

Diagnostic Value of Blue Protocol vs CT Scan in Critically Ill Patients With Respiratory Failure

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ABSTRACT

Background: Acute respiratory failure is a common emergency in critically ill patients, demanding swift and accurate diagnosis. While computerized tomography (CT) remains a diagnostic gold standard, it is often impractical in unstable patients. The BLUE protocol, a bedside lung ultrasound approach, offers a faster, safer alternative. This study compares the diagnostic performance and clinical utility of the BLUE protocol versus CT in evaluating respiratory failure in critical care settings.

Methods: This study is a Cross-Sectional Study. conducted in the ICUs of the Armed Forces Medical Complex Kobry El Qouba and the Armed Forces Medical Complex El Maadi Upon ICU admission, A baseline chest CT scan was conducted for all patients and used as the reference standard, lung ultrasound was performed using the BLUE protocol at standardized thoracic points. Clinical examination, arterial blood gas analysis, and patient history were also recorded. Ultrasound findings were then compared to CT results to assess diagnostic accuracy across common causes of respiratory failure.

Results: In this study, the BLUE protocol demonstrated high diagnostic accuracy in identifying major thoracic pathologies when compared to chest CT. For pleural effusion, it showed sensitivities of 97.4% (right) and 97.8% (left), with 100% specificity bilaterally ($p < 0.001$). In pneumothorax detection, the BLUE protocol achieved 100% sensitivity and specificity on both sides ($p < 0.001$). For pneumonia, sensitivity was 95% on the right and 93.6% on the left, while specificity remained 100% for both sides ($p < 0.001$). These results confirm the strong diagnostic performance and statistical significance of the BLUE protocol in evaluating acute respiratory conditions.

Conclusion: The integration of the BLUE protocol into routine ICU practice facilitates timely and accurate diagnosis, with ultrasound findings showing strong concordance with baseline CT results. This alignment supports its reliability in identifying causes of respiratory failure and enables earlier, more targeted interventions. By reducing diagnostic delays.

Key Words: Diagnosis, lung pathology, radiology, ultrasound.

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INTRODUCTION

Respiratory failure remains a frequent and critical presentation in intensive care units (ICUs), requiring rapid and accurate diagnostic assessment to initiate appropriate management. Imaging modalities are central to this diagnostic process. The mortality rate for acute respiratory failure (ARF) is 30% or higher, and it is responsible for 25-40% of intensive care unit hospitalizations. It requires rapid and precise diagnosis to start the right therapy^[1].

Computed tomography (CT) of the chest has traditionally been regarded as the gold standard for evaluating pulmonary pathology due to its high-resolution imaging and diagnostic precision^[2]. However, its use in critically ill patients is limited by logistical challenges, including the need to transport unstable patients, and potential delays in diagnosis.

Point-of-care ultrasound (POCUS), particularly the Bedside Lung Ultrasound in Emergency (BLUE) protocol, has emerged as a valuable alternative. Introduced by

Lichtenstein *et al.*, the BLUE protocol is a standardized approach for diagnosing the main causes of acute respiratory failure, including pneumothorax, pleural effusion and pneumonia. Blue protocol is designed for use at the bedside, offering rapid, repeatable, and radiation-free assessment, thereby enhancing diagnostic efficiency and safety in the ICU setting^[3].

This paper explores the role of the BLUE protocol in comparison to CT imaging in critically ill patients with respiratory failure, examining diagnostic performance, clinical utility, and their impact on patient outcomes.

PATIENTS AND METHODS

Type of study

This research was a Cross-Sectional Study.

Study setting

The study was conducted in the ICUs of the Armed Forces Medical Complex Kobry El Qouba and the Armed

Forces Medical Complex El Maadi, both in Cairo, Egypt. (from December 2023 to September 2024)

Study subjects

Any patient admitted to ICU suffering from dyspnea either of a medical cause (pneumonia or pleural effusion) or surgical.

Sample size

The number of intensive care unit patients meeting the inclusion criteria was used to establish the sample size for the current study during the study period. The sample size for this study was 75 patients. All patients hospitalized to the intensive care unit (ICU) with dyspnea must have been adults (18 years and over). The sampling type is convenient, focusing on ICU patients available during the data collection phase. This approach ensures that a sufficient number of cases are examined to provide meaningful insights into the role of the BLUE Protocol in managing respiratory failure.

