Role of Chest Ultrasound in Early Prediction of Volume Overload in Trauma Patients with Pulmonary Contusions (Cohort Study)

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Abstract

Background: The lungs are frequently injured in blasts, with the edematous phase causing worsening interstitial edema and infiltration within the first 1-2 hours after injury. Point-of-care ultrasound (POCUS) and B-lines can detect fluid accumulation. The study evaluated the effectiveness of POCUS in monitoring fluid resuscitation in chest trauma patients with lung contusions to prevent volume overload.

Aim of the Study: The study aimed to assess the efficacy of ultrasound in predicting volume overload in trauma patients with lung contusions**.**

Patients and Methods: A cohort study included a total of 100 patients with chest trauma with a lung contusion. It was conducted at Assiut and Alexandria Main University Hospitals. After a thorough clinical evaluation and resuscitation, all patients were subjected to POCUS.

Results: 80 (80%) patients improved without manifestations of volume overload (improved group), and 20 (20%) patients showed manifestations of volume overload (non-improved group). The mean B-line score among all patients was 24.16 ± 7.65, with a significantly higher score among the non-improved group (34.50 ± 6.24 vs. 21.58 ± 5.49). Based on volume overload severity, 12 (12%), 67 (67%), and 21 (21%) patients had mild, moderate, and severe volume overload, respectively. At a cut-off point > 27, B-line scoring has 90% sensitivity, 87.5% specificity, and 88% overall accuracy in predicting volume overload in patients with chest trauma, with an area under the curve of 0.928.

Conclusion: Lung ultrasound plays a crucial role in monitoring patients with chest trauma and lung contusions. A B-line score could be utilized to predict volume overload in these patients.

Keywords : lung contusion, point of care ultrasound, B-lines, volume overload.

Introduction:

Pulmonary contusions are the predominant severe injury in thoracic trauma, accounting for 30–75% of chest injury cases [1]. The incidence of pulmonary contusion is approximately 17% in individuals with several injuries and an injury severity score above 15 [2]. Various factors impact the mortality rate of pulmonary contusions, depending on the severity of the contusion and any related injuries [3]. A chest X-ray is crucial in diagnosing serious pulmonary contusions. However, it often underestimates the extent of the contusion and typically lags behind the clinical presentation by 24-48 hours after the injury [4]. Computed tomography (CT) is a highly sensitive diagnostic tool for detecting pulmonary contusions. However, it is time-consuming, unsuitable for hemodynamically unstable patients, and expensive, with a significant risk of radiation exposure [4]. Point-of-care ultrasonography (POCUS) is highly successful in assessing volume status in trauma patients to establish a balance between compensating for fluid loss and ensuring organ perfusion. Detecting extravascular lung water (EVLW) by identifying sonographic artifacts known as B-lines and computing the B-lines score (BLS) can help determine the increase in EVLW. The study is intended to assess the efficacy of lung ultrasonography (LUS) in monitoring fluid levels in individuals with chest trauma [5–7].

Aim of the Study:

The study aimed to assess the efficacy of ultrasound in predicting volume overload in trauma patients with lung contusions.

Methodology

Study Setting and Design:

A prospective cohort study was conducted at the Emergency and Trauma Unit of Assiut University Hospital and Alexandria University Hospital between June 1, 2020, and June 1, 2022.

Participants and Selection Criteria:

Patients who were 18 years old or older and presented to the emergency trauma unit with chest trauma, either penetrating or blunt trauma, were enrolled. Meanwhile, patients with cardiac arrest or who refused to participate were excluded. All patients signed informed consent, and the Assistant Faculty of Medicine approved the study with IRB No. 17101517, Clinical Trails ID: NCT05054270.

Sample Size Calculation:

A total coverage sample technique was applied here, where all patients who met the selection criteria during the study period were eligible for the study. 100 patients were recruited: 70 from Assiut University Hospital and 30 from Alexandria University Hospital.

Procedure: Data Collection:

All patients in the study were subjected to a history evaluation and clinical examination. The recorded data included age, gender, type of trauma, and associated injuries. All patients underwent a primary survey that included an initial assessment of the airway, breathing/ventilation, circulation, and neurological evaluation of traumatized patients. A baseline laboratory evaluation was done, including a coagulation profile. A chest CT was done in all patients where a lung contusion was diagnosed in the presence of Alveolo-Intersitial Syndrome (AIS).

Assessment of Volume Overload:

Volume overload was assessed based on multiple parameters that include:

Vital Signs Assessment:

vital signs remain a useful bedside tool for assessing volume status. When obtaining postural vital signs, we waited two minutes before measuring the supine vital signs and one minute after standing before measuring the upright vital signs. Orthostatic hypotension is a decrease in systolic blood pressure (SBP) of > 20 mmHg after standing from the supine position. Many additional causes beyond volume depletion cause orthostatic hypotension.

