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Original Article

B-lines in lung ultrasonography as prognostic markers for community-acquired pneumonia

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Abstract: Objective: Community-acquired pneumonia (CAP) is a type of pneumonia with high morbidity and mortality rates in high-risk groups. It is a common reason for referral to the emergency room. A prognostic marker that can be used quickly and easily at the bedside in the emergency room without a blood test and the need to transfer the patient to another department can contribute to quick determination of the best treatment and nursing protocol. Methods: This prospective study included patients with CAP who were referred to the emergency room. CURB-65 and the pneumonia severity index (PSI) were calculated for each patient and were used as reference scores that were compared to a B-line score (BLS) that we developed based on B-line artifacts from lung ultrasonography (LUSG). The CURB-65, PSI, and BLS values compared in terms of need for hospitalization and 30-day mortality. Results: A total of 72 patients were included in the study. Their mean age was 64.60 ± 17.28 years. Of all the factors examined, the BLS showed statistically significant results in terms of mortality and differences between inpatients and outpatients. The AUC value of the BLS and 30-day mortality was 0.753 (95% CI: 0.594-0.911). The maximum likelihood ratio was 3.2. Conclusion: Although randomized, blind, controlled studies are required to evaluate the prognostic effectiveness of the scoring system that we developed based on B-lines in CAP patients' LUSG, we believe that LUSG images can provide valuable prognostic information and that B-line artifacts can be taken into consideration in this respect.

Keywords: B-line artifacts, community-acquired pneumonia, emergency medicine, lung ultrasonography, scoring system

Introduction

Community-acquired pneumonia (CAP) is a common type of pneumonia with high morbidity and mortality rates in high-risk groups. It is a common reason for referral to the emergency room and often leads to hospitalization and admission to intensive care units (ICUs) because of respiratory failure. A delay in diagnosis and treatment severely affects patients' prognosis [1].

The severity and courses of disease differ between CAP patients. While the mortality rate among outpatients is less than 1%, it is in the range of 5-15% among inpatients. It can rise to 25% in patients needing mechanical ventilation support and even to 50% in patients requiring vasopressor treatment [2]. Determining the severity of a disease with such variable and severe clinical manifestations can be valuable in patient management and the determination of treatment [3].

The pneumonia severity index (PSI) and CURB-65 are the most common indices used for the evaluation of CAP [4]. However, their use in the emergency room has certain limitations, such as the time required to obtain blood test results, the need to transfer the patient to another environment for X-ray that lacks the safe conditions of the emergency room, and the need for invasive procedures and imaging methods that expose patients to radiation.

Lung ultrasonography (LUSG) has attracted attention in emergency rooms and ICUs in recent years. It does not emit radiation, can be performed in a few minutes at the bedside, and can be evaluated in real time for multi-diagnosis. LUSG, together with other bedside ultrasonography modalities, expedites the process, increases the correct diagnosis rate, and contributes to applying the appropriate treatment in the first hours after referral to the emergency room [1]. LUSG images contain B-lines, whose area of utilization is not yet clear. B-lines are artifacts originating from the pleural line in LUSG imaging. These hyperechoic artifacts are seen as long and relatively sharp. B-lines originally follow the lung sliding on the pleural line during respiration. "B-lines" or "B-patterns" are based on hyperechoic vertical artifacts identified in search for diffuse or focal parenchymal lung disease. Single B-lines can be found in healthy and elderly people and are therefore not necessarily signs of a critical disease [2]. The presence of at least three hyperechoic B-lines arising from the pleural line in the intercostal space is accepted as a sing of interstitial lung disease.

Although current scoring systems can accurately predict morbidity and mortality in CAP patients, a prognostic marker that can be used quickly and easily to determine prognosis at the bedside in the emergency room without a blood test and the need to transfer the patient to another department will clearly ease the process. The aim of this study was to investigate the effectiveness of B-lines on LUSG in determining the prognosis of patients with CAP in the emergency room.

