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Research Article

Comparative Evaluation of Lung Contusion Assessment Using Ultrasound and Computed Tomography Scan in the First 24 Hours of Intensive Care Unit Admission

Reza Alizadeh Kashani[1]*, Sevak Hatamian[1], Mohammad Reza Maghsoudi[2], and Mahnaz Zoghi[1]

[1]Department of Anesthesia, Shahid Madani Hospital, School of Medicine, Alborz University of Medical Sciences, Karaj, Iran
[2]Department of Emergency Medicine and Toxicology Emergency, Shahid Madani Hospital, School of Medicine, Alborz University of Medical Sciences, Karaj, Iran

Abstract

Introduction: Lung contusion is a common condition often resulting from blunt trauma, and it is connected with substantial health complications and risk of death; therefore, timely diagnosis and treatment are essential. Ultrasonography is a valuable technique that significantly improves medical care, offering time efficiency and life-saving benefits. This study aimed to evaluate lung contusion by comparing the use of ultrasound and computed tomography (CT) scan during the initial 24 hr of intensive care unit (ICU) hospitalization.

Methods: Eighty patients with blunt chest trauma were enrolled in this study. Each patient underwent both chest CT scan and lung ultrasound examinations. Lung ultrasound was performed in 6 anatomical regions on each lung (anterior-superior, anterior-inferior, lateral-superior, lateral-inferior, posterior-superior, and posterior-inferior). Lung contusion was identified by observing localized pulmonary effusion along with disrupting the lung parenchyma. To evaluate the extent of lung damage, the ratio of partial pressure of oxygen in arterial blood to the fraction of inspired oxygen concentration (PaO_2/FiO_2 ratio) was utilized, while the extent of lung involvement was classified using the blunt pulmonary contusion score (BPC-18 score).

Results: In this study, lung ultrasonography demonstrated a sensitivity of 93.6% for detecting lung contusions, with a specificity of 94.1%, positive predictive value (PPV) of 98.3%, negative predictive value (NPV) of 80%, and overall accuracy of 93.7%. Specifically, for the right lung, these measures were 90.9%, 96%, 98%, 82.7%, and 92.5%, respectively. For the left lung, the corresponding values were 88%, 96.6%, 97.7%, 82.8%, and 91.2%. The receiver operating characteristics (ROC) curve assessed the sensitivity and specificity of ultrasound in diagnosing lung contusions within the first 24 hr of ICU admission. The area under the curve (AUC) for this assessment was 0.939, indicating high diagnostic accuracy.

Conclusion: While CT remains the standard for evaluating lung contusions, its accessibility may be limited due to various circumstances, especially during hemodynamic instability. In these situations, ultrasound is highly valuable in diagnosing lung contusions with exceptional sensitivity, specificity, and diagnostic accuracy. Chest ultrasound emerges as an essential, noninvasive, and safe diagnostic tool at the bedside in the ICU for detecting lung contusions.

Keywords: lung contusion, ultrasound, CT scan, trauma

Corresponding Author: Reza Alizadeh Kashani
Email: Dralizadeh.reza@gmail.com

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1. Introduction

A lung contusion is an injury to the lung parenchyma, typically caused by a significant impact to the chest or a sudden shift in body momentum, known as an acceleration-deceleration injury [1]. Lung contusion can arise from a diverse spectrum of causes like explosions, falls from heights, or collisions involving motor vehicles [2]. These injuries are most often detected as lung parenchymal injuries in cases involving blunt trauma to the chest, with prevalence rates ranging from 30% to 75% [3]. Additionally, lung contusion acts as a contributing factor to acute respiratory distress syndrome (ARDS], pneumonia, and persistent respiratory dysfunctions, and is linked to mortality rates between 10% and 25% [2].

