

The correlation of lung ultrasound score (LUSS) with P/F ratio value below 300 in patients with mechanical ventilation

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Abstract

Objective: This study aimed to probe the correlation between lung ultrasound score (LUSS) and the arterial oxygen pressure to the inspired oxygen fraction ratio (P/F ratio) in patients with respiratory failure on the first and second days of intensive care unit (ICU) care.

Design: This was a prospective, analytic study of LUSS and P/F ratio values below 300 in patients under mechanical ventilation.

Setting: We conducted in the ICU of Wahidin Sudirohusodo Hospital Makassar, South Sulawesi, Indonesia, in April 2024.

Patients and participants: Patients with respiratory failure on mechanical ventilation.

Measurement and results: All patients were examined using GE Logiq V2 ultrasonography and blood gas analysis. Of 52 patients, the mean age

was 41.62 ± 15.83 years. Most of the samples were male (61.5%), with the majority having a normal body mass index (BMI). In cases of improvement, there was a significant relationship between the LUSS and the P/F ratio of patients with respiratory failure under mechanical ventilation on the first ($r = -0.851$, $p < 0.001$) and second day ($r = -0.682$, $p < 0.001$). In cases of worsening LUSS ($n = 6$), it was found that there was no significant relationship ($p > 0.05$) between the LUSS and the P/F ratio of patients with respiratory failure on mechanical ventilation either on the first or second day.

Conclusion: There was a significant correlation between LUSS and P/F ratio on the first and second day in cases of improvement in patients with respiratory failure under mechanical ventilation.

Key words: Lung ultrasound score, P/F ratio, mechanical ventilation.

Introduction

In recent years, ultrasonography (USG) has become a favorable clinical technique for critically ill patients. Point-of-care ultrasound is now considered generally useful and, in some cases, has become

mandatory, for example, to guide medical procedures. Its bedside applications include diagnosis and therapeutic management of complex clinical conditions, such as hemodynamic instability, acute respiratory failure, or cardiac arrest. Lung ultrasound has become one of the techniques that has developed most rapidly. (1)

Lung ultrasound is growing in popularity among intensivists due to its ability to transmit the lungs directly to the patient's bedside and its non-invasive. In the evaluation of patients with respiratory failure in the Intensive Care Unit (ICU) or Emergency Department (ED), lung ultrasonography is considered superior to chest X-ray and is generally comparable to lung computed tomography (CT) scan, and reduces the need for patient transportation and radiation exposure. Due to its favorable diagnostic performance, lung ultrasonography (LUS) is a useful imaging modality for treating critically ill patients with respiratory failure, believed to be better than

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simply performing a physical examination to diagnose and evaluate many common respiratory conditions in the ICU. LUS can be performed by a physician at the point of care, quickly, safely, and efficiently because modern ultrasound machines are portable, widely available, inexpensive, and easy to use. (2,3)

A study of the Lung Ultrasound Score (LUSS) value and the arterial oxygen pressure to the inspired oxygen fraction ratio (P/F ratio) has been carried out with significant results at one measurement point. (4) However, no studies have been conducted at two different time measurements. The recent study probed the LUSS value and P/F ratio in patients with respiratory failure on the first and second days of ICU care and then determined whether LUS can be an alternative modality for reliable diagnostics and evaluation in the ICU.

Material and methods

Settings and design

This was a prospective, analytic study of LUSS and P/F ratio values below 300 in patients under mechanical ventilation. It was conducted in April 2024 in the ICU of Wahidin Sudirohusodo Hospital Makassar, South Sulawesi, Indonesia. The Medical Research Ethics Committee of Hasanuddin University Makassar (228/UN4.6.4.5.31/PP36/2024) approved all experimental protocols employed in this study.

Study group

Patients with respiratory failure on mechanical ventilation treated in ICU, aged ≥ 18 years, enrolled in this study. Patients with unstable hemodynamics, obesity, and contraindications for changing positions (spinal cord injury) were excluded.

Study protocol

A total of 52 patients who met the inclusion criteria were included. All patients were examined using GE Logiq V2 ultrasonography, with convex and linear probes, with the image depth set at 6-8 cm. The probe orientation could be linear and longitudinal or transverse. The examination started from the anterior area and moved towards the lateral. (5) Lung ultrasound performed at 12 points on the right and left lungs. LUSS value will be recorded with a score of 0 (good) to 3 (poor). A P/F ratio of less than 300 indicates acute respiratory failure. (6) The first day was when the patient entered the ICU to receive mechanical ventilation and took blood gas analysis samples. The second day was when the patient took a control blood gas analysis on the second day or 24 hours after taking the first blood gas analysis.