Materials and methods

This was a prospective, cross-sectional study conducted in the Emergency Department of the Faculty of Medicine of Namık Kemal University in Tekirdağ, Turkey between February 2019 and February 2020. Outpatients and inpatients aged 18 years or older diagnosed with CAP whose necessary data were accessible were included in the study. Pregnant patients, decompensated heart failure patients and patients less than 18 years old were not included the study. Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee for Non-Interventional Studies of Namık Kemal University (project identification code 18904/28.02.2019).

CAP was defined as the presence of dyspnea, rale and rhonchus, cough-sputum, or fever over 38°C in addition to newly formed infiltration on direct lung X-ray or thorax computerized tomography. The CURB-65 and PSI scores of each patient were calculated. The treatment states of the patients (outpatient, ward patient, or ICU patient) were determined. Two ward patients were later transferred to the ICU, where they died. However, they were included in the ward patient group, as they were initially hospitalized in the ward.

LUSG was performed by the on-duty emergency room chief using a Fujifilm FC1 TTC linear probe with a frequency of 15.9 Hz. Measurements from the USG inspection areas used by Blaivas et al. [5] were taken: area 1 (anterior), from level 2 to level 3 at the midclavicular line; area 2 (anterolateral), from level 3 to level 5 at the anterior midaxillary line; and area 3 (posterolateral), posterior axillary line to observe subsections of the thorax and abdominal dial. B-lines detected in each area were noted separately.

Finally, the mortality rate within 30 days of referral to the emergency room was calculated and analyzed.

We aimed to examine whether the numbers of B-lines which were not specific enough for pneumonia diagnosis but could be used as a prognostic markers. To that end, we compared the widely used CURB-65 and PSI scoring systems with the prognoses based on B-lines. We developed a standard measurement method to interpret the numbers of B-lines, which we named the "B-line score" (BLS).

The criteria we took into account were as follows:

●Number of hemithoraces where Blines were observed (0, 1, or 2).

●Number of areas in which B-lines were observed (1, 2, or 3).

●Number of B lines observed in these areas (any number).

The BLS score was calculated by multiplying the numbers obtained from these three criteria (**Table 1**).

Statistical analysis

The Kolmogorov-Smirnov test was used to test the normality of the analysed parameters. Independent t-tests were used to evaluate BLS

Table 1. B-line score template

Criteria	Number		
A: Number of hemithoraces where B-lines were observed	0	1	2
B: Number of areas where B-lines were observed	1	2	3
C: Number of B-lines observed	Any number		

B-line score: A × B × C.

Table 2. Patients' clinical histories and physical examination and radiological findings (n = 72)

Finding	n (%)
PA X-ray finding	68 (94.4)
Rale	57 (79.2)
Rhonchus	38 (52.8)
Wheezing	11 (15.3)
Smoking	35 (48.6)
Fever ≥38°C	15 (20.8)
Cough	61 (84.7)
Sputum	39 (54.2)
Pulse >100/min	34 (47.2)
MABP ≥100 mmHg	44 (61.1)

Note: PA LG: postero-anterior lung X-ray, MABP: mean arterial blood pressure.

differences in the inpatients-outpatients group, sexes group (male or female), age group (64 and below-65 and above), mortality group (vital or mortal). The chi-square test was used to determine CURB-65 and PSI differences in the inpatients-outpatients group, sexes group (male or female), age group (64 and below-65 and above), mortality group (vital or mortal). The receiver operating characteristic (ROC) curve and areas under the curves (AUCs) were analyzed for BLS using mortality status, to assess the differentiation power between the vital or mortal patient groups in 30 days. A value of $P < 0.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp.) and Analyse-it (Analyse-it Software, Ltd.).

Results

A total of 72 patients were included in the study. Of those, 23 (31.9%) were female, and 49 (68.1%) were male. Their mean age was 64.60 ± 17.28 years. The patients' clinical histories, physical examination findings, and laboratory data are displayed in **Table 2**.

