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The application of BLUE (bedside lung ultrasound in emergency) protocol in the emergency department

Acil serviste BLUE (acil durumda yatakbaşı akciğer ultrasonu) protokolünün uygulanması

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ABSTRACT

Aim: This study aimed to evaluate the effectiveness of lung ultrasonography (US) in detecting the cause of acute respiratory distress in the emergency department.

Materials and Methods: This cross-sectional analytical study was carried out on 195 adult patients who were admitted to the Emergency Department of a University Hospital with acute respiratory failure in 6months period. The validity of the US diagnoses was assessed by comparing the decisions made by researchers according to the BLUE protocol classification with the final judgments made by the primary doctors using gold-standard diagnostic techniques suggested by the guidelines.

Results: The diagnostic accuracy of chest ultrasound was 89.7%. Specifically, ultrasound demonstrated 95.6% sensitivity and 99% specificity for diagnosing Congestive Heart Failure (CHF), 94.3% sensitivity and 97.2% specificity for Chronic Obstructive Pulmonary Disease (COPD), 94.2% sensitivity and 91.2% specificity for pneumonia, and 100% sensitivity and specificity for Pneumothorax (PTX). In contrast, the sensitivity for Pulmonary Embolism (PE) diagnosis was 66.7%. Ultrasound also identified pneumonia associated with CHF with 83.3% sensitivity and 96.0% specificity, and pneumonia associated with COPD with 54.6% sensitivity and 98.4% specificity. The diagnostic accuracy of routine physical examination and chest X-ray, which are standard for assessing respiratory distress at the bedside in the emergency department, was compared with ultrasound. The accuracy rates for CHF were 89.2%/81.9%/97.4%; for COPD were 90.8%/77.8%/96.4%; for pneumonia were 76.9%/93.8%/92.3%; for PE were 90.8%/90.7%/96.4%; and for PTX were 99.5%/100%/100%, respectively. Additionally, the average time difference between the requests and screenings for X-ray and chest CT was 1.36 hours and 2.26 hours, respectively.

Discussion: Our study demonstrated that chest ultrasound is an effective and feasible diagnostic tool for diagnosing CHF, COPD, pneumonia, PE, and PTX. Compared to gold standard tests, ultrasound reduced the diagnostic time and provided more reliable results than physical examination.

Keywords: Lung ultrasonography, blue protocol, emergency department, pulmonary edema, COPD

ÖZ

Giriş: *Bu çalışmada acil serviste akut solunum sıkıntısının nedeninin saptanmasında akciğer ultrasonografisinin (US) etkinliğinin değerlendirilmesi amaçlandı.*

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Gereç ve Yöntem: *Bu kesitsel analitik çalışma, bir Üniversite Hastanesi Acil Servisi'ne 6 aylık sürede akut solunum yetmezliği nedeniyle başvuran 195 yetişkin hasta üzerinde gerçekleştirildi. US teşhislerinin geçerliliği, araştırmacıların BLUE protokol sınıflandırmasına göre verdiği kararlar ile primer doktorların kılavuzların önerdiği altın standart teşhis tekniklerini kullanarak verdikleri nihai kararların karşılaştırılması yoluyla değerlendirildi.*

Bulgular: *Akciğer ultrasonunun tanısal doğruluğu %89,7 olarak bulunmuştur. Özellikle, ultrasonun Konjestif Kalp Yetmezliği (KKY) tanısındaki duyarlılığı %95,6 ve özgüllüğü %99; Kronik Obstrüktif Akciğer Hastalığı (KOAH) tanısındaki duyarlılığı %94,3 ve özgüllüğü %97,2; pnömoni tanısındaki duyarlılığı %94,2 ve özgüllüğü %91,2; ve Pnömotoraks (PTX) tanısındaki duyarlılığı ve özgüllüğü %100 olarak tespit edilmiştir. Buna karşın, Pulmoner Tromboembolizm (PTE) tanısındaki duyarlılık %66,7'dir. Ultrason ayrıca, KKY ile ilişkili pnömoniyi %83,3 duyarlılık ve %96,0 özgüllükle, KOAH ile ilişkili pnömoniyi ise %54,6 duyarlılık ve %98,4 özgüllükle teşhis etmiştir. Acil serviste yatak başında solunum sıkıntısını değerlendirmek için kullanılan rutin fizik muayene ve akciğer grafisinin tanısal doğruluğu ultrason ile karşılaştırılmıştır. KKY için tanısal doğruluk oranları sırasıyla %89,2/%81,9/%97,4; KOAH için %90,8/%77,8/%96,4; pnömoni için %76,9/%93,8/%92,3; PTE için %90,8/%90,7/%96,4; ve PTX için %99,5/%100/%100 olarak saptanmıştır. Ek olarak, çalışmamızda X-ray ve toraks BT istekleri ile tarama süreleri arasındaki ortalama fark sırasıyla 1,36 saat ve 2,26 saat olarak hesaplanmıştır.*