Data analysis

The collected data was analyzed and presented as mean \pm SD or frequency and percentage. Statistical analysis was performed using the IBM[®] SPSS[®] Statistics version 29.0.1.1 for Macbook (SPSS Inc., Chicago, IL, USA). The normality test showed that the data was not normally distributed. The Spearman and Pearson correlation test was used. p -value <0.05 was considered as statistically significant.

Results

Homogeneity

Table 1 shows the demographic data. Of 52 patients, the mean age was 41.62 ± 15.83 years. Most of the samples were male (61.5%), with the majority having a normal body mass index (BMI). Based on ventilator settings, most samples had synchronized intermittent mandatory ventilation (SIMV) mode settings (34.6%).

Lung ultrasound score and P/F ratio on the first and second days

Table 2 presents the LUSS and P/F ratio values in patients with respiratory failure with mechanical ventilation. There was a significant relationship between the LUSS and the P/F ratio of patients with respiratory failure under mechanical ventilation on the first and second days ($r=-0.851$, $p<0.001$ and $r=-0.682$, $p<0.001$, respectively) (**Table 3, Figures 1 and 2**). In cases of worsening LUSS ($n=6$), it was found that there was no significant relationship ($p>0.05$) between the LUSS and the P/F ratio of patients with respiratory failure on mechanical ventilation either on the first or second day (**Table 4**).

Discussion

The respiratory system provides oxygen and removes carbon dioxide from the body. The inability of the respiratory system to perform one or both of these tasks results in respiratory failure. (7) Respiratory failure is a syndrome caused by many pathological conditions; therefore, the epidemiology of this disease process is difficult to ascertain. However, in 2017, in the United States, the incidence of respiratory failure was found to be 1,275 cases per 100,000 adults. The epidemiology of respiratory failure mainly depends on the cause of the respiratory failure. (8)

This study involved patients who experienced respiratory failure with a P/F ratio below 300 with varied cases (postoperative respiratory failure, sepsis, acute respiratory distress syndrome [ARDS], lung edema, etc.) according to the inclusion criteria. The

results of this study show that the majority were aged 17 to 60 years, with an average of 41 years. These results also show that men were the most common gender compared to women, with an average BMI. These results are in accordance with an epidemiological study on respiratory failure in the United States in 2002-2017, which showed an increase in the proportion of patients aged 18-69 years with a decrease in the proportion of female patients. (8)

The risk of complications associated with mechanical ventilation increases with the duration of ventilator use. Patients who require long-term mechanical ventilation are at risk of increased morbidity. Changes in LUSS are predictive of the success or failure of extubation. (9) LUSS is one part of the ultrasonography of critical patients, using simple instruments and one universal probe. (10) This study found that, in general, the average LUSS value improved from the first day to the second day, from 9.96 ± 8.063 to 6.75 ± 7.533 . LUS has proven useful in detecting pneumothorax, interstitial syndrome, and pulmonary consolidation. This modality is easy to apply at the bedside, in real-time, and is free from radiation hazards. Recently, LUS has shifted from a diagnostic to a monitoring tool for quantifying lung aeration. (11)

Apart from LUS, the P/F ratio can also be used as a monitoring instrument for patients with mechanical ventilation. The P/F ratio is the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen, also known as the Carrico index. This instrument is most often used as a clinical indicator of the level of hypoxemia, but its diagnostic accuracy is questionable. In previous literature, the P/F ratio has been applied and studied as a predictor of extubation outcomes in mechanically ventilated patients suffering from hypercapnic respiratory failure. (12) The results of the P/F ratio in this study were found to improve from the first to the second day after using mechanical ventilation.

Then, a correlation test was carried out between the LUSS and P/F ratio at two different times (first and second day), and the results were significant. This study was in accordance with a study conducted in the ICU of Dr. Sardjito Hospital. Of the 60 subjects in this study, patient observation points with high P/F ratio values tended to have lower LUSS values. Based on the correlation results, a value of $p=0.010$ ($p<0.05$) was obtained with a correlation coefficient (r) = 0.332 with a negative sign, which meant there was a significant negative correlation between the LUSS value and the P/F ratio with a close relationship in the weak category (0.2-0.399). It concluded that the higher the P/F ratio value, the lower the

LUSS value in patients with pneumonia who received mechanical ventilation. (4)

In addition, similar results were seen in an Italian study where the LUSS was inversely correlated with the P/F ratio. Thus, the LUSS was found to correlate with changes in gas exchange and pathological changes affecting the lung parenchyma. (13) These data also agreed with the study of Secco et al., who reported similar results. (14) Although P/F can only reflect functional changes, lung ultrasonography can help reveal the pathological picture of the disease. (15)