Chest Auscultation:

Pulmonary edema with bilateral crackles and rhonchi was suggested. Another finding of the chest examination is dull percussion, which was associated with pleural effusion. Pleural effusions are one of the indicators of an increase in third-space volume.

Fluid Chart for Fluid Balance:

fluid consumption, like crystalloid and colloid intake, blood product usage, and urine output, were also assessed at admission and repeated at 12H and 24H to identify fluid balance and fluid overload. Patients with a positive fluid balance increase their susceptibility to volume overload.

Lung Ultrasound Evaluation:

The patients were assessed at admission after 12 hours and 24 hours of resuscitation in a semi-recumbent posture, except for intubated patients who were supine. Ultrasound scans were performed on six areas on each hemithorax (anterior, lateral, and posterolateral) divided through three longitudinal lines (parasternal line, anterior axillary line, mid-axillary line) and one horizontal line at the nipple level.

A diagnosis of lung contusion was made based on the presence of multiple B-lines (more than three) originating from the pleural line or by the detection of a peripheral parenchymal lesion, which is distinguished by the presence of C-lines, confluent consolidations (hepatization), or parenchymal disruption accompanied by localized pleural effusion.

A number of B-lines < 3 is considered normal, while a B-line number >3 indicates the presence of lung contusions. The sum of all B-lines yields a score, the B-lines Score (BLS), denoting the extent of lung contusion. BLS 0 = number of B-Lines <3; 1 = multiple well-defined B-Lines but number > 3; 2 = multiple coalescent B-Lines (white lung); 3 = lung consolidation (presence of tissue-like pattern). BLS ranges from 0 to 36. BLS 0 =indicates all zones are aerated. BLS 36= indicates all zones are consolidated.

Follow-up:

All enrolled patients were followed up clinically and radiologically during the study period if further investigations were recommended. After 12 hours and 24 hours of resuscitation, chest ultrasonography was repeated. All enrolled patients received their standard treatment. The treatment protocol was not changed during the study period. The follow-up of fluid intake was done at admission and repeated at 12 and 24 hours. Measuring outcomes: The primary outcome was the sensitivity and specificity of bedside chest ultrasonography (US) in detecting lung contusions during and after resuscitation.

Statistical Analysis:

The statistical study was conducted in the United States using SPSS version 20. The frequency (%) and standard deviation (SD) represented categorical and continuous data, respectively. User operating characteristic (ROC) curve analysis was employed to evaluate the diagnostic accuracy of lung ultrasound (LUS) with regard to monitoring and predicting fluid resuscitation. All calculated P values were two-sided, and significance was determined at a 95% confidence level with a threshold of less than 0.05.

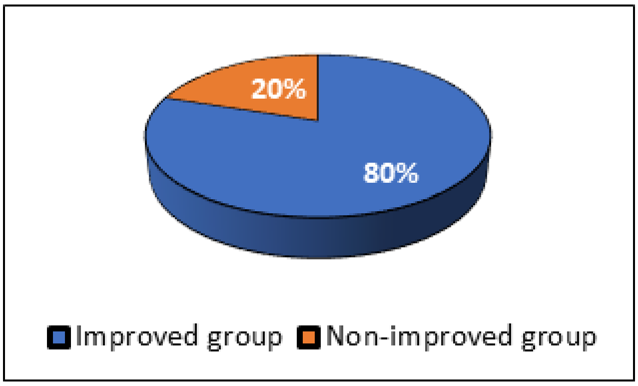
Results:

Baseline data of the studied patients based on their outcome (Table 1):

The mean age of the studied patients was 31.94 ± 10.69 years. Of them, 56 (56%) patients were males, and 44 (44%) were females. The modes of trauma were motor car accidents (54%), falls from height (36%), and blunt trauma (10%). Four (4%), two (2%), and three (3) patients had histories of cardiac disease, chest disease, and renal disease, respectively.

	Total (n= 100)	Outcome		*P* value
		Improved (n=80)	Non-improved (n= 20)	
Age (years)	31.94 ± 10.69	30.65 ± 8.02	37.10 ± 12.69	0.14
Sex				0.36
- Male	56 (56%)	46 (57.5%)	10 (50%)	
- Female	44 (44%)	34 (42.5%)	10 (50%)	
BMI (kg/m^2)	23.54 ± 1.69	23.55 ± 1.63	23.50 ± 1.98	0.92
MOT				0.48
- MCA	54 (54%)	41 (51.2%)	13 (65%)	
- FFH	36 (36%)	30 (37.5%)	6 (30%)	
- Blunt trauma	10 (10%)	9 (11.3%)	1 (5%)	
Cardiac disease	4 (4%)	3 (3.8%)	1 (5%)	0.59
Chest disease	2 (2%)	2 (2.5%)	0	0.63
Renal disease	3 (3%)	3 (3.8%)	0	0.50

The outcome of studied patients based on manifestations of volume overload (Fig.1): Based on manifestations of volume overload and pulmonary edema, The patient' state was categorized into an improved group (patients were improved without manifestation of Volume overload and pulmonary edema) and non-improved group(patients showed manifestation of Volume overload and pulmonary edema).