Inclusion criteria

Patients who were hospitalized to the intensive care unit (ICU) for ARF, which is defined as one of the following, age above 18 years old: a pulse oximeter reading of 90% or less on room air, a respiratory rate of 30 breaths per minute or more, a partial pressure of oxygen in arterial blood sample is 60 mmHg or less, or partial pressure of carbon dioxide in arterial blood sample (PCO₂) of 45 mmHg or higher or an arterial pH of 7.35 or less.

Exclusion criteria

- Patients having required intubation before admission.
- Patients having a multiple diagnosis or a rare (i.e., frequency < 2%) diagnosis.

Data collection instruments

- Ultrasound devices (Siemens Acuson S1000) were the primary instruments used to detect signs of pleural effusion, lung consolidation, or other lung diseases.
- The use of ultrasound instruments allowed for the detection of respiratory disorders by non-invasive, real-time imaging of the lungs.
- Clinical examination
- Arterial blood gases.

Procedure

- A baseline CT (standard of care) was carried out for each patient upon admission. Then a 3-minute lung ultrasound was done by the intensivist without causing any disruption to treatment.

- A detailed history was taken to gather demographic and medical information.
- A comprehensive thorough clinical examination was conducted for all patients.
- The intercostal space is immediately probed with a micro-convex probe.

BLUE-protocol outlines three standardized points: Scanning Points (usually on both lungs):

1. Upper BLUE point – 2nd intercostal space, midclavicular line
2. Lower BLUE point – 4th–5th intercostal space, anterior axillary line
3. PLAPS point (PosteroLateral Alveolar and/or Pleural Syndrome) – posterolateral, used to detect consolidation or effusions

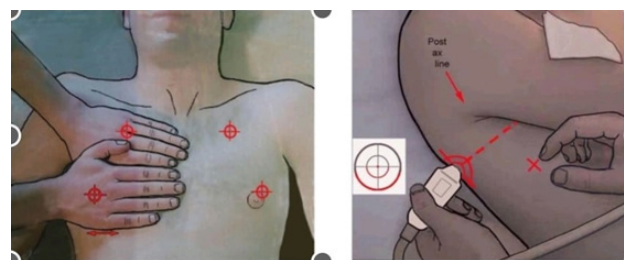


Fig.7: Areas of investigation and the BLUE-points.

Two hands placed this way (size equivalent to the patient's hands, upper hand touching the clavicle, thumbs excluded) correspond to the location of the lung, and allow three standardized points to be defined. The upper-BLUE-point is at the middle of the upper hand. The lower-BLUE-point is at the middle of the lower palm. The PLAPS-point is defined by the intersection of: a horizontal line at the level of the lower BLUE-point; a vertical line at the posterior axillary line^[4].

Main Diagnoses and Ultrasound Signs

Condition	Lung Ultrasound Pattern
Pneumothorax	Absent lung sliding, A-lines, lung point
Pulmonary effusion	Anechoic fluid collection
Pneumonia	Consolidation with air bronchograms, PLAPS, focal B-lines
Pulmonary embolism	Normal anterior scan, DVT may be found, pleural-based infarct
COPD/Asthma	Bilateral A-lines, preserved lung sliding

Data management and analysis

In order to do statistical analysis, the pre-coded data was input into SPSS, a social science software program, version 28. Mean, standard deviation, median, and

interquartile range (IQR) were used to describe quantitative data, whereas number and percent were used for qualitative data. The quantitative variables were compared between the two groups using an independent T-test, whereas the qualitative variables were compared using a chi-square test. For quantitative variables that did not follow a normal distribution, we employed the Mann-Whitney U test and the Wilcoxon chi-square test; for normally distributed data, we utilized the paired sample T test. When necessary, further statistical tests are employed. Statistical significance was defined as a *p-value* lower than 0.05.

Ethical considerations

Patient's data were dealt with complete confidentiality. Any participant had the choice whether to participate or not in this research. The Research Ethics Committee of the Armed forces college of medicine reviewed and permitted the research protocol (Reg. No FW000000206). Informed written consent has been acquired from the patients' relatives

RESULTS

In this observational research, 75 patients hospitalized to the intensive care unit due to dyspnea were evaluated.