Comparison of CURB-65, PSI, and BLS between inpatients and outpatients

The patients who were hospitalized accounted for 40.2%. Their CURB-65 scores were significantly higher than those of the outpatients (P = 0.001). The CURB-65 scores of 21 (72.4%) hospitalized patients were over 2. Similarly, the PSI scores of the inpatients were significantly higher than those of the outpatients (P = 0.000). The PSI class of 28 hospitalized (96.5%) patients was over III. Similarly, the mean BLS of the hospitalized patients (23.10 ± 15.11) was significantly higher than that of the outpatients (11.88 ± 12.46; **Table 3**).

Comparison of CURB-65, PSI, and BLS between age groups

Although the CURB-65 and PSI scores in patients aged 64 years and below were overall lower than those in patients aged 65 and above, CURB-65 scores of 1 and 2 and PSI class III were observed more frequently in patients aged 65 and above. The mean BLS did not differ significantly between the two groups (P = 0.138), which suggests that age does not affect the BLS (**Table 4**).

Comparison of CURB-65, PSI, and BLS in terms of mortality prediction

The 30-day mortality rate was 11.11% (eight patients). All these patients received mechanical ventilation support in the ICU. The CURB-65 and PSI scores successfully differentiated between patients who died within 30 days and those who did not. The success rates were statistically significant. The BSL was likewise statistically successful in predicting mortality (P = 0.02; **Table 5**). The mortality rates in patients with CURB-65 scores of 1, 2, 3, and 4 were 8.7%, 4.8%, 40%, and 100%, respectively. There were no patients with a score of 5. The 30-day mortality rate of PSI class I, II, and III patients was 0%, while those of class IV and V patients were 5.6% and 41.2%, respectively.

ROC analysis of the BLS

The AUC value of the ROC analysis of BLS regarding 30-day mortality was 0.753 (95%

Table 3. Comparison of hospitalization indications between the CURB-65, PSI and BLS systems (n = 72)

Scoring system		Hospitalization indication			P
		Inpatient	Outpatient	Total	
CURB-65 score n (%)	0	1 (3.4)	16 (37.2)	17 (23.6)	0.001*
	1	7 (24.1)	16 (37.2)	23 (31.9)	
	2	13 (44.8)	8 (18.6)	21 (29.2)	
	3	7 (24.1)	3 (7.0)	10 (13.9)	
	4	1 (3.4)	0 (0.0)	1 (1.4)	
	5	0 (0)	0 (0)	0 (0)	
PSI class n (%)	I	0 (0.0)	11 (25.6)	11 (15.3)	0.000*
	II	1 (3.4)	7 (16.3)	8 (11.1)	
	III	6 (20.7)	12 (27.9)	18 (25.0)	
	IV	8 (27.6)	10 (23.3)	18 (25.0)	
	V	14 (48.3)	3 (7.0)	17 (23.6)	
BLS mean ± SD		n = 29	n = 43	n = 72	0.001**
		23.10 ± 15.11	11.88 ± 12.46	16.40 ± 14.58	

Note: *Pearson's chi-square test, **t-test. PSI: pneumonia severity index, BLS: B-line score, SD: standard deviation.

Table 4. Comparison of age groups between the CURB-65, PSI and BLS systems (n = 72)

Scoring system		Age (years)			P
		64 and below	65 and above	Total	
CURB-65 score n (%)	0	16 (48.5)	1 (2.6)	17 (23.6)	0.000*
	1	9 (27.3)	14 (35.9)	23 (31.9)	
	2	6 (18.2)	15 (38.5)	21 (29.2)	
	3	1 (3.0)	9 (23.1)	10 (13.9)	
	4	1 (3.0)	0 (0.0)	1 (1.4)	
	5	0 (0)	0 (0)	0 (0)	
PSI class n (%)	I	11 (33.3)	0 (0.0)	11 (15.3)	0.001*
	II	4 (12.1)	4 (10.3)	8 (11.1)	
	III	7 (21.2)	11 (28.2)	18 (25.0)	
	IV	3 (9.1)	15 (38.5)	18 (25.0)	
	V	8 (24.2)	9 (23.1)	17 (23.6)	
BLS mean ± SD		n = 33	n = 39	n = 72	0.138**
		13.97 ± 15.21	18.46 ± 13.88	16.40 ± 14.58	

Note: *Pearson's chi-square test, **t-test. PSI: pneumonia severity index, BLS: B-line score, SD: standard deviation.

confidence interval [CI]: 0.594-0.911; **Figure 1**). The maximum likelihood ratio was 3.2. The sensitivity, specificity, and likelihood ratio of BLS are presented in **Table 6**. The evaluation of the normality of the comparisons using the independent t-test is shown in **Figure 2**.

