Lung ultrasound score for predicting endotrcheal tube intubation in patients with community- acquired pneumonia: Pilot study

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Abstract

Introduction

Community-acquired pneumonia is a common and high-mortality condition. A new trend of lung ultrasound has been recently utilized for diagnosis of pneumonia due to minimal radiation exposure and bedside convenience. Lung ultrasound score has been known for its capabilities for assessing severity, mortality, and length of hospital stay in several conditions. However, it has not been investigated in patients presenting with community-acquired pneumonia. Therefore, we aimed to evaluate the association between lung ultrasound scores and 72-hour endotracheal intubation.

Methods

A pilot observational study was conducted in an emergency department from March 2022 to April 2023. We enrolled all patients who were at least 18 years old with a diagnosis of community-acquired pneumonia and excluded patients with pregnancy, receiving mechanical ventilation at emergency department arrival, COVID-19 infection, and do-not-resuscitate orders. All eligible patients underwent a 12-region lung ultrasound and

were rated a calculated ultrasound score of 0–3 in each region. The sum of lung ultrasound scores in each region was analyzed to determine the association between lung ultrasound scores and 72-hour endotracheal intubation.

Results

A total of 20 patients were analyzed. We observed that the increased lung ultrasound score was associated with 72-hour endotracheal intubation ($p = 0.02$). The receiver operator characteristic analysis indicated an area under the curve of 0.83 (95% CI, 0.6-1.0). In addition, the optimal cut-off value of the lung ultrasound score value for predicting 72-hour endotracheal intubation was 19, which demonstrated the highest sensitivity of 75% (95%CI, 34.9-96.8), a specificity of 83.3% (95%CI, 51.6-97.9), a positive predictive value of 75% (95%CI, 44.3-91.9), and a negative predictive value of 83.3% (95%CI, 59.5-94.5).

Conclusions

An increased lung ultrasound score was associated with 72-hour endotracheal intubation. Since it was conducted as a pilot study, further research is required to validate its outcome.

Keywords

community-acquired pneumonia, lung ultrasound, lung ultrasound score, emergency department

การศึกษานำร่องเพื่อนำคะแนนจากการทำอัลตราซาวนด์ปอดมาใช้ทำนายการใส่ท่อช่วยหายใจในผู้ป่วยโรคปอดติดเชื้อชุมชน

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บทคัดย่อ

บทนำ

ปอดติดเชื้อชุมชนเป็นโรคที่พบได้บ่อย และมีความรุนแรงสูง ปัจจุบันอัลตราซาวนด์ถูกใช้มากขึ้นในการวินิจฉัยโรคปอดติดเชื้อ เนื่องจากทำได้ง่ายและสัมผัสต่อรังสีน้อย คะแนนจากการอัลตราซาวนด์ปอดถูกนำมาใช้เพื่อหาความรุนแรง อัตราการเสียชีวิต และระยะเวลาในการนอนโรงพยาบาลในหลายสถานการณ์ แต่อย่างไรก็ตามยังไม่มีการศึกษาในผู้ป่วยโรคปอดติดเชื้อชุมชน

วัตถุประสงค์

การศึกษานี้จัดทำขึ้นเพื่อศึกษาหาความสัมพันธ์ระหว่างคะแนนจากการทำอัลตราซาวนด์ปอดและการใส่ท่อช่วยหายใจในผู้ป่วยโรคปอดติดเชื้อชุมชนที่มารับการรักษาในห้องฉุกเฉินภายใน 72 ชั่วโมง

วิธีการศึกษา

การศึกษานำร่องโดยการเก็บข้อมูลไปข้างหน้า ถูกจัดทำในห้องฉุกเฉินระหว่างเดือนมีนาคม พ.ศ. 2565 ถึง เมษายน พ.ศ. 2566 เก็บข้อมูลในผู้ป่วยโรคปอดติดเชื้อชุมชนที่มีอายุตั้งแต่ 18 ปีขึ้นไป เกณฑ์คัดออกคือ ผู้ป่วยตั้งครรภ์ ได้รับการใช้เครื่องช่วยหายใจตั้งแต่เข้ารับการรักษาที่ห้องฉุกเฉิน ติดเชื้อโควิด-19 และผู้ป่วยที่ปฏิเสธการกู้ชีพ ผู้ป่วยทุกคนจะได้รับการทำอัลตราซาวนด์ปอด 12 ตำแหน่ง