Since repetitive pulmonary assessments in individuals experiencing blunt chest trauma seem necessary [4], evaluations such as clinical examination, bedside radiography, and sequential measurement of respiratory parameters are crucial for effectively monitoring clinical progress and treatment outcomes [5]. In addition to the evaluation methods mentioned, ultrasound can be considered a useful method for repetitive assessment in instances of blunt chest trauma.

The pathophysiology of lung contusion is described as follows, it is established that trauma disrupts the integrity of the blood-air barrier [3]. Consequently, blood and interstitial fluids infiltrate the alveolar space, leading to complications such as alveolar edema, alveolar hematoma, reduction in surfactant levels, alveolar collapse, atelectasis, and ultimately, the disruption of the lungs' physiological structure and function [6]. Thus, during inhalation, oxygen cannot enter the alveoli, leading to compromised gas exchange. This results in increased pulmonary vascular resistance, subsequently raising pulmonary arterial pressure [3, 7].

Several methods are available for diagnosing lung contusion. A widely utilized imaging modality for patients in the ICU is the X-ray [8]. Chest X-rays are frequently employed to identify lung contusions; nevertheless, they have certain limitations [9]. The radiographic indicators of a contusion do not manifest immediately after the trauma; rather, there is a delay of 6 to 48 hr before lung contusion signs become apparent on an X-ray [10]. Additionally, interpreting the images can be challenging since lung contusions can look similar to aspiration on X-rays, and concurrent hemothorax or pneumothorax can conceal other injuries [11]. Once signs of lung contusion are evident on a chest X-ray, indicating severe trauma, a computed tomography (CT) scan is recommended for a more accurate diagnosis [12]. The gold standard for diagnosing lung contusion is a chest CT scan [13]. A high-resolution scan can promptly identify lung contusions following trauma [14]. Despite its effectiveness, this diagnostic method has its limitations. The procedure can be expensive, and the time required for a comprehensive chest CT scan may delay immediate diagnosis and treatment initiation. Moreover, hemodynamically unstable individuals are not suitable candidates for this imaging technique [9]. Lastly, there are concerns regarding radiation exposure associated with repeated CT scans [15].

Ultrasonography is a valuable diagnostic tool for identifying lung contusion with both acceptable sensitivity and specificity. Notably, it often surpasses chest X-ray imaging in detecting contusions at their earlier stages [3]. Based on distinct sonographic patterns, it demonstrates satisfactory specificity in distinguishing lung contusion from other interstitial syndromes like ARDS and cardiogenic pulmonary edema, and it presents challenges in differentiating contusion from aspiration or atelectasis due to similarities in anatomic density [9]. The effectiveness of ultrasonography heavily relies on the operator's proficiency, demanding concentrated and supervised instruction to guarantee precise interpretation of sonographic results [16]. Moreover, in settings like the ICU, the risk of cross-contamination is possible since the same probe is utilized across multiple patients. Finally, its utility is limited in obese patients due to challenges in visualizing lung parenchyma [9].

This research sought to examine the evaluation of lung contusion using ultrasound and CT scan during the initial 24 hr of ICU admission at Shahid Madani Hospital in 2023.

2. Methods

This study, conducted at Shahid Madani Hospital, included 80 patients of both genders. The aim was to assess the sensitivity, specificity, and accuracy of ultrasound in diagnosing lung contusions compared to CT—the accepted standard method of diagnosis. By employing a prospective process evaluation design, the sample selection followed a nonrandomized, sequential approach, where eligible individuals were approached in consecutive order until the desired sample size was achieved. The required information for the study was recorded using data from the patient files, and information was obtained from the ultrasound and noncontrast CT scan reports on prepared data sheets.

Patients aged 18 or older presenting with acute blunt chest trauma, either as a singular injury or as part of multiple traumas with/without rib fractures or spine injuries, were included in the study. Lung contusion was diagnosed and confirmed using chest CT scans. All participants in the study gave formal written consent. Patients were excluded from the study if they had penetrating chest trauma, old chest trauma, a history of pulmonary fibrosis, contraindications for chest CT scans that hindered confirmation of lung contusion diagnosis, or if they did not provide consent.

