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# FINDINGS AND PROGNOSTIC VALUE OF LUNG ULTRASONOGRAPHY IN CORONAL VIRUS DISEASE 2019 (COVID-19) PNEUMONIA

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ABSTRACT—**Purpose:** We used lung ultrasonography to identify features of COVID-19 pneumonia and to evaluate the prognostic value. **Patients and Methods:** We performed lung ultrasonography on 48 COVID-19 patients in an intensive care unit (ICU) (Wuhan, China) using a 12-zone method. The associations between lung ultrasonography score, $PaO_2/FiO_2$, APACHE II, SOFA, and $PaCO_2$ with 28-day mortality were analyzed and the receiver operator characteristic curve was plotted. **Results:** 25.9% areas in all scanning zones presented with B7 lines and 23.5% with B3 lines (B-pattern) on lung ultrasonography; 13% areas with confluent B lines (B-pattern), 24.9% in areas with consolidations, and 9.9% in areas with A lines. Pleural effusion was observed in 2.8% of areas. Lung ultrasonography score was negatively correlated with $PaO_2/FiO_2$ ($n = 48$, $r = -0.498$, $P < 0.05$) and positively correlated with APACHE II ($n = 48$, $r = 0.435$, $P < 0.05$). Lung ultrasonography score was independently associated with 28-day mortality. The areas under receiver operator characteristic curves of lung ultrasonography score were 0.735 (95% CI: 0.586–0.844). The sensitivity, specificity, and cutoff values were 0.833, 0.722, and 22.5, respectively. **Conclusions:** Lung ultrasonography could be used to assess the severity of COVID-19 pneumonia, and it could also reveal the pathological signs of the disease. The lung ultrasonography score on ICU admission was independently related to the ICU 28-day mortality.

KEYWORDS—Coronavirus disease 2019, lung ultrasonography, lung ultrasound score, pneumonia, prognostic value

ABBREVIATIONS—COVID-19—Coronavirus Disease 2019; $FiO_2$—fraction of inspiration $O_2$; LUS—lung ultrasonography score; $PaCO_2$—partial pressure of carbon dioxide; $PaO_2$—partial pressure of oxygen; SOFA—Sequential Organ Failure Assessment

## Key Points

- The characteristic findings of lung ultrasonography in COVID-19 included thickening pleural line with irregularity; focal, multifocal, and confluent B lines; consolidations; A lines and pleural effusions.
- Lung ultrasonography scores (LUS) were negatively correlated with $PaO_2/FiO_2$ and positively correlated with APACHE II score.
- Elevated LUS at the ICU admission was associated with worse 28-day mortality.

## INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pneumonia was first reported in China and is now a global pandemic issue. Traditional imaging tools like X-ray have had limited utility for clinical examination and decision-making in clinical management of COVID-19 patients. Previous evidence showed that lung ultrasonography was able to detect interstitial lung disease, subpleural consolidations, and acute respiratory distress syndrome regardless of etiologies (1–3). COVID-19 pneumonia with different sonographic manifestations may indicate different phases, severity, and prognosis. The latest suggestion proposes that lung ultrasonography be applied to diagnose, monitor, and follow-up cases with COVID-19 pneumonia (4).

Many studies have shown lung ultrasonography to be beneficial in assessing the severity and prognostic value of lung diseases such as adult respiratory distress syndrome (ARDS) (5–7). In addition, lung ultrasonography gives similar results to chest CT. Moreover, lung ultrasonography is superior to standard chest radiography for the evaluation of pneumonia and/or ARDS and added advantages include ease of use at point of care, repeatability, absence of radiation exposure, and low cost (8). It also enables daily monitoring of clinical evolution, response to treatment, and possible complications (e.g., pneumothorax, over-infections) (9, 10).

With these advantages, lung ultrasonography is currently preferred to other imaging techniques. Moreover, it is more accurate for interstitial diseases and may show pathological signs before the chest X-ray is presented. Indeed, an assessment

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LL and AQ contributed equally to this study and therefore shared the first authorship.

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This study was approved by the institutional ethics board of Zhongnan Hospital of Wuhan University (No. 2020088K). Informed consent was waived as it was an observational study, and the data are anonymized.

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

LL and AQ collected the data and wrote the manuscript. XY did the statistical analysis. SZ, YL, and FZ collected the data. JL, BH, and SC revised the manuscript. ZP designed and finalized the manuscript.