Tartışma: *Çalışmamız; akciğer US'un KKY, KOAH, pnömoni, PTE ve PTX tanısında etkili ve uygulanabilir bir tanısal araç olduğunu gösterdi. US, altın standart testlerle karşılaştırıldığında tanı süresini kısalttı ve fizik muayeneye göre daha güvenilir sonuçlar ortaya koydu.*

Anahtar Sözcükler: *Akciğer ultrasonografisi, BLUE protokolü, acil servis, akciğer ödemi, KOAH.*

INTRODUCTION

Respiratory distress is one of the most common reasons for visiting the Emergency Departments (ED) among all age groups (1). Also, acute dyspnea is a leading symptom of many diseases that may cause morbidity and mortality. A rapid distinction of the underlying pathologies causing dyspnea may sometimes be difficult in EDs (2). However, it is crucial to differentiate reasons of high morbidity and mortality in the EDs.

It is known that physical examination and bedside radiography during the evaluation of dyspnea in the ED may be insufficient for the diagnosis and treatment process, and the application of further tests may lead to serious time loss (3). Therefore, it has been suggested that the lung B-mode ultrasound (US) can be used for rapid diagnosis in patients with acute dyspnea (4). The low running cost, bedside availability, repeatability, and absence of radiation are emphasized as the advantages of US. In most studies, it has been highlighted that lung US is highly sensitive to the variations of pulmonary content and air-fluid balance (5, 6). Additionally, it has been reported that lung US may be a useful technique for the diagnosis of some pulmonary diseases based on the differences in air and fluid contrast (3, 7, 8).

BLUE protocol is the application of lung US based on the grouping of artifacts, pleural changes, alveolar consolidation, and pleural effusions to make an accurate diagnosis (3, 8).

This study aimed to investigate the efficacy of the BLUE protocol in identifying the underlying cause in patients referred to the EDs with acute respiratory failure.

MATERIALS and METHODS

Study design and Patient selection

This cross-sectional analytical study was carried out on 195 adult patients who were admitted to the ED of a University Hospital with acute respiratory failure in six months. The ethical approval was obtained Ege University, Ethical Committee (Approval number: 10-9.1/4). Patients under the age of 18, having structural lung disease, had undergone surgical intervention (pneumonectomy or lobectomy) or pleurodesis were excluded from the study.

Investigators

All patients were evaluated with lung US by investigators who did not participate in the primary follow-up and treatment of the individual patient. The investigators were emergency medicine resident doctors who had received "basic emergency ultrasonography" training and had experience of using the US in emergency patient care for at least two years. The diagnosis and treatment of the patients were carried out by other ED physicians who were blind to the US results. The investigators and treating physicians filled two different data collection forms, which were collected in two separate closed boxes.

Table-1. Gold standards according to guideline recommendations (9-13).

Pneumothorax	Chest radiography, CT (if necessary)
Cardiogenic edema	ECHO, functional tests, AHA recommendations
PTE	Wells criterion, D-dimer, Thorax angio CT
COPD attack	PFT (Respiratory function test)
Pneumonia	Infectious profile, radiological asymmetry, microorganism isolation, response to antibiotics

CT: Computed Tomography, ECHO: Echocardiography, AHA; American Heart Association, PTE: Pulmonary Thromboembolism, COPD: Chronic Obstructive Pulmonary Disease

Additionally, a cardiologist (for diagnosis of CHF), a radiologist (for diagnosis of PTX and PTE), and a chest physician (for diagnosis of COPD and Pneumonia) who are experts in their fields examined the filled forms and evaluated whether an accurate diagnosis was made according to the gold standards recommended by the current guidelines (Table-1).