2.1. Lung Ultrasonography

For lung parenchymal ultrasound, each lung was divided into 6 regions (anterior-superior, anterior-inferior, lateral-superior, lateral-inferior, posterior-superior, posterior-inferior). While the patient was lying supine with arms elevated above the head, the designated regions of the left and right chest walls were examined using the Philips Innosight Diagnostic Ultrasound System (2020) with a Philips C6-2 Curved Array probe (2-6 MHz) and software version 1.0.3. The probe made direct contact with the thoracic wall during the procedure. Due to blunt chest trauma, the areas known as posterior were examined manually by positioning the probe between the mattress and the patient's back to achieve the most posterior placement possible. The diagnosis of lung contusion was made by a single attending ICU physician without knowledge of the chest CT scan results. The primary indicators of lung contusion identified by ultrasound are the presence of multiple B-lines and a disrupted tissue pattern [3, 13].

Lung contusion in this study was marked by the detection of a minimum of three B-lines between two ribs, peripheral parenchymal lesions, or subpleural consolidation by localized pulmonary effusion on ultrasound (Figure **1**) [10, 17].

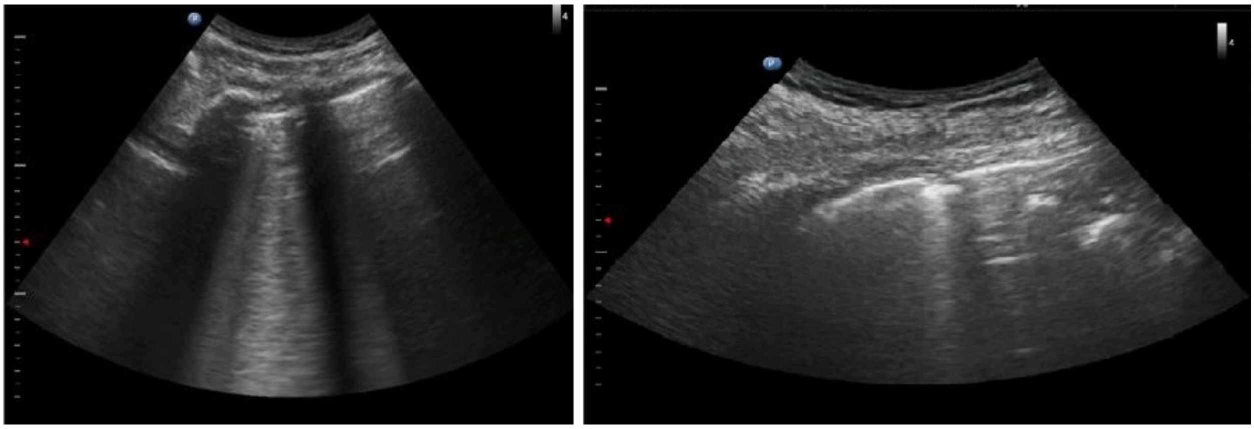

Figure 1: (a) Presence of multiple B-Lines in lung contusion: Vertical comet-tail artifacts originating from the pleural line, well-defined, hyperechoic, and moving with lung sliding, (b) Isolated peripheral parenchymal lesion on ultrasound.

We designated the anterior-superior, anterior-inferior, and lateral-superior regions as corresponding to the upper and middle lobes, while the posterior-superior, posterior-inferior, and lateral-inferior points were associated with the lower lobe for each lung. Ultrasound examinations were conducted at the bedside for all patients within the first 24 hr of admission, with a maximum time gap of 1 hr between ultrasound and CT scan procedures.

2.2. Chest CT Scan

A Philips Brilliance 16-slice CT scanner was utilized to perform noncontrast chest CT scans. These scans were conducted using volumetric acquisition with 2.00 mm slice thickness and 0.00 mm intervals, covering the area from the apex to the diaphragm. This technique is regarded as the gold standard for diagnostic imaging in this context. The 12 lung regions previously examined by lung ultrasound were analyzed using chest CT scans to detect abnormalities [18].

