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## Original Contribution

# The impact of the BLUE protocol ultrasonography on the time taken to treat acute respiratory distress in the ED



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## 1. Introduction

Respiratory distress is one of the most common complaints in the emergency department (ED) [1]. In extreme scenarios, during which respiratory distress becomes respiratory failure, the survival of the patients will significantly drop [2]. For instance, a recent cohort study showed that the mortality rate among hospitalized patients with respiratory distress was as much as 10% [3].

Hence, in the management of a patient with respiratory distress, using a timely approach to differentiate the underlying causes and initiating specific therapies (decompression of the pneumothorax, intubation and ventilation support, bronchodilators or corticosteroid nebulization, anticoagulation and fibrinolytic therapy in pulmonary thromboembolisms, etc.) is of undisputed importance.

In 2008, the Bedside Lung Ultrasound in Emergency (BLUE) protocol was developed to guide the diagnosis of respiratory distress [4]. Lichtenstein and his colleagues who proposed the BLUE protocol, showed that the diagnostic accuracy of lung ultrasound (LUS) in the Intensive Care Unit (ICU) was 90.5%. Similarly, Silva et al. demonstrated that LUS was more accurate in cases of acute respiratory failure than routine approaches (patient history and physical examination, radiologic and laboratory evidence) [5].

The BLUE protocol enables physicians to differentiate the underlying causes of respiratory failure. More to the point, LUS was proved to be effective in the monitoring of therapeutic responses in acute respiratory distress syndrome (ARDS) [6].

The BLUE protocol can be applied using a simple ultrasound machine equipped with a micro-convex array transducer [7]. Nevertheless, performing an accurate LUS requires specific training [8]. Although current evidence encourages the use of LUS in treating respiratory distress in critical care, it is not widely accepted in EDs [9].

We hypothesized that utilizing a bedside testing protocol such as the BLUE protocol in the ED may shorten the time interval between patient admission and the delivery of any definitive treatment [10]. We have therefore conducted a randomized clinical trial to assess whether or not the application of the BLUE protocol by a trained emergency physician has an impact on the timely diagnosis and treatment of respiratory distress in the ED.

## 2. Methods

From August 2015 to March 2016, all consecutive patients who visited the EDs of two university affiliated teaching hospitals in Tehran, Iran were evaluated. Patient flow in these EDs can be as high as 150,000 annually.

Patients were included in the study if they met the following criteria: 1. They were aged over 12 years and 2. Were suffering from acute respiratory distress (within the past seven days). Exclusion criteria were: 1. dyspnea due to a previously diagnosed medical condition, 2. lack of consent and 3. cardiopulmonary arrest on arrival in the ED.

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Initially, a group of three board-certified emergency physicians visited the patients. After taking the patients' history and performing a physical examination, the patients were randomly (using computerized block randomization) divided into BLUE protocol and control groups. Both groups were evaluated using routine approaches [chest X-ray and biochemistry for all patients, lung CT scan in 6 (33.3%) BLUE protocol and 8 (53.3%) control patients, based on the discretion of treating physicians (Table 2)], but in BLUE protocol group each patient received an additional LUS examination with a 2–5 MHz curved array transducer and a 7.5–10 MHz linear probe (SonoAce X8 Ultrasound System, Samsung Electronics Co., Ltd) by another attending emergency physician skilled in ultrasound. The sonographer was not involved in the other steps of patient care, but the treating physicians used the results of the lung ultrasound examination in their decision making. The bedside ultrasound test was performed upon admission to the ED and lasted for up to 5 min.

The LUS was evaluated for the main diagnoses, including pneumonia, pulmonary edema, pneumothorax, COPD, asthma and plural effusion. According to the BLUE protocol, three quadrants on each side of the chest (the upper and lower parts of the anterior chest and the posterolateral chest wall) were examined by LUS [4].

Eventually, a definite diagnosis was made by using standardized tests for all patients. Triage time, the time of admission to the ED and the time of receiving definitive treatment were recorded for each patient.

Based on prior studies, the average time taken to receive special treatment for dyspnea is about 90 min [4].

To show the difference in the timings, with a standard deviation of 40 min and  $\alpha = 0.05$ , we needed to recruit 13 patients into each arm of the study.

The local ethics committee of Tehran University of Medical Sciences approved the conduct of the study. Informed consent was obtained from all the participants.