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with an ultrasound protocol could help to determine the ventilation strategy: if diffuse loss of aeration, keep high positive end-expiratory pressure levels, and if posterior consolidations, consider pronation.

Lung ultrasonography is most beneficial in a scenario (such as COVID-19) that includes limited access to traditional imaging and difficulty transportating patients. However, data on COVID-19 has been limited, and most published studies were case reports. Thus, in our study, we aimed to use bedside ultrasonography to identify the features of COVID-19 pneumonia, and evaluate whether lung ultrasonography could predict outcomes of COVID-19.

## PATIENTS AND METHODS

### Design, setting, and patients

This a prospective observational cohort study was conducted in Zhongnan Hospital of Wuhan University (Wuhan, China). Adult patients with COVID-19 pneumonia admitted to the intensive care unit (ICU) were included consecutively from January 8 to April 14 2020 and received lung ultrasonography on admission within 24 h and on deterioration. Patients who then experienced clinical deterioration underwent a repeated examination. Clinical deterioration was defined as respiratory (acute new onset hypoxemia requiring mechanical ventilation, veno-venous extracorporeal membrane oxygenation, or mechanical ventilation parameters worsened more than 30%). Clinical variables collected were based on the performance of the ultrasound. The diagnosis of SARS-CoV-2 pneumonia was confirmed by both real-time reverse transcription-polymerase chain reaction (RT-PCR) assays and serological tests, in accordance with the World Health Organization interim guidance on diagnosis and treatment of COVID-19 (11). This study was approved by the institutional ethics boards of Zhongnan Hospital of Wuhan University (No. 2020088K). Informed consent was waived.

### Lung ultrasonography protocol

The lung ultrasonography was performed at the bedside with a imaging device (Venue R2; GE, Waukesha, Wis), according to international guidelines (12). A protocolized lung ultrasonography examination (a 12-zone method) was performed on admission of the first day Within 24 h in the ICU and repeated if the patient's condition was deteriorated (12). A Convex probe (2–5 MHz) was used for intercostal lung views through longitudinal scans to calculate the lung ultrasonography score (LUS). Each chest side was divided into six areas: two anterior chest areas (from the parasternal to the anterior axillary, divided into upper and lower halves), around the third intercostal space for LUS anterior; two lateral chest areas (from the anterior to the posterior axillary line, separated into upper and basal halves) for LUS lateral, and two posterior chest areas (beyond the posterior axillary line separated into upper and basal halves) for LUS posterior.

The LUS was computed using the sum of point values from each scanning site (0: normal; 1: moderate interstitial syndrome; 2: severe interstitial syndrome [multiple or coalescent B-lines]; 3: alveolar consolidation). A score from 0 to 36 was then calculated (13). LUS was required to assess the whole lung in 10-min 12 areas (2 posterior, 2 lateral, and 2 anterior) in sequence. If a patient is in the prone position, or in severe hard-to-detect conditions, the operator should try to have a partial view of posterior basal areas with at least eight scanning sites. They should employ a single focal point on the pleura line and adjust the right depth and brightness to get an optimal image.

Four ultrasound aeration patterns and accordingly grade were defined: normal aeration: presence of lung sliding with A lines or fewer than two isolated B lines; moderate loss of lung aeration: multiple, well-defined B lines; severe loss of lung aeration: multiple confluent B lines; and lung consolidation, the presence of a tissue pattern characterized by dynamic air bronchograms.

After scanning, the operator saves the data in figure or video format with the patients' information (name, admission number, gender, time) for retrospective analysis. In this study, only the data including the 12 complete lung regions were used for statistical analysis. All lung ultrasound images were examined by senior ICU physicians who were certified by CCUSG (Chinese Critical Care Ultrasound Study Group). Two physicians were blind to each other's ultrasound diagnosis. Inter-observer variability for LUS score was determined by a second independent blinded and experienced observer, who measured the LUS score in 18 randomly selected patients. Inter-observer variability was assessed using the Bland–Altman method and the within-subject coefficient of variation. The within-subject coefficient of variation (calculated as the ratio of the standard deviation of the measurement difference to the mean value of all measurements) provides a scale-free, unitless estimate of variation expressed as a percentage.