แต่ละตำแหน่งจะถูกให้คะแนนตั้งแต่ 0 ถึง 3 คะแนน จากนั้นนำผลรวมของคะแนนในแต่ละตำแหน่งมาวิเคราะห์หาความสัมพันธ์ระหว่างคะแนนจากการทำอัลตราซาวนด์ปอดกับอัตราการใส่ท่อช่วยหายใจที่ 72 ชั่วโมง

ผลการศึกษา

จากผู้เข้าร่วมวิจัยทั้งหมด 20 คน พบว่าคะแนนอัลตราซาวนด์ปอดที่เพิ่มขึ้นมีความสัมพันธ์กับอัตราการการใส่ท่อช่วยหายใจภายใน 72 ชั่วโมง ($p = 0.02$) การคำนวณเพื่อหาพื้นที่ใต้โค้งของเส้นกราฟ Receiver Operating Characteristic curve มีค่าเท่ากับ 0.83 (95%CI, 0.6-1.0) และพบว่าจุดตัดของคะแนนจากการทำอัลตราซาวนด์ปอดเพื่อทำนายการใส่ท่อช่วยหายใจเท่ากับ 19 คะแนน โดยมีค่าความไว เท่ากับร้อยละ 75 (95%CI, 34.9-96.8) ค่าความจำเพาะเท่ากับร้อยละ 83.3 (95%CI, 51.6-97.7) ค่าการทำนายผลบวกเท่ากับร้อยละ 75 (95%CI, 44.3-91.9) ค่าการทำนายผลลบเท่ากับร้อยละ 83.3 (95%CI, 59.5-94.5)

สรุป

คะแนนจากการทำอัลตราซาวนด์ปอดที่สูงขึ้นมีความสัมพันธ์กับการใส่ท่อช่วยหายใจที่ 72 ชั่วโมง อย่างไรก็ตามเนื่องจากการศึกษานี้เป็นการศึกษานำร่อง จึงจำเป็นต้องมีการศึกษาเพิ่มเติมต่อไป

คำสำคัญ

โรคปอดติดเชื้อชุมชน, อัลตราซาวนด์ปอด, คะแนนจากการทำอัลตราซาวนด์ปอด, ห้องฉุกเฉิน

Introduction

Community-acquired pneumonia (CAP) is one of the most common causes of emergency department (ED) visits which is characterized by three clinical criteria: 1) clinical symptoms including fever, dyspnea, and productive cough; 2) abnormal physical examination such as rales, or bronchial breath sounds; 3) the observation of new lung infiltration on chest imaging[1,2]. Various clinical prognostic factors such as CURB-65, Pneumonia Severity Index (PSI) and SMART-COP were developed to predict prognostic outcome[3–6]. Additionally, certain prognostic factors, such as systolic blood pressure of less than 90 mmHg, the presence of lung infection in multiple sites, tachypnea, and desaturation were found to be associated with the need for invasive mechanical ventilation, and the use of inotropic drugs[5]. Chest radiograph remains the routine evaluation for CAP diagnosis. However, alternative methods such as chest computed tomography and lung ultrasound are also available and feasible with relatively high sensitivity and specificity[7].

Ultrasound is a quick, non-invasive, less radiation exposure, and significantly convenient tool in an emergency setting. It has been applied as a useful diagnostic modality and severity assessment for various clinical settings such as pneumothorax, pleural effusion, pulmonary edema, and pneumonia. Furthermore, a prior meta-analysis study demonstrated that lung ultrasound carries a greater sensitivity and specificity compared to chest radiography regarding CAP diagnosis[7].