In chest CT scans, lung contusions were defined as areas of nonsegmental consolidation and ground-glass opacification, predominantly involving the peripheral regions and extending deeply into the area of trauma, or as irregular interstitial infiltrates [3, 19]. In this study, lung involvement severity was categorized based on the blunt pulmonary contusion score (BPC-18 score), where each lung is divided into three lobes (upper, middle or ligula, and lower). The severity of contusion in each lobe is graded on a scale from 0 to 3, where 0 indicates no contusion, 1 represents mild contusion, 2 denotes moderate contusion, and 3 reflects severe contusion (Figure **2**). The severity score for each lung ranges from 0 to 9, and the combined score for both lungs ranges from 0 to 18. A score of 0 indicates no contusion, 1-2 indicates mild contusion, 3 indicates moderate contusion, 4-9 indicates severe contusion, and 10-18 indicates very severe contusion.

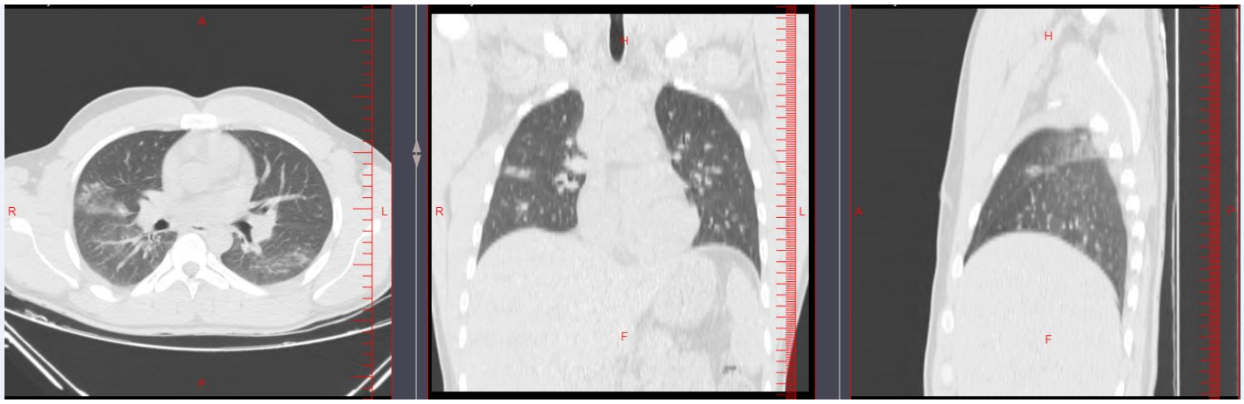

Figure 2: Chest CT images show mild right middle lobe contusion (RML BPC-18 Score = 1), (a) RML in axial plane, (b) RML in coronal plane, (c) RML in sagittal plane.

The information obtained from the CT scans is interpreted by the attending ICU physicians who were uninformed about any other patient's reports, while reporting chest CT scans.

Additionally, the arterial oxygen pressure to oxygen concentration ratio (PaO_2/FiO_2) in arterial blood gas (ABG) was used as an indicator for the severity of lung injury: < 100 indicates severe lung injury, 100-199 indicates moderate lung injury, and 200 or greater indicates mild lung injury.

2.3. Statistical Analysis

The data were analyzed using the IBM Corp. (2019). IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp. Qualitative data were presented using numerical and percentage representations, while quantitative data were described through mean and standard deviation. Evaluation of various predictive factors in relation to the outcome was assessed through sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. Additionally, a receiver operating characteristic (ROC) curve was generated to determine the optimal cutoff point, with the area under the ROC curve indicating the test's diagnostic efficacy. Test performance can be categorized as follows: equal to chance (AUC = 0.5), less accurate ($0.5 < AUC \leq 0.7$), moderately accurate ($0.7 < AUC \leq 0.9$), highly accurate ($0.9 < AUC \leq 1.0$), and perfect performance tests (AUC = 1.0) [20]. The concordance between ultrasound and CT scan results of lung contusion was calculated using the kappa statistics. To assess the congruency (agreement) between chest CT scan and ultrasound results across PaO_2/FiO_2

and BPC scores, we utilized the Chi-square test to determine statistical significance, with a significance level set at $p < 0.05$.