Ultrasonographic Evaluation and Procedure

The US Device

The ultrasonographic evaluation was performed by a portable USG device (Sonosite Micromaxx, SonoSite Inc., USA) using a 5-MHz micro convex probe and a 7.5-MHz linear probe.

Procedure

US was performed without interruption during the admission of the patient to the ED (within the first 10 minutes).

Each hemithorax was divided into three regions by anterior and posterior axillary lines (Figure-1a-b). All three areas of both lungs were longitudinally scanned (Figure-2a-b). Findings such as artifacts (A-line, B-line), lung sliding (present/absent), pleural effusion (present/absent), alveolar consolidation (present/absent) were recorded according to the systematic analysis per the BLUE protocol (14).

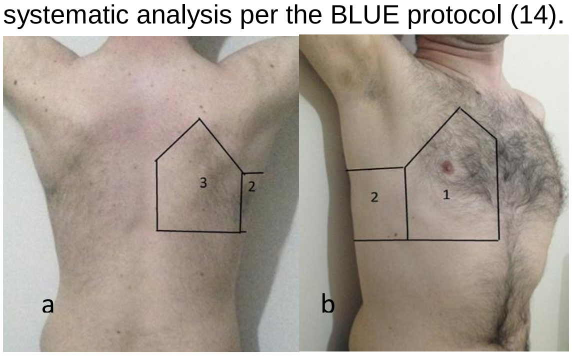

Figure-1a-b. Three lung regions based on anterior and posterior axillary lines

Venous study, a part of the BLUE protocol, was carried out after performing the US. Subclavian, jugular, femoral, and popliteal veins of the patients were detected by the linear probe, followed by the compression method and Doppler. Veins which could not be compressed or did not show blood flow were accepted as positive for DVT (1, 15).

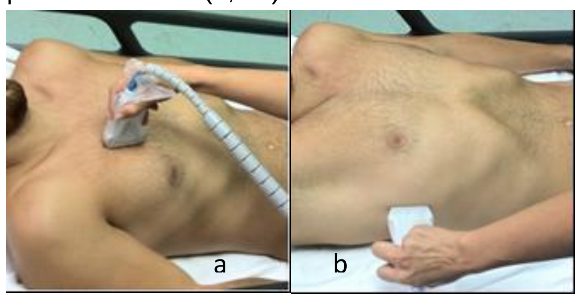

Figure-2a-b. Longitudinal scanning of the chest wall during lung US.

Interpretation of Lung Ultrasonographic Images:

In the ultrasonographic image, it was confirmed that when the pleural line (a hyperechoic white horizontal line located 0.5 cm below the rib line) was visible, the US probe had seen the parenchyma.

The surface appearance of the normal lung consists of the bat sign (normal intercostal appearance of the pleura and lung parenchyma), lung sliding (a movement in rhythm with respiration, indicating sliding of the visceral pleura against the parietal pleura), the A-line (hyperechoic horizontal artifacts arising from the pleural line), and comet-tail artifacts (irrelevant with lung sliding, and not erasing A-lines). The A-profile was defined as the presence of anterior lung sliding with A-lines (3, 16, 17).

Pleural effusion: The roughly quadrangular shapes and sinusoid signs with a regular lower border (the visceral pleura) was required for the diagnosis of pleural effusion (18–20).

Chronic Obstructive Pulmonary Disease (COPD): An A-profile without DVT or "posterior and/or lateral alveolar and/or pleural syndrome" (PLAPS) (the nude profile) was the typical profile indicating asthma or COPD.

Interstitial edema: The B-profile is a profile where three or more B-lines are observed between two ribs. The B-line always arises from the pleural line and moves in concert with lung sliding. Additionally, it isa well-defined, always long, laser-like, and hyperechoic comet-tail artifacts erasing A-lines (17, 21).