Lung ultrasound score (LUS) serves as a quantitative tool for assessing the extent of lung aeration loss. Previous studies have successfully utilized LUS as a predictive measure for mortality rate in critically ill and COVID-19 patients[8,9,10]. LUS has also proven to be effective in predicting the need for pediatric intensive care unit admission in infants suffering from acute bronchiolitis[11]. Moreover, LUS was a useful tool to predict the need to respiratory support in the neonates and bronchopulmonary dysplasia[12,13]. To our knowledge, the relationship between LUS and two major adverse outcomes such as endotracheal intubation (ETI) and mortality rate in patients with CAP has not yet been reported. Therefore, this study aimed to investigate the association between LUS and ETI at 72 hours after ED arrival.

Methods

This was a prospective single-center observational pilot study in a non-trauma ED of a university hospital with approximately 20,000 annual ED visits. Adult patients were enrolled from March 2022 to April 2023. This study was approved by the Institutional Review Board.

Study population

We enrolled adult patients aged 18 years and older who had received the diagnosis of CAP. The diagnosis is based on at least two of the following three criteria: clinical symptoms (productive cough, fever, and pleuritic chest pain), clinical findings (rales and bronchial breath sounds), and the observation of infiltration on chest imaging[1,2]. The clinical diagnosis was confirmed by attending physician and chest x-ray was confirmed by radiologist.

We excluded patients with pregnancy, prompt initiation of mechanical ventilation after ED arrival, COVID-19 infection, and do-not-resuscitate orders.

Study protocol

After obtaining signed consent, baseline characteristics such as gender, age, comorbidities, initial vital signs, laboratory results, and radiographic findings were collected. Three ultrasound operators; two emergency physicians who are ultrasound specialists and one emergency resident, were pre-trained in LUS assessment with at least 25 lung ultrasound experiences before the study's participation. Only one operator performed the lung ultrasonography on each patient. All operators were blinded to patients' physical examination, chest x-ray, and laboratory throughout the study.

Ultrasound protocol

The study was conducted using a Venue Go™ ultrasound machine (GE Healthcare, Chicago, IL) equipped with a curvilinear probe (C1-5-RS transducer with a frequency of 1.4-7.5 MHz). The patient was initially placed in a supine or semi-upright position. The lung ultrasound was then applied as a bilateral scanning. The hemithorax was divided into six regions by using specific reference lines: 1) a horizontal line that separates each hemithorax into the superior and inferior regions; 2) four vertical lines including parasternal line, anterior axillary line, posterior axillary line, and paravertebral line. Following the placement of these reference lines, each hemithorax was subsequently categorized as anterior-superior, anterior-inferior, lateral-superior, lateral-inferior, posterior-superior, and posterior-inferior regions (Figure 1).

The ultrasound operators systematically scanned each region of the lung and assigned a score from each region based on specific grading criteria which ranged from 0-3: A score of 0 was given when there was a presence of lung sliding with A-lines or fewer than three isolated B-lines; A score of 1 was given when multiple B-lines were observed (more than 3 B-lines with less than or equal to 7 mm between each line); A score of 2 was given when there were confluence or multiple B-lines (more than 3 B-lines with less than or equal to 3 mm between each line); A score of 3 was given when lung consolidation, dynamic air bronchograms, and/or pleural effusion were observed (Figure 2). The most severe ultrasound pattern observed in each region was scored and used to calculate