2.4. Ethical Approval

A formal written consent was obtained from all the patients, included. The study obtained ethical approval from the Alborz University of Medical Science Ethics Committee under the ethical code IR.Abzums.REC.1401.302 on February 13, 2023. All the personal information was kept confidential and were not disclosed to any individual or legal entity. The Helsinki Declaration guidelines were adhered to in this study. Given that chest ultrasound and CT scans are routine practices for chest trauma at the involved institutions, no additional expenses were imposed on the patients.

3. Results

A total of 80 participants were included in this study, with a mean age of 37.3 ± 18.1 years (range = 18-90). Of these participants, 67 were male (83.8%) and 13 were female (16.3%). Among the patients, 48 had spontaneous breathing (60%) and 32 required mechanical ventilation (40%). Based on the BPC-18 score, the mean severity score of lung contusion, according to CT scan reports was 3.6 ± 3.4 (range: 0-18). Table **1** presents the descriptive data of the patients, detailing key demographic and clinical characteristics. In Table **2**, we present the diagnostic accuracy of ultrasound in detecting lung contusions compared with CT scans. This study evaluated the diagnostic performance metrics of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy for both lungs. Overall, the combined metrics for both lungs were 93.6%, 94.1%, 98.3%, 80%, and 93.7%, respectively. Specifically, in the right lung, these metrics were 90.9%, 96%, 98%, 82.7%, and 92.5%, while in the left lung, they measured 88%, 96.6%, 97.7%, 82.8%, and 91.2%. These results underscore the robust performance of the diagnostic assessments across both lung regions; however, the sensitivity of ultrasound for detecting lung contusion was higher in the lower lobes (right and left lung: 83%) compared to the upper and middle lobes (right lung: 63.6% and left lung: 67.6%). The specificity was high in all lobes, with the highest specificity observed in the lower lobes (right lung: 96.2% and left lung: 96.8%). The ROC curve for determining the sensitivity and specificity of ultrasound in diagnosing lung contusions during the first 24 hr of ICU admission is shown in Figure **3**. The area under the curve (AUC) for diagnosing lung contusions during the first 24 hr of ICU admission was AUC = 0.939, with $p < 0.001$. Table **3** illustrates the agreement between chest CT scan and ultrasound results across various categories of PaO_2/FiO_2 and BPC scores. In all 35 severe cases according to PaO_2/FiO_2 and all 44 cases, classified as severe and very severe, according to BPC score, a 100% agreement was observed between chest CT scan and chest ultrasound findings (p-value < 0.05).

Table 1: Descriptive data of the studied patients (BPC Score: Blunt pulmonary contusion score. PaO_2/FiO_2 ratio: Partial pressure of oxygen in arterial blood to the fraction of inspired oxygen concentration, CT-Scan: computed tomography scan).

	Number	Percent (%)
Sex		
Male	67	83.8
Female	13	16.3
Ventilation		
Spontaneous	48	60
Mechanical	32	40
BPC score		
Normal	17	21.3
Mild	14	17.5
Moderate	5	6.3
Severe	37	46.3
Very severe	7	8.8
PaO_2/FiO_2 ratio		
<100	35	43.8
100-199	17	21.3
≥200	28	35
Lung contusion in ultrasound		
No	20	25
Yes	60	75
Lung contusion in CT scan		
No	17	21.3
Yes	63	78.8

Table 2: Diagnostic accuracy of ultrasound in detection of lung contusion compared with CT (PPV: Positive predictive value, NPV: Negative predictive value).

