LUS.

Variables		N	%
Preliminary Type of shock with LUS	Cardiogenic	12	15.0%
	Obstructive	4	5.0%
	Others	64	80.0%
After fluid resuscitation (last diagnosis)	Septic	32	40.0%
	Hypovolemic	30	37.5%
	Cardiogenic	12	15.0%

Obstructive	4	5.0%
Distributive(anaphylactic)	2	2.5%

It was found that there were 32 patients (40%) with septic shock, 30 patients (37.5%) with hypovolemic shock, 10 patients (12.5%) with cardiogenic shock, 4 patients (5%) with obstructive shock, 2 patients (2.5%) with anaphylactic shock, and 2 patients (2.5%) with mixed septic and cardiogenic shock.

In 32 patients diagnosed with septic shock, an A-profile was found in all of them with 100% sensitivity, 32.3% specificity, 47.5% PPV, and 100% NPV. An AB-profile was found in six of them with 15.8% sensitivity, 100% specificity, 100% PPV, and 66% NPV. In 30 patients diagnosed with hypovolemic shock, an A-profile was found in all of them: 100% sensitivity, 35.3% specificity, 42.1% PPV, and 100% NPV. A C-profile was found in two patients with 6.3% sensitivity, 97.1% specificity, 50% PPV, and 68.8% NP. In ten patients diagnosed with cardiogenic shock, B-profiles were found in all of them, with 100% sensitivity, 95.2% specificity, 80% PPV, and 100% NPV. In four patients diagnosed with obstructive shock, an A-profile was found in all of them with 100% sensitivity, 25.5% specificity, 7.9% PPV, and 100% NPV. In two patients diagnosed with anaphylactic shock, an A-profile was found in all of them, with 100% sensitivity, 25% specificity, 5.3% PPV, and 100% NPV. Finally, in two patients diagnosed with mixed septic and cardiogenic shock, a B-profile was found in all of them with 100% sensitivity, 83.3% specificity, 20% PPV, and 100% NPV, whereas a C-profile was discovered in one of them, with 50% sensitivity, 97.9% specificity, 50% PPV, and 97.9% NPV (Table 4).

Table 4: Validity of different lung US profile before resuscitation according to final diagnosis in predicting type of shock.

Variables		**N**	**%**	**Sensitivity %**	**Specificity %**	**PPV %**	**NPV %**
Septic	A profile	32	100.0%	100.0	32.3	47.5	100.0
	AB profile	6	15.8%	15.8	100.0	100.0	66.0
Hypovolemic	A profile	30	100.0%	100.0	35.3	42.1	100.0
	C profile	2	6.3%	6.3	97.1	50.0	68.8
Cardiogenic	B profile	10	100.0%	100.0	95.2	80.0	100.0
Obstructive	A profile	4	100.0%	100.0	25.5	7.9	100.0
Distributive (anaphylactic)	A profile	2	100.0%	100.0	25.0	5.3	100.0
Septic and cardiogenic	B profile	2	100.0%	100.0	83.3	20.0	100.0
	C profile	1	50.0%	50.0	97.9	50.0	97.9

Regarding the relationship between different LUS profiles after resuscitation and types of shock, in 32 patients diagnosed with septic shock, a B-profile was found in all of them with 100% sensitivity, 90.5% specificity, 90.5% PPV, and 100% NPV, and an AB-profile was found in six of them with 15.8% sensitivity, 100% specificity, 100% PPV, and 66% NPV. In 30 patients diagnosed with hypovolemic shock, an A-profile was found in all of them with 100% sensitivity, 94.1% specificity, 88.9% PPV, and 100% NPV; a C-profile was found in two of them with 6.3% sensitivity, 97.1% specificity, 50% PPV, and 68.8% NPV. In two patients diagnosed with anaphylactic shock, a B-profile was found in all of them with 100% sensitivity, 50% specificity, 9.5% PPV, and 100% NPV (Table 5).

Table 5: Validity of different lung US profile after resuscitation in predicting type of shock.

Variables		N	%	Sensitivity %	Specificity %	PPV %	NPV %
Septic shock	B profile	32	100.0%	100.0	90.5	90.5	100.0
	AB	6	15.8%	15.8%	100.0	100.0	66.0
Hypovolemic	A profile	30	100.0%	100.0	100.0	100.0	100.0
	C	2	6.3%	6.3%	97.1	50.0	68.8
Distributive (anaphylactic)	B profile	2	100,0%	100.0	50.0	9.5	100.0

4. Discussion

One of the main challenges for the intensivist is undifferentiated shock, accurate identification, and management. The most widely implementable protocols include lung ultrasonography as a core view created by Lichtenstein a few years ago [3].

Our present study was conducted on 80 patients admitted to our medical critical care department who were admitted mainly with undiagnosed circulatory shock. We followed the LUS protocol in a stepwise approach that facilitates rapid, non-invasive differentiation of different types of shock and defines patients who are fluid responders. The diagnosis of shock followed Weil's classification of shock [7].