In pathological conditions of the lungs, an ultrasound examination will reveal other artifact images, such as B-line images and shred signs/tissue-like signs, in addition to the A-line images. B-line has been associated with the amount of fluid in the lungs, which can occur in several conditions of the patient's lung disease, such as pneumonia. The amount of fluid in the lungs will contribute to a decrease in the P/F ratio. (16)

Apart from the B-line image, lung ultrasonography can also show a shred/tissue-like sign, indicating lung consolidation. Lung consolidation results from massive loss of aeration in the lungs, such as lobar bronchopneumonia, lung contusions, and atelectasis. This is indicated by an ultrasound image with a texture like liver tissue (hepatization). Within the consolidation area, hyperechoic points associated with air-filled bronchi can be seen. Gas penetration into the consolidating bronchi during inspiration produces a clearer image of these hyperechoic points during inspiration. Consolidation in the lungs will affect the process of oxygen diffusion from the lungs to the blood vessels, which will result in a reduction in the partial pressure of oxygen in the blood and ultimately affect the P/F ratio. (4,16)

Then, the results of separate tests in this study on samples that experienced worsening LUSS showed no significant relationship with the P/F ratio in patients with respiratory failure on mechanical ventilation on either the first or second day. Insignificant result is thought to cause the LUSS value in patients who experience worsening tends to be static or minimal changes. The maximum LUSS value in each lung area is 3; in cases of worsening, the LUSS value will remain 3 so that the value will be static and make the correlation test results insignificant. Serious cases, such as pneumonia, ARDS, and other complications, require a longer time to improve lung conditions, whereas this study was only carried out for 2 days. Therefore, the results of the LUSS values taken have not experienced any significant changes.

In addition, these results are in accordance with a

study in Singapore in 2020, which showed no significant correlation between the P/F ratio and focal ARDS. The possible cause was that the degree of impaired oxygenation was more related to the extent of lung involvement in ARDS and not the distribution of lung involvement. To illustrate, for every 1-point increase in total LUSS, the P/F ratio decreased by 1.7 (95% CI -3.3 to -0.19, $p=0.028$). Based on these results, thoracic imaging remains required for identifying focal ARDS. (17)

Conclusion

There was a significant correlation between LUSS

and P/F ratio on the first and second days in cases of improvement in patients with respiratory failure under mechanical ventilation.

Declaration of competing interest

No potential conflict of interest relevant to this article was reported.

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Table 1. Demographic data

Demographic	n (%)
Age (years)	
- 17-39	22 (42.3)
- 40-59	22 (42.3)
- ≥60	8 (15.4)
- Mean±SD	41.62±15.83
Gender	
- Male	32 (61.5)
- Female	20 (38.5)
Body mass index (kg/m ²)	
- Underweight	7 (13.5)
- Normal	34 (65.4)
- Overweight	11 (21.2)
- Obese 1	0 (0)
- Obese 2	0 (0)
- Mean±SD	22.51±3.22
Ventilator settings	
- ACMV	1 (1.9)
- SIMV VC	7 (13.5)
- SIMV PC	10 (19.2)
- SIMV	18 (34.6)
- AC PC	6 (11.5)
- C	10 (19.2)
Total	52 (100)

Legend: ACMV=Assist/Control Mode Ventilation; SIMV VC=Synchronized Intermittent Mandatory Ventilation Volume Control; SIMV PC=Synchronized Intermittent Mandatory Ventilation Pressure Control; AC PC=Assist Control, Pressure Control Ventilation; C=Continuous Ventilation.

Table 2. Lung Ultrasound Score and P/F ratio values in patients with respiratory failure on mechanical ventilation

Variables	Day	Mean±SD
Lung Ultrasound Score	First	9.96±8.063
	Second	6.75±7.533
P/F ratio	First	252.02±45.090
	Second	323.19±80.568

Legend: P/F ratio=arterial oxygen pressure to inspired oxygen fraction ratio.

Table 3. Correlation of Lung Ultrasound Score value with P/F ratio on the first and second days

Day	Variable	Mean±SD	Coefficient correlation	p-value
First	Lung Ultrasound Score	9.96±8.063	-0.851	<0.001*
	P/F ratio	252.02±45.090		
Second	Lung Ultrasound Score	6.75±7.533	-0.682	<0.001*
	P/F ratio	323.19±80.568		

Legend: P/F ratio=arterial oxygen pressure to inspired oxygen fraction ratio.

*Data was tested using the Spearman correlation test.