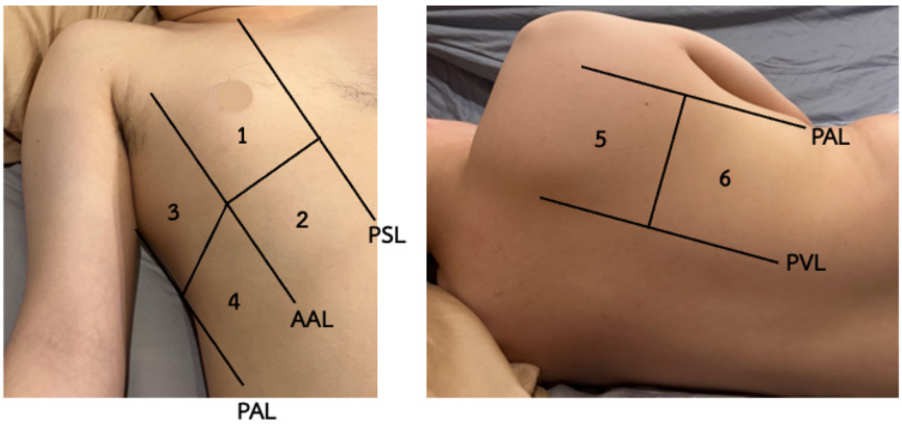

Figure 1 Divided six regions of the right hemithorax using one horizontal and four vertical reference lines for lung ultrasound examination.

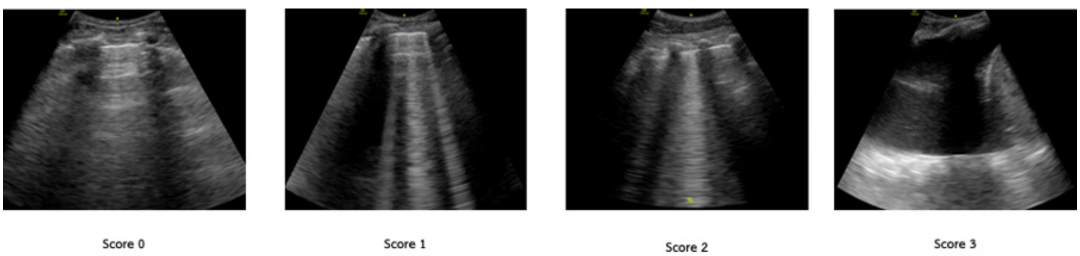

Figure 2 The grading of lung ultrasound scores from best to worst (0-3).

the sum of the LUS where 0 represented the best and 36 represented the worst possible scores[14].

Ultrasound video recordings of each patient were collected to assess the LUS inter-rater reliability by each operator independently. All chest radiographs or computed tomography of the chest were interpreted by a radiologist who was blinded to LUS and patients' charts. All patients were followed up for 72-hour ETI, length of hospital stays (LOS), and mortality rate. If the patients were discharged before 28 days or were transferred to another hospital, telephone was used to follow up.

Outcome

The primary outcome was the association between LUS and 72-hour ETI following the initial ED visit.

The secondary outcome was the association between LUS and LOS, the 28-day mortality rate, and the composite outcome of non-invasive ventilation, high-flow nasal cannula, and ETI 72 hours after ED arrival.

Statistical analysis

All data were analyzed using PASW Statistics for Mac, version 29.0 (SPSS, Inc., Chicago, IL). Patient demographics were presented using descriptive statistics. Categorical data were described as numbers and percentages. Continuous data were displayed as mean and standard deviation or median and interquartile range as appropriate. Comparison of baseline characteristics between intubation and non-intubation groups was performed using Chi-square or Fisher's exact test and Student's t-test or Mann-Whitney U test as appropriate.

To determine the optimal LUS cut-off value for predicting 72-hour ETI, we conducted a receiver operator characteristic (ROC) analysis and calculated the area under the curve along with the p-value. This analysis includes sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The relation between LOS and the LUS was calculated using Spearman rank correlation. The intra-class correlation coefficient was used to determine the inter-rater reliability. The p-value of less than or equal to 0.05 was considered statistically significant.