The data were analyzed using the SPSS statistical software package (SPSS, Chicago, IL, USA). The variables were initially analyzed using the Kolmogorov–Smirnov test, then we used the Student's *t*-test for the continuous variables and the Mann–Whitney *U* test for comparing the non-continuous variables. The qualitative data were analyzed using the Chi-squared test. We considered a *p* value of below 0.05 to be statistically significant.

### 3. Results

Fifty patients were recruited into the study. Of these, 29 (58%) were male and 21 (42%) were female. The mean ( $\pm$ SD) age of the participants was 63/17  $\pm$  42/61 years.

There was no significant difference between the case study and control groups in terms of age, gender and Body Mass Index (BMI) (Table 1).

A definitive diagnosis was made by performing routine evaluations, including a chest radiography and CT scan, an echocardiography by cardiologists, a bronchoscopy and pulmonary function tests by pulmonologists and biochemical data. However, in the BLUE group, the treating emergency physicians used the results of the LUS as a guide in the decision-making process. This means that if the LUS

**Table 1**  
Demography of the participants

	BLUE protocol	Control	<i>P</i> value
Age (year, mean $\pm$ S)	65.56 $\pm$ 14.65	57.28 $\pm$ 19.6	0.1
Gender (n%)			
Male	17(68%)	12(48%)	0.15
Female	8(32%)	13(52%)	
BMI (kg/m <sup>2</sup> )	23.97 $\pm$ 4.42	25.63 $\pm$ 5.72	0.26

**Table 2**  
Diagnostic tools in patients with acute respiratory distress

Diagnostic evaluation	BLUE group n(%)	Control group n(%)
Pulmonary function test	0	2(11.1)
Echocardiography	6(40)	7(38.9)
Chest CT scan	6(33.3)	8(53.3)
Bronchoscopy	3(16.7)	0

indicated a definite diagnosis, the next step was to confirm that specific diagnosis by routine means (Table 2).

The most frequent final diagnoses for both groups were pneumonia and cardiogenic pulmonary edema, respectively (Table 3).

The median admission-treatment time interval for the BLUE group was 17 min, while it was 38 min for the control group. The difference between the two groups was statistically significant ( $p < 0.0001$ ) (Fig. 1).

The average hospital stay (mean  $\pm$  SD) for the BLUE group was 7  $\pm$  5.8 days, while for the controls it was 7.72  $\pm$  6.8 days. The difference between the two groups was not statistically significant (*p* value: 0.07).

There was one (4.2%) death in the BLUE group and there were three deaths (13.6%) in the control group. This difference was not statistically significant (*p* value: 0.34).

### 4. Discussion

The vast majority of the literature demonstrates that the benefits of ultrasound in the field of critical care are ubiquitous. As technology develops, new ultrasound machines are enabling physicians to obtain clearer images at the patient's bedside [11,12,27–29].

Nowadays, bedside ultrasound is well-known in various fields of patient care in EDs, including point-of-care echocardiography, EFAST (Extended Focused Assessment with Sonography for Trauma) and RUSH (Rapid Ultrasound in Shock) examination. In addition, ultrasound is an adjunct to many ED procedures, such as central and peripheral venous access, thoracentesis, paracentesis, arthrocentesis and confirming correct laryngeal intubation. Current evidence encourages the use of ultrasound in various fields of medicine, as well as in emergency medicine [13,14].

Lichtenstein et al. evaluated 260 dyspneic patients in the ICU using both LUS and conventional methods. They reported that over 25% of patients evaluated by conventional methods still had an uncertain diagnosis within the first 2 h of admission, while even more patients received incorrect therapies. They have reported that the BLUE protocol was 90.5% accurate in diagnosing the underlying causes of acute respiratory distress, including cardiogenic pulmonary edema, pneumonia, COPD exacerbation, asthma attack, pulmonary emboli and pneumothorax [11].

**Table 3**  
Final diagnosis and time-to-treatment in the participants

Diagnosis	BLUE group		Control group	
	n(%)	Treatment onset (min)	n(%)	Treatment onset (min)
Pneumonia	13(52)	34	12(48)	73
Asthma	1(4)	15	2(8)	24
COPD	1(4)	25	2(8)	46
ILD*	1(4)	15	3(12)	38
Cardiogenic pulmonary edema	6(24)	18	3(12)	28
Pneumothorax	2(8)	10	2(8)	15
Pneumonia + pulmonary edema	1(4)	17	1(4)	75
Total n(%)	25(100)		25(100)	
Median time-to-treatment (min)	17		38	