A total of 75 patients were included in the study. The mean age of the study population was 63.6 ± 6.28 years, with an age range of 50 to 75 years. The sex distribution was nearly equal, comprising 38 males (50.67%) and 37 females (49.33%). Regarding comorbid conditions, (50.67%) had a history of hypertension (HTN). Diabetes mellitus (DM) was present in 51 patients (68%), while 23 patients (30.67%) had pre-existing heart disease. Baseline oxygen saturation on room air (SaO_2) was $87.4 \pm 2.76\%$, with a range from 83% to 93%. Arterial blood gas (ABG) analysis revealed a mean pH of 7.3 ± 0.05 (range: 7.25–7.44), a mean partial pressure of carbon dioxide (PCO_2) of 46.8 ± 7.99 mmHg (range: 35–70 mmHg), and a mean bicarbonate (HCO_3^-) level of 24 ± 2.41 mmol/L (range: 20–28 mmol/L). The mean partial pressure of oxygen (PO_2) was reported as 87.4 ± 2.7 mmHg; however, the stated range of 40–59 mmHg appears inconsistent with the mean value and may require verification.

(Table 2) evaluates the diagnostic accuracy of the BLUE (Bedside Lung Ultrasound in Emergency) protocol in identifying pleural effusion compared to chest CT, which is considered the gold standard. On the right side of the chest, CT imaging detected 38 positive and 37 negative cases of pleural effusion, whereas the BLUE protocol identified 37 positive and 38 negative cases. The sensitivity of the BLUE protocol on the right side was calculated at 97.4%, indicating its strong ability to correctly detect true positive cases. Furthermore, its specificity was 100%, meaning it accurately identified all true negative cases without false positives. The *p-value* for these findings was less than 0.001, demonstrating a highly significant correlation between the BLUE protocol and CT results.

Similarly, on the left side, the CT chest scan identified 47 positive and 28 negative cases, while the BLUE protocol reported 46 positive and 29 negative cases. The sensitivity of the BLUE protocol in this case was slightly higher at 97.8%, and again, the specificity remained at 100%. These results underscore the protocol's excellent performance in diagnosing pleural effusion on both sides of the chest. The statistical significance on the left side also showed a *p-value* of less than 0.001, reinforcing the reliability of the BLUE protocol

(Table 3) presents the diagnostic performance of the BLUE (Bedside Lung Ultrasound in Emergency) protocol in detecting pneumothorax, using chest CT as the reference standard. The data is separated by side (right and left) and includes measures of sensitivity, specificity, and statistical significance.

On the right side of the chest, chest CT identified 5 positive and 70 negative cases of pneumothorax. The BLUE protocol demonstrated complete agreement, also identifying 5 positive and 70 negative cases. As a result, the sensitivity and specificity of the BLUE protocol for right-sided pneumothorax were both 100%, indicating its perfect ability to detect all true positive and true negative cases. The *p-value* for these results was less than 0.001, confirming that the findings are statistically significant. Similarly, on the left side, chest CT detected 8 positive and 67 negative cases. The BLUE protocol showed identical results, diagnosing 8 positive and 67 negative cases. Consequently, the sensitivity and specificity of the BLUE protocol on the left side were also 100%. The statistical analysis again yielded a *p-value* of less than 0.001, reinforcing the strong concordance between the BLUE protocol and CT chest in identifying pneumothorax.

(Table 4) illustrates the diagnostic performance of the BLUE (Bedside Lung Ultrasound in Emergency) protocol in detecting pneumonia, using chest CT as the reference standard. Data are presented for both the right and left lungs, highlighting the sensitivity, specificity, and statistical significance of the findings. On the right side, chest CT identified 40 cases of pneumonia and 35 negative cases. The BLUE protocol detected 38 of these positive cases and identified 37 as negative. This resulted in a sensitivity of 95%, reflecting the protocol's strong ability to correctly identify most true positive cases. The specificity was 100%, indicating that all negative cases were accurately recognized without any false positives. The statistical analysis produced a *p-value* of less than 0.001, signifying a highly significant association between the findings of the BLUE protocol and chest CT. On the left side, chest CT diagnosed 47 positive and 28 negative cases. The BLUE protocol closely mirrored these results, detecting 44 positive and 31 negative cases. The sensitivity on the left side was slightly lower at 93.6%, while the specificity remained at 100%, again confirming the protocol's reliability in ruling out pneumonia in true negative cases. The *p-value*, also below 0.001, supports the statistical significance of the observed concordance between the two diagnostic methods.