Result

From March 2022 to April 2023, twenty-two patients were eligible. Of these, 2 patients were excluded from the study

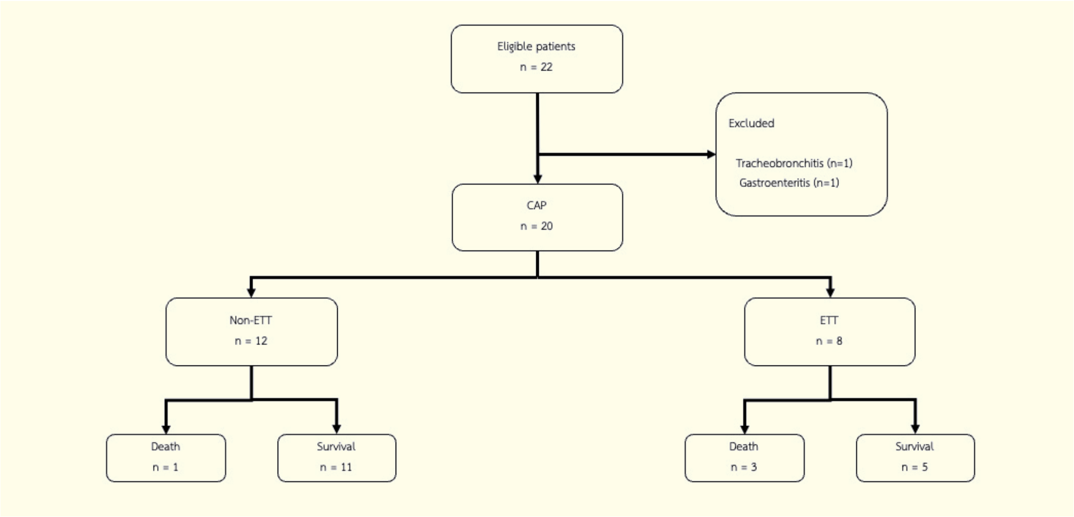

Figure 3 Flow of enrollment

because their final diagnosis did not meet the criteria for CAP. Consequently, we enrolled a total of 20 patients in this current analysis. Of these 8 patients (40%) were intubated within 72 hours after the initial ED visit and 4 patients (20%) died within 28 days. (Figure 3)

The baseline characteristics of patients are shown in Table 1. The median age was 66.7±12.3 years. Sixty-five percent of patients were male. The most common underlying disease found in our study was hypertension. The mean respiratory rate was 32±7 breaths per minute. The median time from ED arrival to performing lung ultrasound was 182 minutes (58.3,257.3). The mean of oxygen saturation at room air was 93±6%. All of the eligible patients had received standard treatment. Baseline characteristics between patients with 72-hour ETI and without ETI were not significantly different except for LOS (p = 0.01).

Primary and secondary outcomes

The median LUS was 15.0 (10.3, 22.0). The median LUS of patients with ETI and without ETI were 22.0 (14.5, 23.0) and 11.0 (8.5, 17.6) respectively. Increased LUS was found to be associated with 72-hour ETI after the initial ED visit (p = 0.02). The ROC analysis assessing LUS predicting a 72-hour ETI following ED arrival yielded an area under the curve of 0.828, (95% CI, 0.64-1.00) as illustrated in Figure 4.

Table 1 Baseline characteristics of patients.