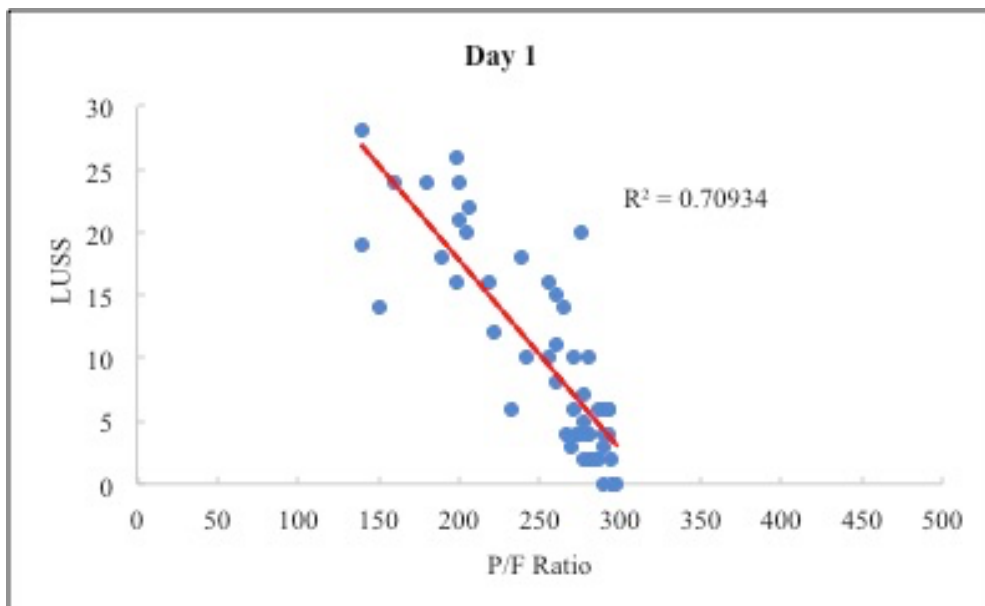
Table 4. Correlation of Lung Ultrasound Score value with P/F ratio on the first and second days (worsening cases)

Day	Variable	Mean±SD	Coefficient correlation	p-value
First	Lung Ultrasound Score	10.67±6.532	-0.065	<0.203*
	P/F ratio	271.83±27.982		
Second	Lung Ultrasound Score	17.33±7.866	-0.232	<0.658**
	P/F ratio	181.00±68.173		

Legend: P/F ratio=arterial oxygen pressure to inspired oxygen fraction ratio.

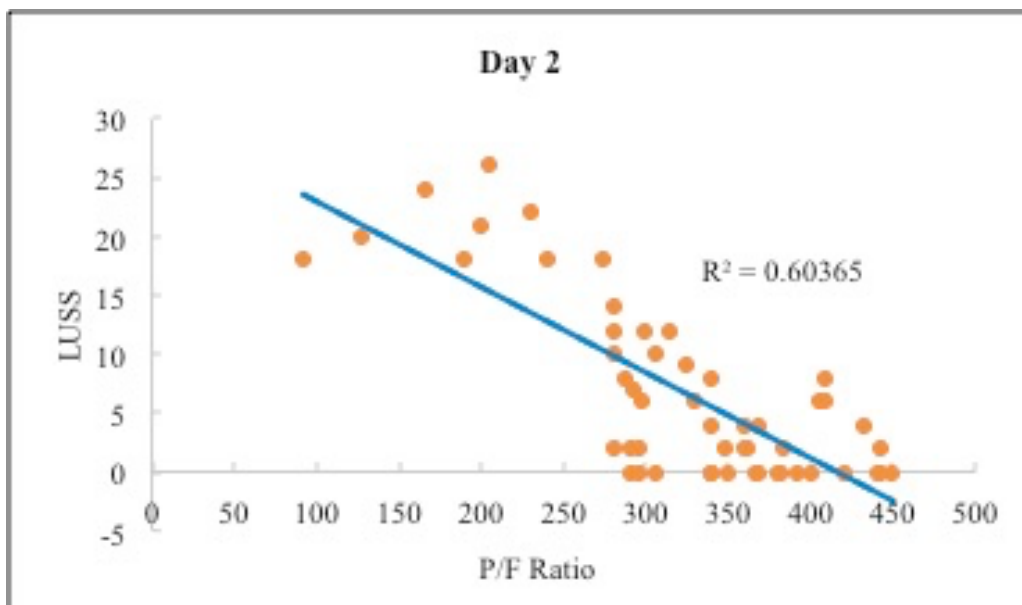
*Data was tested using the Spearman correlation test; **Data was tested using the Pearson correlation test.

Figure 1. Distribution of the Lung Ultrasound Score value and P/F ratio on the first day



Legend: P/F ratio=arterial oxygen pressure to inspired oxygen fraction ratio.

Figure 2. Distribution of the Lung Ultrasound Score value and P/F ratio on the second day



Legend: P/F ratio=arterial oxygen pressure to inspired oxygen fraction ratio.

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