Comparison of CURB-65, PSI, and BLS between the sexes

The frequency of PSI class I was higher in females than in males, and the frequency of class III and above was higher in males than in females (P = 0.005). The BLS was similarly higher in males. Although the difference was not statistically significant, it was close to the level of significance (P = 0.074). The CURB-65 scores did not differ significantly between the two sexes (P = 0.411; **Table 7**).

Discussion

Recent evidence suggests that LUSG is of critical importance in the evaluation of many lung

Table 5. Comparison of mortality between the CURB-65, PSI and BLS systems (n = 72)

Scoring system		Mortality			P
		Died (n = 8)	Survived (n = 64)	Total	
CURB-65 score n (%)	0	0 (0.0)	17 (26.6)	17 (23.6)	0.001*
	1	2 (25.0)	21 (32.8)	23 (31.9)	
	2	1 (12.5)	20 (31.2)	21 (29.2)	
	3	4 (50.0)	6 (9.4)	10 (13.9)	
	4	1 (12.5)	0 (0.0)	1 (1.4)	
	5	0 (0)	0 (0)	0 (0)	
PSI class n (%)	I	0 (0.0)	11 (17.2)	11 (15.3)	0.000*
	II	0 (0.0)	8 (12.5)	8 (11.1)	
	III	0 (0.0)	18 (28.1)	18 (25.0)	
	IV	1 (12.5)	17 (26.6)	18 (25.0)	
	V	7 (87.5)	10 (15.6)	17 (23.6)	
BLS mean ± SD		n = 8	n = 64	n = 72	0.020**
		27.25 ± 13.35	15.05 ± 14.25	16.40 ± 14.58	

Note: *Pearson's chi-square test, **t-test. PSI: pneumonia severity index, BLS: B-line score, SD: standard deviation.

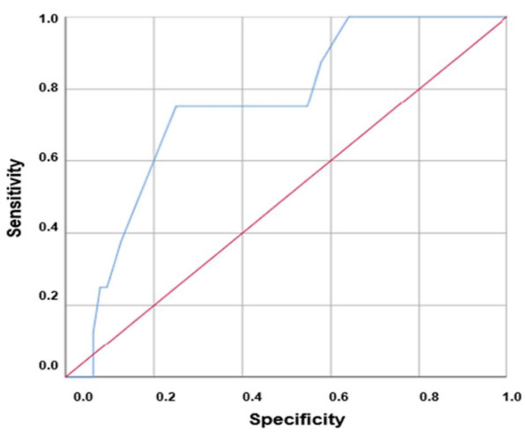

Figure 1. ROC analysis of the BLS with respect to 30-day mortality. AUC: 0.753 (95% confidence interval: 0.594-0.911).

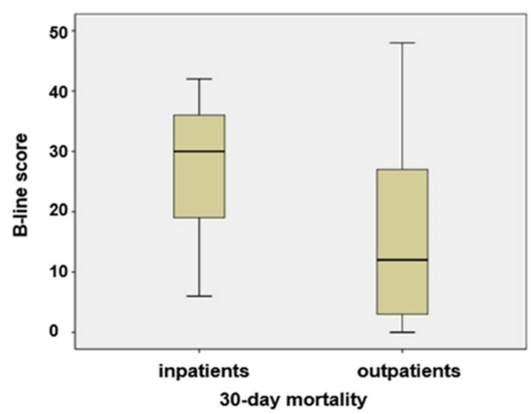

Figure 2. Normality test of the BLS with respect to 30-day mortality. Comparison between inpatients and outpatients using the independent t-test.