	All (n=20)	ETI (n=8)	No ETI (n=12)	P value
Age, year	66.7±12.3	64.8±13.3	67.9±12.0	0.60
Male (%)	13 (65)	6 (75)	7 (58.3)	0.64
Body mass index (kg/m^2)	21.6±4.6	20.3±3.0	22.4±5.1	0.30
Body temperature (°C)	37.5±1.0	37.4±1.2	37.5±1.0	0.84
Systolic blood pressure (mmHg)	135.6±28.0	127.4±28.4	141.0±27.6	0.30
Diastolic blood pressure (mmHg)	79.85±18.0	77.1±24.9	81.7±12.3	0.59
Heart rate (beats per minute)	109±19.8	118.4±21.7	102.8±16.5	0.84
Respiratory rate (breaths per minute)	32.3±7.2	32.5±6.8	32.2±7.7	0.92
O_2 saturation at room air (%)	92.5±6.0	90.9±6.5	93.6±5.6	0.33
Underlying disease (%)				
Hypertension	7 (35)	2 (25)	5 (41.7)	0.64
Diabetes mellitus	3 (15)	2 (25)	1 (8.3)	0.54
Chronic obstructive pulmonary disease	2 (10)	1 (12.5)	1 (8.3)	1.00
Asthma	1 (5)	-	1 (8.3)	
Old pulmonary tuberculosis	2 (10)	1 (12.5)	1 (8.3)	1.00
Cancer	1 (5)	-	1 (8.3)	
Cerebrovascular disease	1 (5)	1 (12.5)	-	
Chronic kidney disease	1 (5)	-	1 (8.3)	
Cirrhosis	1 (5)	1 (12.5)	-	
Smoking (%)	9 (45)	3 (37.5)	6 (50)	0.67
Previous corticosteroids used, no.	3 (15)	2 (25)	1 (8.3)	0.54
Treatment				
Systemic corticosteroid, no.	5 (25)	2 (25)	3 (25)	1.00
Vasopressor used	1(5)	1 (12.5)	-	
Time from ED visit to ultrasound, minutes	182 (58.3,257.3)	188.5 (27.3,298.5)	173.5 (77.3,256.0)	0.88
Hemoglobin (g/dL)	11.6±2.0	11.0±2.8	11.9±1.2	0.30
LOS (IQR), days	6 (3.5,26.5)	29.5 (6,50.5)	3 (1,12)	0.01
28 day-mortality	4 (20)	3 (37.5)	1 (8.3)	0.26

Note: All data were presented as n (%), mean ± standard deviation or median (interquartile range); ED, emergency department; LOS, length of hospital stays

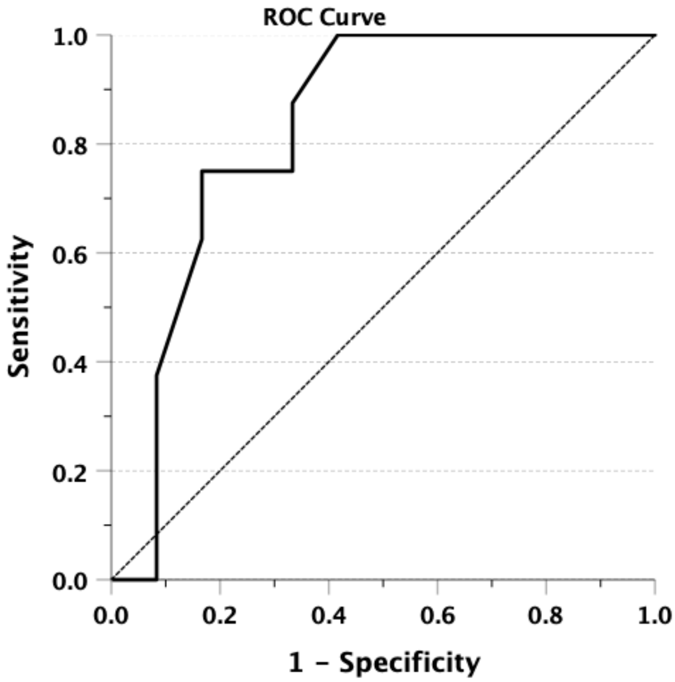

Figure 4 ROC curve of LUS for predicting 72-hour ETI

Table 2 showed sensitivity, specificity, PPV, and NPV for different cut points of LUS. The score of 19 was determined to be the optimal cut-off of LUS for 72-hour ETI with a sensitivity of 75% (95% CI, 34.9-96.8), specificity of 83.3% (95% CI, 51.6-97.9), PPV of 75% (95% CI, 44.3-91.9), and NPV of 83.3% (95% CI, 59.5-94.5) respectively.

The median LUS of survival and non-survival groups were 12.0 (10.0, 21.3) and 22.0 (15.3, 25.0) respectively. Increased LUS was also significantly associated with 28-day mortality ($p = 0.01$). The median LUS of patient with and without composite outcome of non-invasive ventilation, high-flow nasal cannula, and ETI at 72 hours after ED arrival were 19.0 (12.0, 23.0) and 11.0 (8.0, 22.0). This study did not find a significant association between increased LUS and the composite outcome of non-invasive ventilation, high-flow nasal cannula, and ETI ($p = 0.11$). In addition, there was a weak positive correlation between LOS and LUS (Spearman's coefficient of 0.43).