Pneumonia: Alveolar consolidations (hypoechoic tissue-like sign - C profile), bronchograms (internal hyperechoic punctiform appearance corresponding to air-filled bronchi), A profile plus PLAPS (the evaluation of pleural effusions and alveolar consolidations), and A/B profile (B-lines on one side, A-lines on the other) were the typical profiles indicating pneumonia (3, 22, 23).

Pneumothorax (PTX): Abolished lung sliding, the absence of B-lines, loss of "seashore sign," and detection of lung-point were the typical profiles indicating pneumothorax (3,24).

Pulmonary Thromboembolism (PTE): In the venous analysis, the detection of A-profile plus DVT positivity was connected to PTE (3, 16, 25).

Statistical Analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS, version 20, IBM, Armonk, New York 10504, NY, USA). Data were expressed as numbers, percentages, and mean±SDs (standard deviations). Sensitivity, specificity, positive (PPV) and negative (NPV) predictive values, accuracy, and likelihood ratios (LR) were calculated with 95% confidence intervals in relation to the final diagnosis, confirmed with recommended gold standards according to the guidelines. The McNemar Test was used to compare the sensitivity and the specificity of lung US and conventional ED evaluation. The level of significance, p, was set at 0.05.

RESULTS

The study included 215 patients with acute respiratory failure. Although 20 patients were included in the study during the initial evaluation, they were excluded according to the exclusion criteria (Table-2).

Table-2. Patient flow diagram.

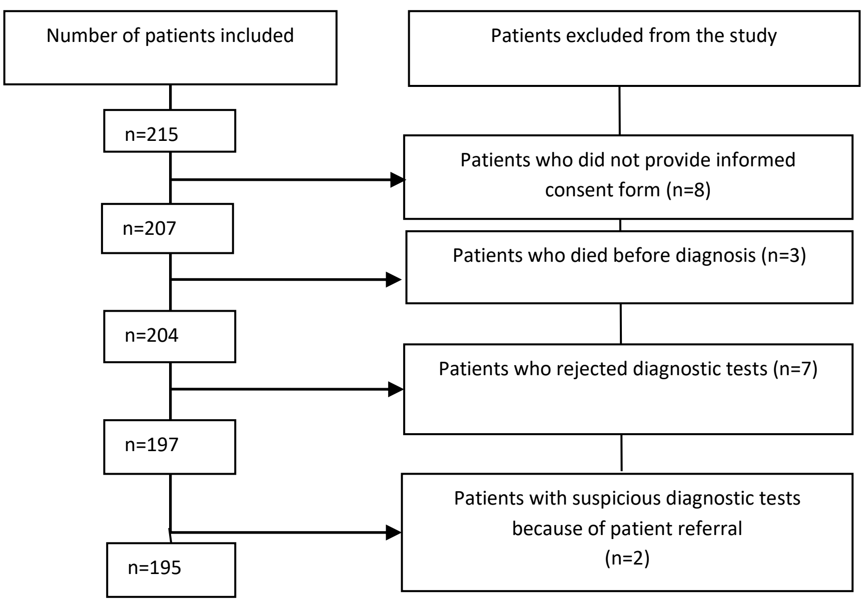

Table-3. Sensitivity, specificity, positive-negative predictive values, and diagnostic accuracy rates of US diagnoses.