Table 6. Sensitivity and specificity ratios of possible BLS values

BLS >	Likelihood ratio	Sensitivity (%)	Specificity (%)
-1	1	100	0
17	2	75	62.5
27	3	75	75
31	3	37.5	87.5
38	3.2	25	92.2
41	2	12.5	93.8
45	0	0	93.8

Note: BLS: B-line score.

pathologies, such as pneumothorax, pneumonia, lung edema, and acute respiratory disease syndrome [6]. In this study, the BLS, which we designed based on B-lines on LUSG, was compared with CURB-65 and the PSI, which we used as reference scores, to examine whether the number of B-lines that are not specific enough for pneumonia diagnosis could be used as a prognostic marker for CAP patients. The CURB-65 score showed differences in age, mortality distributions, between inpatients and outpatients, the PSI showed differences in age, mortality, sex, between inpatients and outpatients while the BLS showed differences in mortality. The BLS was also statistically successful in differentiating between inpatients and outpatients. Moreover, unlike the other scoring systems, the BLS, based on B-line artifacts, which are known to increase

Table 7. Comparison of the sex factor between the CURB-65, PSI and BLS systems (n = 72)

Scoring system		Sex			P
		Female	Male	Total	
CURB-65 score n (%)	0	8 (34.8)	9 (18.4)	17 (23.6)	0.411*
	1	8 (34.8)	15 (30.6)	23 (31.9)	
	2	4 (17.4)	17 (34.7)	21 (29.2)	
	3	3 (13.0)	7 (14.3)	10 (13.9)	
	4	0 (0.0)	1 (2.0)	1 (1.4)	
	5	0 (0)	0 (0)	0 (0)	
PSI class n (%)	I	8 (34.8)	3 (6.1)	11 (15.3)	0.005*
	II	4 (17.4)	4 (8.2)	8 (11.1)	
	III	2 (8.7)	16 (32.7)	18 (25.0)	
	IV	6 (26.1)	12 (24.5)	18 (25.0)	
	V	3 (13.0)	14 (28.6)	17 (23.6)	
BLS mean ± SD		n = 23	n = 49	n = 72	0.074**
		12.30 ± 13.19	18.33 ± 14.93	16.40 ± 14.58	

Note: *Pearson's chi-square test, **t-test. PSI: pneumonia severity index, BLS: B-line score, SD: standard deviation.

with age, was not affected by the age factor. It was likewise not affected by the sex factor. Therefore, we conclude that the scoring system that is least affected by age and sex factors is the BLS. Like the reference scoring systems, the BLS was statistically successful in predicting 30-day mortality.

The first parameter we aimed to examine was the effectiveness of the BLS in differentiating between inpatients and outpatients. Alıcı et al. reported that of 84 patients, all the patients treated in the ICU were class IV and V patients according to the PSI, while no class I, II, or III patients required intensive respiratory or vasopressor support; however, 35.7% of the ICU patients were classified as groups 1 and 2 according to CURB-65 [7]. The sensitivity and specificity of CURB-65 in differentiating between need for intensive respiratory and vasopressor support were 64.2% and 90%, respectively, while those of the PSI were 92.8% and 85.7%, respectively [7]. Although the main purpose of CURB-65 and the PSI is to predict mortality, they have predicted the need for hospitalization, intensive respiratory and vasopressor support with high accuracy in many studies [8-10]. In line with the literature, the reference CURB-65 and PSI scores in our study were statistically successful in predicting the need for hospitalization. When we compare CURB-65, PSI and BLS between inpatients and outpatients, the BLS system we formed was able to make this differentiation (**Table 3**). So our results support the suggestion that BLS system can be used to determine whether patients should be hospitalized.

Many studies have shown that an advanced age is a predictive factor for mortality, especially in pneumonia patients aged 65 years and above [11]. Zhang et al. reported that the mortality rate increases in patients older than 85 years [12]. Similarly, Conte et al. found than among 2,000 patients, mortality increased with age [13]. These studies have concluded that including the age in scoring systems naturally affects risk estimations.