		CT scan		Sensitivity%	Specificity%	PPV	NPV	Accuracy	p-value	Kappa
		Negative	Positive							
Right lung	Negative	24	5	90.9	96	98	82.7	92.5		
	Positive	1	50							
Upper/middle lobes	Negative	33	16	63.6	91.6	90.3	67.3	76.2	<0.001	0.833
	Positive	3	28							
Lower lobe	Negative	26	9	83	96.2	97.7	74.2	87.5		
	Positive	1	44							
Left lung	Negative	29	6	88	96.6	97.7	82.8	91.2		
	Positive	1	44							
Upper/lingula lobes	Negative	43	11	67.6	93.4	88.4	79.6	82.5	<0.001	0.819
	Positive	3	23							
Lower lobe	Negative	31	8	83	96.8	97.5	79.4	88.7		
	Positive	1	40							

Table 2: Continued.

		CT scan		Sensitivity%	Specificity%	PPV	NPV	Accuracy	p-value	Kappa
		Negative	Positive							
Total	Negative	16	4	93.6	94.1	98.3	80	93.7	<0.001	0.825
	Positive	1	59							

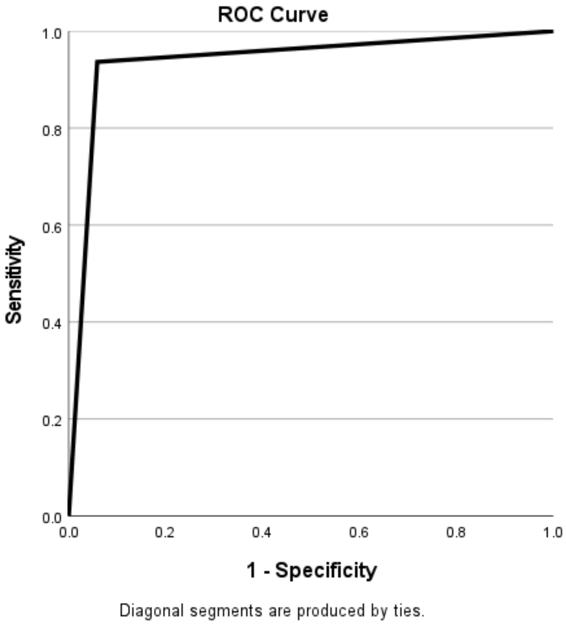

Figure 3: ROC curve for ultrasound with CT.

Table 3: Agreement between chest CT scan and chest ultrasound results across different PaO_2/FIO_2 and BPC score categories (BPC Score: Blunt pulmonary contusion score. PaO_2/FIO_2 ratio: Partial pressure of oxygen in arterial blood to the fraction of inspired oxygen concentration).

PaO_2/FIO_2 ratio	Agreement between CT and Ultrasound results		p-Value
	No	Yes	
<100 (Severe)	0	35	0.049
100 – 199 (Moderate)	2	15	
≥200 (Mild)	3	25	
BPC Score			
0 (Normal)	1	16	0.036
1-2 (Mild)	3	11	
3 (Moderate)	1	4	
4-9 (Severe)	0	37	
10-18 (Very severe)	0	7	

4. Discussion

This study evaluated the diagnostic efficacy of lung ultrasonography, with a chest CT scan serving as the gold standard for lung contusion diagnosis. This was the first study to assess the diagnostic accuracy of lung ultrasound across various lung anatomical regions in patients with chest contusions within 24 hr. The study revealed that the agreement between ultrasound and CT for diagnosing lung contusion showed a high level of concordance, with kappa values of 0.833 for the right lung and 0.819 for the left lung. The overall computed kappa value for both lungs was 0.825. This study indicated that the regular use of lung ultrasound is beneficial for managing and monitoring ICU patients with lung contusions.