Table 2 Sensitivities, specificities, PPVs, and NPVs from different LUS measurements.

LUS	Sensitivity % (95%CI)	Specificity % (95%CI)	PPV % (95%CI)	NPV % (95%CI)
≥17	75 (34.9-96.8)	66.7 (34.9-90.1)	60.0 (38.0-78.6)	80.0 (53.0-93.4)
≥18	75 (34.9-96.8)	75 (42.8-94.5)	66.7 (41.0-85.2)	81.8 (56.5-94.0)
≥19	75 (34.9-96.8)	83.3 (51.6-97.9)	75.0 (44.3-91.9)	83.3 (59.5-94.5)
≥20	62.5 (24.5-91.5)	83.3 (51.6-97.9)	71.4 (38.8-90.8)	76.9 (56.8-89.4)

Note: LUS, lung ultrasound score; PPV, positive predictive value; NPV, negative predictive value; CI, confidence interval

The three ultrasound operators exhibited excellent reliability in interpreting LUS, with an intra-class correlation of 0.99.

Discussion

This pilot study primarily aimed to investigate an association between increased LUS and other adverse clinical outcomes such as ETI and mortality rate. We found that our results were consistent with the majority of the prior studies in terms of the positive relationship between increased LUS and patients' adverse outcomes. For instance, the result of an observational study of infants aged under 6 months with a diagnosis of bronchiolitis revealed that increased LUS was associated with the need for mechanical ventilation and prolonged respiratory support[11]. A previous meta-analysis conducted by Song G, et al. also found that increased LUS was associated with a higher mortality rate and increased severity among COVID-19 patients[8]. Furthermore, increased LUS in septic shock patients admitted to the intensive care units was correlated with worse clinical outcomes, including 28-day mortality, APACHE II score, and lactate levels[15].

In general, lung aeration loss is typically caused by various conditions such as infections, traumas, or any conditions that lead to fluid accumulation in the lung. This gas exchange reduction within the lung can be detected as positive findings from the lung ultrasound scan, such as the presence of multiple B-lines, lung consolidation, dynamic air bronchogram, and pleural effusion. Therefore, the LUS has been established as a valuable predictive tool for assessing as well as predicting adverse outcomes using a summation of the score findings from each region from both hemithorax[14].

We utilized a 12-region lung ultrasound scoring system as opposed to the 6- or 8-region scoring system[16,17] based on the fact that the 12-region lung ultrasound provides more lung parenchyma coverage, particularly the posterior region which is frequently missed by those two lung ultrasound assessments. However, the 12-region approach may require additional time and could potentially lead to a delay in patients' assessment in the ED setting.

In this study, we found that the LUS at 19 exhibited the highest sensitivity, specificity, PPV, and NPV for predicting 72-hour ETI. On the contrary, a previous study conducted by Giorno EPC, et al. suggested that the optimal cut-off value was 7 among patients aged less than 18 years with any type of lower respiratory illness[18]. The discordance of this result may be attributed to the fact that the children had more severity at lower scores because they have relatively weak respiratory muscle strength and fewer comorbidities compared to adults.

There are several limitations to our study. First, this is a single-center observational study so it might limit its external validity. Second, data collection was performed at the operators' convenience, resulting in a convenient sampling and allowing the disease progression that potentially could change in LUS readings. Third, we excluded patients who had received mechanical ventilators upon ED arrival so that patients with possibly increased LUS were not enrolled in this study. Forth, the time interval between patients' ED arrival and their ultrasound assessment ranged from minutes to several hours. Consequently, the variability in waiting times may result in differences in ultrasound findings following treatment. Finally, this study was a pilot study, further study is needed to validate the outcomes.

Conclusion

An increased lung ultrasound score was associated with 72-hour endotracheal intubation. Since it was conducted as a pilot study, further research is required to validate its outcome.

Conflict of interest

The authors declare no conflict of interest.

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