B**-lines scoring and severity of volume overload (Table 2):** Analysis of B-lines scoring and severity of volume overload revealed a substantially higher score in the non-improved group compared to the better group (34.50 ± 6.24 vs. 21.58 ± 5.49; p< 0.001).80% of the non-improved group experienced severe volume overload, while 78.8% of the improved group had mild volume overload.

	Total (n= 100)	Outcome		*P* value
		Improved (n=80)	Non-improved (n= 20)	
B-lines scoring	7.65±24.16	5.49±21.58	6.24±34.50	**< 0.001**
Volume overload				**< 0.001**
Mild	12 (12%)	12 (15%)	0	
Moderate	67 (67%)	63 (78.8%)	4 (20%)	
Severe	21 (21%)	5 (6.3%)	16 (80%)	

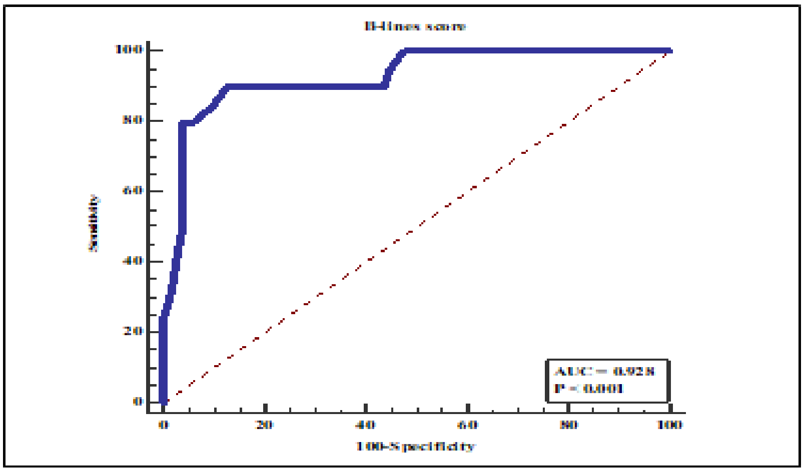
Fluid consumption in the examined individuals was categorized by their outcome(Table 3): Colloid intake frequency was considerably greater in the non-improved group at admission (85% vs. 45%; p< 0.001) and after 12 hours (75% vs. 30%; p< 0.001). The group that did not show improvement had a significantly greater rate of blood product usage compared to the group that did show improvement upon admission (80% vs. 36.3%; p< 0.001) and after 24 hours(60% vs. 22.2%; p< 0.001).

	Total (n= 100)	Outcome		*P* value
		Improved (n=80)	Non-improved (n= 20)	
Fluid intake (ml)				
At admission	261.95±2168.40	248.46±2122.88	239.19±2350.50	< 0.001
After 12 hours	255.01±1227	179±1170	248.09±1455	< 0.001
After 24 hours	125.32±880	114.28±856.25	125.13±975	< 0.001
Crystalloid intake				
At admission	100 (100%)	80 (80%)	20 (100%)	---
After 12 hours	98 (98%)	79 (98.8)	19 (95%)	0.36
After 24 hours	90 (92%)	74 (92.5%)	18 (90%)	0.50

	Total (n= 100)	Outcome		*P* value
		Improved (n=80)	Non-improved (n= 20)	
Colloid intake				
At admission	53 (53%)	36 (45%)	17 (85%)	< 0.001
After 12 hours	39 (39%)	24 (30%)	15 (75%)	< 0.001
After 24 hours	4 (4%)	3 (3.8%)	1 (5%)	0.59
Blood products				
At admission	45 (45%)	29 (36.3%)	(%80) 16	< 0.001
After 12 hours	32 (32%)	23 (28.7%)	(%45) 9	0.13
After 24 hours	30 (30%)	18 (22.5%)	(%60) 12	< 0.001

Accuracy of B-lines scoring in prediction volume overload in patients with chest trauma (Table 4)(Fig.2): The B-lines scoring demonstrated 90% sensitivity,87.5% specificity, and 88% overall accuracy in predicting volume overload in patients with chest trauma when the cut-off point was set at >27. The area under the curve was calculated to be 0.928.