In this study, the total lung sensitivity and specificity were 93.6% and 94.1%, respectively. The sensitivity for right lung was 90.9% and the specificity was 96%. For the left lung, the sensitivity was 88% and the specificity was 96.6%. The findings of this study revealed that ultrasound has greater sensitivity for detecting lung contusions in the lower lobes of both lungs compared to the upper and middle lobes. Given that the incidence and severity of pulmonary contusions from blunt chest trauma are often higher in the lower lobes, this may lead to better visualization of B-lines and sub-pleural consolidations on ultrasound, resulting in higher sensitivity for detecting pulmonary contusions in the lower lobes. However, while specificity was high across all lung lobes, it was notably higher in the lower lobes. In a study by Soldati et al., in 2006, involved 121 patients with blunt chest trauma, the clinical utility of chest ultrasonography in diagnosing lung contusion in the emergency department was evaluated, comparing it with CT scans. The sensitivity and specificity of ultrasound were found to be 94.6% and 96%, respectively [16]. In a comparable study conducted in 2015 by Helmy et al., which involved a cohort of 50 patients, ultrasound exhibited robust diagnostic performance with a sensitivity of 97% and specificity of 90% [9]. In a similar study conducted by Jahanshir et al., in 2020 on 157 patients with chest trauma, ultrasonography was found to have a sensitivity of 58.1% and a specificity of 100% for detecting lung contusion [21]. The differences in diagnostic metrics may be due to differences in patient selection methods, the severity of lung contusion, misinterpretation of ultrasound findings, and variations in study methodologies. Thus, the expertise of ICU physicians and the high diagnostic accuracy of ultrasound devices are pivotal in identifying lung contusions. As demonstrated in a study led by Rocco et al., achieving consistent results with ultrasound typically requires a minimum training period of 6 months, as the technique's reproducibility is closely tied to the operator's experience [22].

Ultrasound is a readily accessible screening tool in the emergency department, where its screening and diagnostic accuracy are crucial [23]. In this study, ultrasound demonstrated an overall accuracy of 93.7%, with accuracies of 92.5% for the right lung and 91.2% for the left lung. Various studies have indicated that the accuracy of ultrasound results are significantly influenced by the operator's experience [24]. Diagnosing lung contusion via ultrasound based on signs alone presents challenges, and operators must first rule out pneumothorax, highlighting the importance of operator skill in achieving accurate ultrasound diagnoses [25]. The ultrasound appearance of lung contusion often manifests as two main features. One characteristic indicative of lung contusion on ultrasound is the alveolar-interstitial syndrome, which manifests as an increase in B-line artifacts that appears as thickened or irregularly spaced vertical lines extending from the pleural line. Another observable sign is the presence of peripheral parenchymal lesions, identified by the appearance of C-lines that present as hypoechoic focal areas near the pleural line, indicating localized areas of consolidation within the lung tissue [3, 9].

The agreement between ultrasound and CT in diagnosing lung contusions was high, with kappa values of 0.833 for the right lung, 0.819 for the left lung, and an overall kappa of 0.825 for both lungs. In a 2012 study by Stefanidis involving 107 critically ill patients, lung ultrasound demonstrated substantial agreement with CT scans for detecting and localizing alveolar-interstitial syndrome across all lung fields bilaterally, yielding an overall agreement of 0.78 [26].

In the present study, considering the ROC curve, the AUC for ultrasound in diagnosing lung contusion within the first 24 hr of ICU admission was AUC = 0.939 (p-value < 0.001), which demonstrated a statistically meaningful difference and had high sensitivity and specificity for diagnosing lung contusion within the first 24 hours of ICU admission, indicating high diagnostic value. Vafaei et al., conducted a study in Iran in 2016, involving 152 individuals with chest trauma, the diagnostic accuracy of ultrasound was evaluated against that of chest CT scans. The area under the ROC curve for ultrasonography in detection was 0.80 (p-value < 0.001) [27].