Firstly, obstructive shock was suspected and excluded in 4 patients by lung ultrasound: an A-profile was found in all of them with 100% sensitivity, 25.5% specificity, 7.9% PPV, and 100% NPV. This was coupled with our last diagnosis, the clinical examination and ECHO findings, showing the crucial role of the lung ultrasound protocol in discounting this type of shock. This agreed with Lichtenstein *et al.*, 2015, who reported that if pericardial effusion, right ventricle dilatation (suggesting pulmonary embolism), and tension pneumothorax are absent, obstructive shock can be excluded, schematically [8].

This disagreed with AbdelAal *et al.*, 2019, who found a normal lung US A-profile in only 2 and a normal C-profile in 3 of the 19 obstructive shock patients included in their work [9].

Then the next step is investigating cardiogenic shock; it was found in 10 patients with a B-profile that was found in all of them, with 100% sensitivity, 95.2% specificity, 80% PPV, and 100% NPV. This agrees with Lichtenstein *et al.*, 2017, who reported that we scan the lung, searching for lung rockets. If absent, we can rule out a hemodynamic pulmonary edema (cardiogenic shock) [10].

The clinical picture and echocardiography finding, mainly the ejection fraction, matched our LUS finding; this was in concordance with Price *et al.*, 2017, report that echocardiography and lung ultrasound can be used to identify insufficient cardiac output and the presence of congestion [11].

On the other hand, a previous study recruited 11 cyanogenic shock patients and they found a normal lung US A-profile in 2 patients, a normal C-profile in 1 patient, and a normal B-profile in 5 patients [9].

Then, according to the followed approach, patients in our study who were neither obstructive nor cardiogenic and remained with an A-profile are called LUS-responders and are to receive fluid therapy while waiting to distinguish between septic and hypovolemic shock, provided clinical improvement of shock parameters or not and a concordant appearance or not of lung artifacts (B-profile). So, in our study group who received fluid therapy we found 30 diagnosed as hypovolemic shock they kept their A-profile without trans-formation to B-profile even though they experienced clinical improvement

Using LUS, a profile was found in all of them with 100% sensitivity, 94.1% specificity, 88.9% PPV, and 100% NPV. And the C profile was found in one of them with 6.3% sensitivity, 97.1% specificity, 50% PPV, and 68.8% NPV. This agreed with Lichtenstein *et al.,* 2015, describing the improvement of clinical signs of circulatory failure with an unchanged A-profile under fluid therapy reasonably defining hypovolemic shock [8].

This disagreed with AbdelAal *et al.*, 2019, who found that of the 4 patients diagnosed with hypovolemic shock included in their study, 1 had an A-profile, 1 had a C-profile, and 1 had a B-profile [9].

On the other hand, we found 34 patients who showed a distinct response to fluid therapy in the form of conversion of the A-profile into the B-profile, citing subclinical interstitial pulmonary edema that alarmed us to pause fluid therapy (LUS-end point) and start adding the convenient vasopressor and focused our diagnosis towards distributive shock, mainly septic shock, which was found in 32 patients in whom LUS profiles were as follows: B-profile: was found in all of them with 100% sensitivity, 90.5% specificity, 90.5% PPV, and 100% NPV. AB profiles were found in 6 of them with 15.8% sensitivity, 100% specificity, 100% PPV, and 66% NPV, and in 2 patients with anaphylactic shock that was easily differentiated from septic shock, whose LUS profiles were found to be as follows: B-profile: was found in all of them with 100% sensitivity, 50% specificity, 9.5% PPV, and 100% NPV.

This conception agreed with Gargani *et al.,* 2007, who reported that interstitial edema is an early and infra-clinical step of pulmonary edema [12].

On the other hand, those findings disagreed with those of AbdelAal *et al.*, 2019, who found that in 30 patients with septic shock combined in their study, only 14 of them expressed a C-profile and 1 showed a normal A-profile [9].

In our present study, there were two patients who were preliminary diagnosed by LUS and the LUS protocol as having isolated cardiogenic shock, but as a last diagnosis, they were diagnosed as having mixed shock, mostly cardiogenic and septic.

Their LUS findings from the start showed a B-profile in both of them with 100% sensitivity, 83.3% specificity, 20% PPV, and 100% NPP. profile in 2 of them with sensitivity 50%, specify 97.9%, PPV 50.0%, and NPP 97.9%. This is in agreement with Lichtenstein *et al.,* 2014, who found that if a B-profile is seen on admission, the LUS protocol cannot be used. The diagnosis is usually cardiogenic shock, but sometimes lung sepsis. The inferior caval vein roughly correlates with volemia [13].

This disagreed with AbdelAal *et al.,* 2019, study, which included two patients with mixed shock showing in their LUS and found the following: One patient showed consolidation, and the other showed no specific finding [9].

Conclusion

These findings show our preference of LUS-protocol in differentiating both hypovolemic and septic shock in directing fluid Yet, we should point to their benefit on certain occasions in combination with the LUS protocol, like we mentioned before in mixed shock.

Ethical considerations: The study was approved by the Faculty of Medicine, Fayoum University Research Ethical Committee.

Patient consent: Approval and consent to participate: In-formed written consent from patients who were invited to participate in the research was obtained.

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Conflicts of Interest: All authors declare no conflict of interest.

Availability of data and materials: The datasets used and/or analyzed during the current study were available from the corresponding author on reasonable request

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