Diagnoses	Ultrasound Signs	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	+LR	- LR	Accuracy
Pulmonary edema	Diffuse bilateral anterior B-1 lines associated with lung sliding (B profile)	95.6 (89.1-98.8)	99 (94.8-99.9)	98.9 (92.5-99.8)	96.3 (90.8-98.5)	99.4 (14.1-699.57)	0.04 (0.02-0.1)	97.4 (94.1-99.2)
COPD	Predominant anterior A lines without PLAPS and with lung sliding (normal profile), or with absent lung sliding without lung point	94.3 (84.38-98.8)	97.2 (92.9-99.3)	92.6 (82.6-97.05)	97.9 (93.9-99.3)	33.5 (12.7-88.2)	0.06 (0.02-0.18)	96.4 (92.7-98.5)
Pneumonia	Alveolar consolidation	94.2 (85.8-98.4)	91.2 (84.92-95.6)	85.6 (77.0-91.3)	96.6 (91.7-98.7)	10.79 (6.12-19.0)	0.06 (0.02-0.16)	92.3 (87.6-95.6)
PTE	Predominant anterior bilateral A lines plus venous thrombosis	66.7 (41.0-86.7)	99.4 (96.9-100)	92.3 (62.3-98.9)	96.7 (93.9-98.2)	118 (16.3-855.9)	0.34 (0.18-0.65)	96.41 (92.7-98.5)
PTX	Absent anterior lung sliding, absent anterior B lines, and present lung point	100 (47.8-100)	100 (98.1-100)	100	100	0	0	100 (98.1-100)
COPD +Pneumonia		83.3 (62.6-95.39	96.0 (91.7-98.3)	74.0 (57.5-85.8)	97.6 (94.4-99.0)	20.36 (9.64-42.68)	0.17 (0.07-0.42)	94.4 (90.1-97.1)
Pulmonary edema + Pneumonia		54.6 (23.4-83.3)	98.4 (95.3-99.7)	66.7 (36.4-87.4)	97.3 (94.99-98.6)	33.5 (9.63-116.2)	0.46 (0.24-0.88)	95.6 (92.1-98.2)

COPD: Chronic Obstructive Pulmonary Disease, PLAPS: Posterior and/or lateral alveolar and/or pleural syndrome, PTE: Pulmonary Thromboembolism, PTX: Pneumothorax, PPV: Positive Predictive Value, NPV: Negative Predictive Value, LR: Likelihood Ratio

Of the patients, 129 (66.2%) were male, and 66 (33.8%) were female. The mean age was 66.7±13.6 years (range 23 to 90 years).

When all diagnostic groups were taken into account, the diagnostic accuracy of lung US was 89.7%. Further, this diagnostic accuracy was not affected by patient-related variables such as age, gender, comorbidity, and vital status.

A statistically significant similarity/accuracy was detected in patients diagnosed with pulmonary edema, COPD, pneumonia, PTE, and PTX when the ultrasonographic diagnosis was compared to the gold standard diagnostic tests (p<0.001). Ultrasonographic accuracy rates are given in Table-3.

According to the gold standard tests, patients who were diagnosed with Congestive Heart Failure (CHF) (n = 91), COPD (n = 53), pneumonia (n = 69), and PTX (n = 5) could be diagnosed by US with high sensitivity and specificity. On the other hand, ultrasonographic specificity was quite low in patients diagnosed with PTE (n = 18).

Besides, US has revealed combined pathologies such as pneumonia associated with CHF, or pneumonia associated with COPD, with high sensitivity and specificity (Table-3).

In our study, we calculated the sensitivity, specificity and diagnostic accuracy rates of lung auscultation and radiography separately for each disease and compared them with lung US. These results are shown in Table-4.

Finally, we separately calculated the average of the difference between XR and CT request and scan times to give an idea of the time it takes to reach a diagnosis in traditional diagnostic processes. The mean difference between XR and thorax CT request and scanning times was calculated as 1.36 and 2.26 hours, respectively.

Table-4. Comparison of sensitivity, specificity, and diagnostic accuracy rates of lung auscultation, radiography, and US.

Diagnoses	Lung auscultation			Radiography			US		
	Sensitivity (95% CI)	Specificity (95% CI)	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	Accuracy	Sensitivity (95% CI)	Specificity (95% CI)	Accuracy
CHF	85.7 (76.8-92.2)	92.3 (85.4-96.6)	89.2 (84.0-93.2)	64.4 (53.6-74.3)	97.1 (91.8-99.4)	81.9 (75.8-87.1)	95.6 (89.1-98.8)	99 (94.8-99.9)	97.4 (94.1-99.2)
COPD	84.9 (72.4-93.3)	93.0 (87.4-96.6)	90.8 (85.8-94.4)	24.3 (13.7-38.3)	97.9 (93.9-99.6)	77.8 (71.3-83.5)	94.3 (84.38-98.8)	97.2 (92.9-99.3)	96.4 (92.7-98.5)
Pneumonia	39.7 (28.0-52.3)	96.8 (92.1-99.1)	76.9 (70.4-82.6)	92.6 (83.7-97.6)	94.4 (88.9-97.7)	93.8 (89.4-96.7)	94.2 (85.8-98.4)	91.2 (84.92-95.6)	92.3 (87.6-95.6)
PTE	0 (0-18.5)	100 (97.5-100)	90.8 (85.8-94.4)	11.1 (1.37-34.7)	98.8 (95.9-99.8)	90.7 (85.7-94.4)	66.7 (41.0-86.7)	99.4 (96.9-100)	96.4 (92.7-98.5)
PTX	80.0 (28.36-99.5)	100 (98.1-100)	99.5 (97.2-100)	100 (47.8-100)	100 (98.1-100)	100 (98.12-100)	100 (47.8-100)	100 (98.1-100)	100 (98.1-100)