The PaO_2/FiO_2 ratio is an indicator of pulmonary shunt fraction used to classify the severity of ARDS into three groups: mild (≥200), moderate (100-199), and severe (<100). A lower PaO_2/FiO_2 ratio correlates with increased injury severity and poorer hospital outcomes [28, 29]. The severity of lung involvement can be categorized based on the BPC 18 score: the contusion severity score for both lungs is rated from 0 to 18 according to the chest CT scan [30]. In this study, we observed remarkable consistency between chest CT scan and chest ultrasound results across different categories of PaO_2/FiO_2 and BPC scores. Specifically, we found a perfect agreement, with 100% concordance observed in all severe cases based on PaO_2/FiO_2 levels, as well as in all severe and very severe cases according to BPC scores. Previous studies have indicated that lung contusions exceeding 20% can predispose patients to various complications, including ARDS and infections [31, 32]. The results of this research underscore the robust diagnostic precision of ultrasound as a diagnostic tool, particularly in patients with severe lung contusions where accurate and timely assessments are crucial.

Previous studies indicate that ultrasound is a diagnostic tool for various pulmonary diseases in the emergency department [33, 34]. In 2021, a study by Attia et al., involved 109 multiple trauma patients in the emergency department, evaluated the diagnostic effectiveness of chest ultrasound against plain chest X-ray. The findings demonstrated that ultrasound significantly contributes to the acute assessment of traumatic hemothorax [35]. In 2022, a study by Elsayed et al., involved 120 patients suspected of having pneumonia to assess the diagnostic accuracy of ultrasound. Their findings revealed that ultrasound is highly sensitive, with an accuracy rate of 95% for diagnosing pneumonia [36]. In 2023 Elatroush et al., investigated a cohort of ICU patients suffering from respiratory failure, with the aim of evaluating the accuracy of lung ultrasound. The results demonstrated moderate to high sensitivity and specificity in detecting conditions such as pneumothorax, pleural effusion, and pulmonary edema [37]. In a study led by Rovida in 2022, ultrasound was found to be highly beneficial for assessing rib fractures, sternal injuries, and imaging the pericardium to detect effusions and tamponade [25].

Given the findings of this study and considering that ultrasound is a safe, noninvasive, and cost-effective modality, it is recommended that critical care physicians consider using bedside ultrasound to facilitate the timely diagnosis of lung contusion in the ICU. This recommendation is based on the high sensitivity, specificity, diagnostic value, and positive and negative predictive values of ultrasound in detecting lung contusions.

5. Conclusion

In conclusion, chest ultrasound proved invaluable as a noninvasive, safe, and practical bedside diagnostic tool in ICU and emergency settings for detecting lung contusions. While CT remains the gold standard for evaluating lung contusion, accessibility can be restricted, particularly during episodes of hemodynamic instability. In such cases, ultrasound demonstrates considerable value in diagnosing lung contusions with remarkable sensitivity, specificity, and diagnostic accuracy.

Acknowledgment

None.

Conflict of Interest

All authors declare that there is no conflict of interest.

Ethical Approval

The study obtained ethical approval from the Alborz University of Medical Science Ethics Committee under the ethical code IR.Abzums.REC.1401.302 on 2023-02-13. All personal information remained confidential and was not disclosed to any individual or legal entity. The Helsinki Declaration guidelines were adhered to in this study. Since chest ultrasound and CT scan are routines for chest trauma in the enrolling institutions, no additional expenses were imposed on the patients.

Informed Consent Statement

Formal written consent was obtained from all the participants included in the study.

Artificial Intelligence (AI) Disclosure Statement

AI-unassisted work.

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Author Contribution

Reza Alizadeh Kashani: Corresponding author, first author, performing ultrasound. Sevak Hatamian: Interpreting CT scans. Mohammad Reza Maghsoudi: Gathering information and analysis. Mahnaz Zoghi: Gathering information and analysis.

Data Sharing Statement

Date sets are not available publicly because of legal/security/privacy/policy reasons. However, it is available on request from the corresponding author.

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