### Data collection

At baseline, demographic data and a medical history were collected from each patient and/or a family member. Vital signs, laboratory findings, imaging results, medications, important treatments (including continuous renal replacement therapy, mechanical ventilation, extracorporeal membrane oxygenation), and patients' outcomes were recorded from the electronic medical records. The data were reviewed by a trained team of physicians. All patients were followed up for 28 days to assess their outcomes.

### Statistical analysis

We described the categorical data with frequency (percentages), and continuous variables with mean or medians. We used Chi-squared test for categorical data. We used *t* test for continuous data within normal distribution, and Wilcoxon–Mann–Whitney test for continuous variables without normal distribution. Correlations between LUS and oxygenation index as well as APACHE II, SOFA, $PaCO_2$, $PaO_2$, and respiratory rate were analyzed by bivariate correlation analysis. We analyzed the predictive value using the logistic regression model. Receiver operator characteristic curve (ROC) was plotted; and the sensitivity, specificity of mortality, and cutoff value by LUS were calculated. Statistical analyses were performed using IBM SPSS v26 software. $P < 0.05$ was regarded as statistically significant.

## RESULTS

### Characteristics of subjects

A retrospective analysis of the data was performed in the current study from January 8 to April 14, 2020. As shown in Table 1, a total of 48 subjects were included in this study; 12 subjects died within 28 days of observation and their clinical characteristics were compared with the survivors. Comorbidities were present in 70.8% of patients, with hypertension being the most common, followed by diabetes, ischemic heart disease, and smoking. The non-survivors had higher levels of white blood cells, lymphocytes, creatinine, Troponin-I, and brain natriuretic peptide ($P > 0.05$ for all). Generally, the non-survivors had significantly higher APACHE II, $PaCO_2$, and LUS ($P < 0.05$ for all). Therefore, these variables were included for further analyses.

### Ultrasonography features of COVID-19 pneumonia

Characteristic findings included thickening pleural line with irregularity; focal, multifocal, and confluent B lines (B-pattern); consolidations in a variety of patterns including multifocal small, non-trans lobar, and translobar with occasional mobile air bronchograms; and A lines and pleural effusions.

Of the 48 enrolled patients, 25.9% areas in all scanning zones presented with B7 lines and 23.5% with B3 lines (B-pattern) on lung ultrasonography; 13% areas with confluent B lines (B-pattern), 24.9% in areas with consolidations, and 9.9% in areas with A lines. Pleural effusion was observed in 2.8% of areas. Typical lung ultrasonography images are shown in Figure 1. The Bland–Altman plot showed a random scatter of points around 0, indicating no systematic bias or measurement error proportional to the measurement value.

### LUS and clinical deterioration

In 16 patients, sequential LUS exams were performed due to clinical deterioration. In this group of patients, theLUSworsened with clinical deterioration ($P = 0.011$). In these 16 patients, who underwent a repeated LUS because of further respiratory