	Indices
Sensitivity	%90
Specificity	%87.50
Positive predictive value	%64.3
Negative predictive value	%97.2
Accuracy	%88
Cut-off point	27 <
Area under curve	0.928
P value	0.001 >



Discussion

Lung contusion (LC) is challenging to diagnose in most cases despite its frequent occurrence. Without utilizing advanced diagnostic techniques like CT scans, traditional radiology will underestimate the prevalence of certain conditions [8–10]. Point-of-care ultrasound (POCUS) is a crucial component of emergency management as it can forecast lung contusions within 72 hours following trauma. It is an essential diagnostic tool, particularly for hemodynamically unstable patients who cannot be moved to a CT and need bedside imaging. It also provides a reasonably precise assessment of resuscitation [11, 12].

The significance of lung ultrasound (LUS) in monitoring fluid resuscitation in patients with lung contusions has not been investigated in any studies to date. To prevent excessive fluid volume, this study aimed to assess POCUS's efficacy in monitoring fluid resuscitation in trauma patients with lung contusions.

Animal research can utilize the same measurement instruments, including monkeys and pigs. A robust linear correlation between the B series value and the wet/dry ratio is ascertained through postmortem gravimetric analysis, the gold standard for quantifying extravascular lung water (EVLW) in the pig model [15]. Using the same porcine model, we examined whether the B line could detect elevated EVLW before initiating functional decline. The presence of extravascular lung water (EVLW) accumulation before the onset of lung damage in piglets is detected by B-rays in the absence of any chest X-ray findings or changes in blood lipid levels [16].

In humans, when evaluated using a restricted four-region scan of the front of the chest, the quantity of B-lines strongly correlates with the invasive assessment of extravascular lung water (EVLW), consistent with the experimental findings. Hospitalized patients with acute heart failure were evaluated in a study by Platz (2019) utilizing a 4-zone lung ultrasound (LUS) method. Patients discharged with a greater number of B-lines had an increased risk of hospitalization for heart failure or all-cause mortality, according to the study [17]. A study was conducted by Buessler (2020) in which 117 patients who presented to the emergency department with unclear acute heart failure were evaluated using various approaches to lung ultrasound (LUS) to detect extravascular lung water (EVLW). For evaluating B-lines, the study contrasted four-zone, six-zone, eight-zone, and twenty-eight-zone approaches. In addition to clinical diagnostic scores, implementing the 6-zone and 8-zone techniques improved the diagnostic precision of acute failure, according to the study [18].

Our study was the first to examine the significance of the B-lines score in assessing fluid overload in patients with lung contusion, as stated in the literature. 80% of the patients showed improvement without signs of volume excess or pulmonary edema. Meanwhile, 20% of the patients exhibited symptoms of volume overload and pulmonary edema. The mean B-lines score for all patients was 24.16 ± 7.65, with a substantially higher score observed in the non-improved group (34.50 ± 6.24 vs. 21.58 ± 5.49; $p < 0.001$). 80% of the non-improved group exhibited severe volume overload, while 78.8% of the improved group had mild volume overload. For a cut-off point greater than 27, the B-Lines scoring system demonstrates 90% sensitivity, 87.5% specificity, and 88% overall accuracy in predicting volume overload in patients with chest injuries. The area under the curve is 0.928.

The global lung ultrasonography B-score is the sum of individual region scores, ranging from 0 (fully aerated regions) to 36 (completely consolidated regions). In patients with ARDS, the regional lung ultrasound score strongly correlates with the tissue density determined by quantitative CT. Every successive increase in the score from zero to three is correlated with a significant escalation in density [19-20]. Lung ultrasound can detect high-risk patients for the development of ARDS within 72 hours of blunt chest trauma. According to our results, an LUS score of four or more was the cut-off value for determining high-risk patients (sensitivity 91.67% and specificity 84.21%) [21].

An elevated lung ultrasonography score is an early indicator of potential problems arising from fluid resuscitation in sepsis patients and can assist clinicians in managing fluid levels [22]. Researchers have found that the United States demonstrates a high % accuracy rate of 95.4% in diagnosing alveolar interstitial syndrome, but the accuracy in diagnosing peripheral parenchymal lesions is around 65.9% [14].

The primary constraints of the present investigation were that our study was the first, to our knowledge, to examine the value of lung ultrasound (LUS) in fluid monitoring for lung contusion. Ultrasound is operator-dependent, and the limited sample size and short follow-up time hinder assessing more accurate outcomes. It may be helpful to assess the diameter of the inferior vena cava by ultrasound.

Conclusion:

Point-of-care ultrasound (POCUS) plays a crucial role in assessing chest trauma patients with lung contusions, especially in hemodynamic instability. Our study was the first to utilize BLS of lung contusions, which will be very helpful to avoid volume overload. For a cut-off point greater than 27, the B-Lines scoring system demonstrates 90% sensitivity, 87.5% specificity, and 88% overall accuracy in predicting volume overload in patients with chest injuries.

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