DISCUSSION

Results of our study concerning sensitivity and specificity rates were similar to the study of Lichtenstein et al. and other scientific studies which utilized the BLUE protocol (3, 26). This result proved the reliability of lung US, which was applied in patients from different contexts.

In our study; COPD, CHF and pneumonia were identified with high accuracy, sensitivity and specificity rates. This result is similar to literature (3-5). The study also recognized cases where these diseases were combined with pneumonia with high accuracy and specificity. The ability of lung US to distinguish several accompanying pathologies with high accuracy, unlike traditional diagnostic methods, may be an important result for ED practice. There is no US study in the literature with which we can compare this result regarding combined diagnoses.

In this study, it was found that both the sensitivity and specificity rates of US in detecting pneumothorax were 100 %. Therefore, lung US can be defined as a rapid, accurate, and effective tool in the detection of pneumothorax (2,3,14,27). These results suggest the use of bedside lung US as a first-line diagnostic tool in patients with suspected PTX.

According to our results, lung US had low sensitivity and high specificity in detecting PTE. The proportions observed in our study were lower than those reported in the literature (3,28–30). This decrease might be due to the small number of cases, the application in a position that the patient can tolerate instead of the recommended position or the US operator. On the other hand, the negative predictive value of US was detected as 97%. This result suggested that lung US may be safe with D-Dimer to rule out PTE. However, larger studies are needed to reach a definitive conclusion.

In our study, sensitivity, specificity, and diagnostic accuracy of lung US were compared with lung auscultation and chest radiography. Lung US revealed superior results regarding diagnostic accuracy in patients diagnosed with pulmonary edema, COPD, PTE, and pneumonia. The sensitivity and specificity of lung US in the definition of pneumonia was higher compared to auscultation but similar to chest radiography. When these findings were evaluated together with the results of other similar studies, it was thought that the combined use of physical examination and lung US could reduce the need for additional imaging procedures or specific tests to recognize the underlying reason of acute respiratory distress (19, 31–35).

One of the study results is; the mean difference between the request and scanning times for XR and thorax CT were calculated as 1.36 and 2.26 hours, respectively. These results proved to us that routine use of lung US, which were can complete in first 10 minutes of admission, in patient with respiratory distress will make a great contribution in terms of correct time management.

CONCLUSION

Lung US has a high diagnostic accuracy rate in the EDs. It prevents loss of time due to incorrect differential diagnoses by providing a more reliable preliminary diagnosis than auscultation. It also minimizes radiation exposure by reducing the need for chest radiography and CT. Additionally; it reduces the requirements of advanced techniques such as V/Q scintigraphy. This bedside diagnostic method is fast, inexpensive, and repeatable. For emergency services, the BLUE protocol can be considered as a viable algorithm. Finally, lung US can be performed in a routine emergency service setting after a standard training.

Limitations

Since our study group consisted of acute respiratory distress patients, US imaging had to be performed in positions that the patient could tolerate, instead of the recommended positions. This has made it challenging to evaluate especially diseases, which were identified using focal US findings.

In emergency services, procedures for detecting the underlying pathology are frequently postponed to resuscitation procedures (such as providing airway, breathing and circulation safety). If US administration could adversely affect or prolong the diagnosis or treatment process of any patients, those patients were not included in the study, which limited the number of participants.

Conflict of interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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