The presence of B-lines on LUSG is known to be related to age. Radzina et al. reported that a single B-line in elderly and healthy people is not a significant sign of pneumonia [2]. Whereas the CURB-65 and PSI systems use age as a criterion, we did not include it in the BLS system and it was not significantly associated with the score. This suggests that B-lines than can be observed in the healthy population and increase with age does not affect the system. Therefore, it can be postulated that the reliability of the scoring system increases.

Several studies have used CURB-65 and the PSI to predict morbidity and mortality [9, 14-16]. Ahn et al. reported 28-day mortality rates of 5.8%, 15.7%, and 23.6% in patients with CURB-65 scores of 1, 2, and 3, respectively. The rate rose to 50% in patients with

CURB-65 scores of 4 and 5 [16]. In the same study, the 28-day mortality rate of PSI class I and II patients was 0%, whereas those of class III, IV, and V patients were 16.2%, 15.3%, and 32.7%, respectively [16]. In our study, the CURB-65 and PSI systems were statistically successful in predicting 30-day mortality. So our mortality rates can be considered consistent with the literature. Likewise, our BLS accurately predicted mortality.

A comparison of the AUC values of existing indices can provide another perspective on the evaluation of the sensitivity and specificity of newly designed prognostic scoring systems. In terms of predicting 30-day mortality with CURB-65, Alıcı et al. reported 83.3% sensitivity, 85.9% specificity, and an AUC of 0.890 (for patients with a score of 3 or higher). For the PSI, the authors reported 100% sensitivity, 78.2% specificity, and an AUC of 0.891 (for class IV and V patients) [7]. Wang et al. reported an AUC of 0.767 for CURB-65, and an AUC of 0.761 for the PSI [14]. Ahn et al. reported an AUC of 0.673 for CURB-65 and an AUC of 0.586 for the PSI [16]. In our study, the AUC of the BLS in the prediction of 30-day mortality was 0.586 (95% CI: 0.594-0.911). With a cutoff value of 27, the BLS showed 75% sensitivity and specificity. This value is consistent with the literature.

Studies on the predictors of CAP mortality in adults have highlighted the importance of the sex factor [17-20]. Although no studies have compared the PSI and CURB-65 according to sex only, Zhang et al. reported that the male sex is one of 11 factors affecting mortality in CAP patients [12]. Our study also revealed a statistically significant difference in PSI scores between the sexes. The BLS was also higher in males; although not statistically significant, the difference was close to the level of significance. CURB-65, on the other hand, showed a similar distribution in both sexes. Therefore, the response of the sex factor to the scoring systems as being statistically significant or being close to the level of significance can be accepted as positive, as the sex factor is important for the prognosis of CAP patients.

The investigation of B-lines simultaneously on LUSG in the emergency room for the diagnosis of CAP can provide insight into prognosis. It can also be used in the development of the prognosis together with the acceleration of necessary inotropic agents and antibiotherapies. It can be considered a safe and noninvasive method for patients who are not stable enough to move to another department for imaging procedures. Moreover, it does not require time-consuming laboratory tests, as is the case with other scoring systems, such as the PSI. The BLS can therefore be considered a method that can contribute to timely initiation of treatment according to patients' prognosis, thus reducing the length of stay in the emergency room as it is basic, practical, and as effective as reference diagnostic methods. Further comprehensive studies are required to confirm the employability and reliability of the BLS.

Limitations

1. Patients with oncological diagnoses were not excluded in the study, so changes in the pleura and lung parenchyma due to malignancy may have affected the numbers and morphology of the artifacts.

2. The level of training and experience of each USG operator may have affected the findings.

Conclusion

This study demonstrates the usefulness and prognostic value of the scoring system for CAP patients that we designed based on B-lines. We suggest that LUSG can provide valuable information for the prognosis of pneumonia, and B-lines can be taken into consideration in this respect. Further comprehensive research is needed to validate this scoring system.

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Disclosure of conflict of interest

None.

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