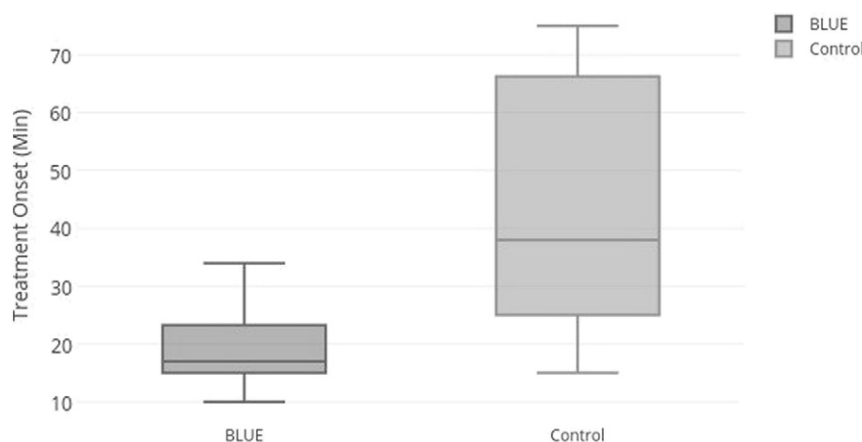


Fig. 1. Admission-treatment time interval in acute dyspneic patients.

There are also other reports about the accuracy of LUS in diagnosing the causes of acute respiratory distress [15–18].

In 2009, Cardinale et al. reported that bedside LUS cuts costs and saves time in the treatment of acute respiratory distress in the ICU [19]. In 2014, Ünlüer and Karagöz compared LUS and radiography in the management of pneumonia. They showed that LUS was more rapid and also more accurate in diagnosing pneumonia [20].

In 2015, Neto et al. applied the BLUE protocol to 57 dyspneic patients in the ICU. They reported that all patients were evaluated by LUS in <20 min, and that the most common causes of dyspnea were pneumonia and cardiogenic pulmonary edema [21].

In 2013, Xirouchaki et al. applied LUS to 189 critical ICU patients with respiratory failure to assess the impact of LUS on decision-making and the therapeutic management of the patients. They reported that patient management was impacted directly as a result of LUS information in 119 of 253 cases (47%) [22]. In 2016, Mozzini et al. showed that the application of LUS by trained internal medicine residents expedited the diagnosis of the causes of respiratory distress [23]. Other studies showed that utilizing LUS (not specifically the BLUE protocol) in different cases, such as pneumonia and pneumothorax, shortens the time taken to establish a definitive diagnosis [9,24]. Although evidence supports the accuracy of the BLUE protocol, its time-saving advantages have not been fully elucidated, specifically in the ED environment.

The recommended justification for the preference of LUS in cases of acute dyspnea is the fact that LUS is portable and can be performed at the bedside, such that there is no need to move the patient to the CT scan or radiology units. Besides, in comparison to a portable X-ray machine, a US machine is more convenient to handle, and provides greater accuracy in diagnosing lung abnormalities in the hands of a skilled operator [30–33]. While the BLUE protocol can be performed by a single skilled operator, obtaining a CT scan or X-ray requires at least a radiology technician, a nurse to monitor the patient and staff to transfer the bed. It is therefore predictable that organizing a group of staff will take more time. There is a further time gap between taking an image and transferring the data to the hospital's PACS (Picture Archiving and Communication System). Conversely, for US, the image is readily available at bedside without any of the abovementioned delays [8,25,26].

Although the BLUE protocol seems complicated at first sight, studies have shown that the skill can be learned simply by encouraging emergency physicians to learn the examination [34]. Others have shown this propensity not to be limited only to emergency physicians, but can be extended to nurses as well [11,35].

Based upon the current literature, the BLUE protocol is simple to use and requires simple equipment (an ultrasound machine with a simple convex probe) [7].

The results of the present study into the application of the BLUE protocol in the ED were in accordance with all of the previous reports

showing a significant improvement in the diagnosis and time taken to manage patients when LUS was applied in the ICU and in critical care.

Our limitations were: 1. Crowding of the EDs, which had an impact on patient care. Some patients left the ED due to overcrowding to seek medical care in private hospitals; 2. All of the LUS exams were performed by one skilled operator, so we could not compare the results of these exams with those of another operator to calculate the inter-observer reliability. Also, it is not clear whether or not novice sonographers would reach the same conclusions after participating in a short course; and 3. Our sample size was limited and this can impact the final outcome of the patients.

## 5. Conclusion

Our findings showed that utilizing the BLUE protocol in cases of acute respiratory distress in the ED will significantly shorten the time taken to manage patients and decrease the gap in delivering definite therapies.

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