Table 1: baseline Patient characteristics

		Total (n=75)
Age (years)	Mean $\pm$ SD	63.6 $\pm$ 6.28
	Range	50 - 75
Sex	Male	38 (50.67%)
	Female	37 (49.33%)
Smokers [n (%)]		38 (50.67%)
HTN		38 (50.67%)
DM		51 (68%)
Heart disease		23 (30.67%)
Dyspnea		75 (100%)
SaO ₂ on room air (%)	Mean $\pm$ SD	87.4 $\pm$ 2.76
	Range	83 - 93
pH	Mean $\pm$ SD	7.3 $\pm$ 0.05
	Range	7.25 - 7.44
PCO ₂	Mean $\pm$ SD	46.8 $\pm$ 7.99
	Range	35 - 70
HCO ₃	Mean $\pm$ SD	24.2 $\pm$ 2.41
	Range	20 - 28
PO ₂	Mean $\pm$ SD	87.4 $\pm$ 2.7
	Range	40-59

Table 2: Diagnostic performance of bedside lung ultrasound in comparison with the standard CT scan for diagnosis of pleural effusion in each lung* Significant as P -value ≤ 0.05 .

Pleural effusion							
		Positive	Negative				
					Positive	Negative	
Right side	CT chest	38	37	Left side	CT chest	47	28
	BLUE protocol	37	38		BLUE protocol	46	29
	Sensitivity of BLUE protocol	97.4 %			Sensitivity of BLUE protocol	97.8 %	
	Specificity of BLUE protocol	100 %			Specificity of BLUE protocol	100 %	
	<i>P-value</i>	<0.001			<i>P-value</i>	<0.001	

Table 3: Diagnostic performance of bedside lung ultrasound in comparison with the standard CT scan for diagnosis of Pneumothorax in each lung* Significant as P -value ≤ 0.05 .

Pneumothorax							
		Positive	Negative				
Right side	CT chest	5	70	Left side	CT chest	8	67
	BLUE protocol	5	70		BLUE protocol	8	67
	Sensitivity of BLUE protocol		100 %		Sensitivity of BLUE protocol		100 %
	Specificity of BLUE protocol		100 %		Specificity of BLUE protocol		100 %
	<i>P-value</i>		<0.001		<i>P-value</i>		<0.001

Table 4: Diagnostic performance of bedside lung ultrasound in comparison with the standard CT scan for diagnosis of Pneumonia in each lung* Significant as P -value ≤ 0.05

Pneumonia								
		Positive	Negative					
					Positive	Negative		
Right side	CT chest	40	35	Left side	CT chest	47	28	
	BLUE protocol	38	37		BLUE protocol	44	31	
	Sensitivity of BLUE protocol	95 %			Sensitivity of BLUE protocol	93.6 %		
	Specificity of BLUE protocol	100 %			Specificity of BLUE protocol	100 %		
	<i>P-value</i>	<0.001			<i>P-value</i>	<0.001		

DISCUSSION

Computerized tomography (CT) scans, while valuable, often come with limitations, including delays in obtaining results, and the need for patient transport, which can be particularly hazardous for critically ill patients. In this context, lung ultrasonography has emerged as a promising alternative, offering a rapid, non-invasive, and bedside diagnostic tool that can facilitate immediate clinical decision-making^[2].

Critical ultrasonography, has several fundamental applications, one of which is lung ultrasound. With sensitivity and specificity ranging from 90% to 100%, ultrasonography exceeded CT in detecting all of these abnormalities, making it a reasonable "gold standard" at the bedside for the severely sick."^[3]

The Bedside Lung Ultrasound in Emergency (BLUE) method can identify acute respiratory failure in less than three minutes. Medical disorders include pneumothorax, COPD, PE, pneumonia, and PE-related swelling might lead

to individualized profiles. Our intensive care unit's medical training curriculum now includes bedside ultrasound^[4].

The BLUE procedure has shown to be an effective diagnostic tool in intensive care units (ICUs) because to its excellent sensitivity and specificity rates, which frequently surpass 90%. Although the results are encouraging, more research is needed to thoroughly evaluate the diagnostic accuracy of the BLUE procedure before it can be used in clinical practice^[4].

This study aimed to test the specificity and sensitivity of the BLUE protocol in critically ill patients admitted to the intensive care unit, investigate the feasibility of using lung ultrasonography for the rapid diagnosis of severe respiratory failure, and initiate medication without delay.

At the Armed Forces Medical Complex Kobry EL-kobba and Armed Forces Medical Complex EL-Maadi Hospitals, 75 patients hospitalized with dyspnea were part of this cross-sectional research.

Based on the results of this study, bedside lung ultrasound scanning can accurately diagnose pneumonia and hemodynamic lung edema, two of the most common causes of acute respiratory failure (ARF). It can also detect the typical symptoms of these conditions with a high degree of specificity and sensitivity, as compared to the final diagnosis and the standard CT scan evaluation. The excellent agreement and generally high diagnostic accuracy of ultrasonography of the lungs (P -value <0.001 and kappa coefficient, ≥ 0.86) between lung ultrasound scanning and the standard CT scanning evaluation confirmed the high diagnostic yield of lung ultrasound scanning. There was also almost perfect agreement (P -value <0.001 and kappa coefficient, ≥ 0.7) between lung ultrasound scanning performed at admission and the study repeated 4 days later in the detection of conventional signs observed in the different most common etiologies of ARF with good sensitivity, specificity and predictive values.

This modality may be confidently and easily employed by non-radiologists in the assessment of acute respiratory failure, and our results were similar to and comparable with those of other research.

In same line with us, a study conducted a randomized clinical experiment to determine the effect of a trained emergency physician's implementation of the BLUE protocol on the rapid identification and respiratory distress management in the emergency department. Fifty people with severe respiratory distress were enrolled in the research. Their results show that the BLUE approach can drastically cut down on the amount of time it takes to manage patients and the time it takes to provide certain treatments in the emergency department while they are experiencing acute respiratory distress^[5].

Another study compared the preliminary diagnosis established using the lung ultrasound to the final diagnosis, assessed all clinical and investigative data of one hundred patients who were part of the study, and determined the lung ultrasound's diagnostic value according to the BLUE protocol. The three items that were examined were alveolar consolidation, pleural effusion, artifacts (such as interstitial syndrome's horizontal A lines or vertical B lines), and lung slide. When necessary, a venous scan was performed to detect deep venous thrombosis. Pulmonary oedema accounted for 23% of the final diagnosis, pneumothorax for 9%, pulmonary embolism for 2%, and pneumonia for 34%. In their study, the lung ultrasound demonstrated the following accuracy rates: Pulmonary edema had a sensitivity of 96% and specificity of 99%, pneumothorax had a sensitivity of 100% and specificity of 100%, pulmonary embolism had a sensitivity of 100% and specificity of 99%, and pneumonia had a specificity of 88% and specificity of 92%. Lung ultrasonography, according to the authors, has a high diagnostic yield when used in the BLUE protocol to assess patients suffering from acute respiratory failure^[6].

Another study assessed the efficiency of the BLUE protocol in identifying respiratory failure in patients admitted to the intensive care unit (ICU). The technique involves doing a bedside ultrasound of the lungs. According to the results, the US profile was able to correctly identify the following conditions: 21 cases of asthma or chronic obstructive pulmonary disease (COPD) with a sensitivity of 80.95% and a specificity of 96.2%; 22 cases of pulmonary edema with a sensitivity of 90.9% and a specificity of 94.8%; 11 cases of pulmonary embolism with a sensitivity of 72.7% and a specificity of 98.8%; 4 cases of pneumothorax with a sensitivity of 75% and 100% accuracy; and 42 cases of pneumonia with a sensitivity of 92.86% and a specificity of 91.4%. According to Omar *et al.*, the BLUE protocol is an essential tool for the rapid diagnosis of ARF-causing disorders; it is also a practical and user-friendly tool for the intensive care unit^[7].

Also, a study conducted a hospital based cross-sectional, descriptive, prospective study among 150 patients who were admitted into ICU suspected with ARF. Patients were tested initially using lung ultrasound scanning and BLUE protocol without interrupting other management. In patients admitted to the critical care unit with severe respiratory failure, lung ultrasonography consistently detected pneumothorax, alveolar-interstitial syndromes, parenchymal consolidations, and pleural effusion, just as computed tomography (CT) imaging. Accuracy was 90.48% in diagnosing pulmonary edema using lung ultrasound scanning in the ICU^[8].

Another study compared the findings of lung ultrasonography from the initial presentation to the definitive diagnosis when utilizing standard procedures with a cross-sectional study of sixty consecutive patients admitted to the critical care unit due to the abrupt development of dyspnea. Although the results from the lung ultrasonography were significantly better than those from the chest computed tomography (CT) scan, the BLUE protocol had a sensitivity of 91.4% for the diagnosis of pneumonia, 92.8% for pulmonary edema, 90% for pneumothorax, 88.8% for pleural effusion, and 78.6% for chronic obstructive pulmonary disease (COPD). They propose the BLUE protocol for lung ultrasonography, a noninvasive, fast, dynamic, and bedside method that may play an important part in the intensive care unit's diagnostic process for patients experiencing sudden onset of respiratory distress^[9].

CONCLUSIONS

The integration of the BLUE protocol into routine ICU practice facilitates timely and accurate diagnosis, with ultrasound findings showing strong concordance with baseline CT results. This alignment supports its reliability in identifying causes of respiratory failure and enables earlier, more targeted interventions. By reducing diagnostic delays.

LIMITATION OF THE STUDY

1. Small sample size
2. Time of doing BLUE protocol after ct chest can alter the result

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Suh ES, Hart N. Respiratory failure. *Medicine*. 2012 Jun 1;40(6):293-7.
2. Brooks D, Wright SE, Beattie A, McAllister N, Anderson NH, Roy AI, Gonsalves P, Yates B, Graziadio S, Mackie A, Davidson J. Assessment of the comparative agreement between chest radiographs and CT scans in intensive care units. *Journal of Critical Care*. 2024 Aug 1;82:154760.
3. Bhalla AS, Das A, Naranje P, Irodi A, Raj V, Goyal A. Imaging protocols for CT chest: a recommendation. *Indian Journal of radiology and imaging*. 2019 Jul;29(03):236-46.
4. Lau YH, See KC. Point-of-care ultrasound for critically-ill patients: a mini-review of key diagnostic features and protocols. *World Journal of Critical Care Medicine*. 2022 Mar 9;11(2):70.
5. Seyedhosseini J, Bashizadeh-Fakhar G, Farzaneh S, Momeni M, Karimialavijeh E. The impact of the BLUE protocol ultrasonography on the time taken to treat acute respiratory distress in the ED. *The American journal of emergency medicine*. 2017 Dec 1;35(12):1815-8.
6. Yadav S, Singh A, Manisha K, Khanna P. Point of care ultrasound in coronavirus disease 2019 pandemic: one modality helping multiple specialties. *Journal of Medical Ultrasound*. 2021 Jan 1;29(1):9-14
7. Abdallah Alkumity AA, Basiony FS. Relevance of Bedside lung Ultrasound in Emergency protocol (BLUE protocol) in the diagnosis of lung pathology in patients with respiratory failure admitted to intensive Care Unit. *Al-Azhar International Medical Journal*. 2022 May 1;3(5):120-5.
8. Neeraj G, Vadlani V, Diwakarla V, Pasha SA. Efficacy of BLUE Protocol in Diagnosing Respiratory Failure in Patients Attending a Multidisciplinary ICU In a Teaching Hospital. *European Journal of Cardiovascular Medicine*. 2023 Oct 1;13(4).
9. Amin Koraa AE, Elansary AM, Mohamed Hussen MH, Hussen RM, Elgamal LA. The Value of BLUE Protocol in the Diagnosis of Acute Onset of Respiratory Distress in Critically Ill Patient. *QJM: An International Journal of Medicine*. 2024 Jun 1;117(Supplement_1):hcae070-004.