TABLE 1. **Characteristics of the subjects on admission**

| Characteristics | Total (n = 48) | Survival (n = 36) | Non-survival (n = 12) | *P* value |
|---|---|---|---|---|
| Age (years) | 65.5 ± 14.6 | 66.1 ± 12.9 | 63.6 ± 19.1 | 0.703 |
| Gender (male/female) | 34/15 | 25/11 | 8/4 | 0.009 |
| APACHE II score | 10.5 ± 9.2 | 8.8 ± 8.3 | 15.3 ± 10.4 | 0.032 |
| SOFA score | 4.8 ± 2.9 | 9.4 ± 4.4 | 8.8 ± 3.0 | 0.811 |
| LUS | 20.9 ± 6.1 | 19.7 ± 6.2 | 24.5 ± 3.9 | 0.015 |
| Baseline physical examination | | | | |
| Respiratory rate | 23.6 ± 4.1 | 23.0 ± 4.1 | 25.3 ± 3.5 | 0.054 |
| Heart rate, beats/minute, median (IQR) | 95.5 (80–109) | 95 (82–109.7) | 96 (80–108.5) | 0.703 |
| Systolic blood pressure, mm Hg, median (IQR) | 129 (113.5–143.5) | 125.5 (112.25–139.25) | 137 (118.75–149) | 0.22 |
| Diastolic blood pressure, mm Hg, median (IQR) | 71 (61.25–79.5) | 66.5 (60–80.75) | 74.5 (64.25–76) | 0.504 |
| Temperature, Celsius, median (IQR) | 36.8 (36.5–37.8) | 36.85 (36.5–37.7) | 36.8 (36.5–38) | 0.821 |
| PH | 7.39 ± 0.09 | 7.39 ± 0.10 | 7.39 ± 0.07 | 0.559 |
| $PaO_2$ (mm Hg) | 81.0 ± 36.2 | 85.3 ± 40.7 | 68.1 ± 8.3 | 0.182 |
| $PaCO_2$ (mm Hg) | 47.0 ± 15.0 | 44.7 ± 14.1 | 53.9 ± 16.0 | 0.248 |
| $PaO_2/FiO_2$ | 87.1 ± 79.8 | 82.8 ± 85.4 | 100.3 ± 61.5 | 0.008 |
| PEEP ($cmH_2O$) | 8.4 ± 3.5 | 8 ± 2.7 | 9.5 ± 4.7 | 0.383 |
| Comorbidity | | | | |
| Ischemic heart disease, n (%) | 9 (18) | 6 (16) | 3 (25) | 0.000 |
| COPD, n (%) | 4 (8) | 3 (8) | 1 (8) | 0.000 |
| Chronic kidney disease, n (%) | 2 (4) | 1 (2) | 1 (8) | 0.000 |
| Diabetes, n (%) | 9 (18) | 5 (13) | 4 (33) | 0.000 |
| Smoking, n (%) | 9 (18) | 6 (16) | 3 (25) | 0.000 |
| Hypertension, n (%) | 21 (43) | 14 (38) | 7 (58) | 0.386 |
| Baseline laboratory results | | | | |
| White blood cells, $10^3/\mu L$, median (IQR) | 9.89 (7.46–15.33) | 9.52 (6.39–13.63) | 11.18 (9.1–19.2) | 0.094 |
| Lymphocytes, $10^3/\mu L$, median (IQR) | 0.71 (0.33–1.08) | 0.65 (0.33- 1.37) | 0.77 (0.47–0.81) | 0.742 |
| Creatinine, mg/dL, median (IQR) | 65 (48.4–87.75) | 64.3 (45.47–95.85) | 72.1 (57.5–76.6) | 0.556 |
| Troponin-I, ng/L, median (IQR) | 1.2 (0.05–10.05) | 1.1 (0.02–11) | 1.75 (0.15–9.6) | 0.75 |
| Brain natriuretic peptide, pg/mL, median (IQR) | 46.85 (10.2–221.27) | 38.7 (10.17–160.82) | 132.74 (15.09–343.75) | 0.343 |
| PLT, $10^9$/L, mean ± SD | 187.2 ± 77.5 | 187.1 ± 86.0 | 187.3 ± 49.0 | 0.808 |

APACHE II indicates Acute Physiology and Chronic Health Evaluation II; SOFA, Sequential Organ Failure Assessment; LUS, lung ultrasound score.

deterioration, no significant correlation was found between the change in LUS nor the change in PEEP requirements ($P = 0.374$).

### *Correlations between LUS score with $PaO_2/FiO_2$ and APACHE II*

LUS was significantly negative correlated with $PaO_2/FiO_2$ (n = 48, $r = -0.498$, $P < 0.05$) and positively correlated with APACHE II (n = 48, $r = 0.435$, $P < 0.05$) (Fig. 2).

### *Associations between LUS, $PaO_2/FiO_2$, SOFA, APACHE II, $PaO_2$, $PaCO_2$, age, baseline physical examination, comorbidity, and baseline laboratory results with 28-day mortality*

We analyzed the associations between LUS, $PaO_2/FiO_2$, SOFA, APACHE II, $PaO_2$, $PaCO_2$, PEEP, respiratory rate, PH, heart rate, systolic blood pressure, diastolic blood pressure, temperature, white blood cells, lymphocytes, PLT, creatinine, Troponin-I, brain natriuretic peptide, age, and comorbidity with 28-day mortality using the logistic regression model. As shown in Table 2, in univariable analysis and multivariable analysis, only LUS was independently associated with 28-day mortality.

### *Predictive values of LUS for 28-day mortality*

Figure 3 demonstrates that LUS was significantly correlated with the 28-day mortality ($P = 0.016$). The areas under ROC curves (AUC) of LUS was 0.735 (95% CI: 0.586–0.844). The sensitivity, specificity and cutoff values for LUS were 0.833, 0.722 and 22.5, respectively.

## DISCUSSION

In this study, we performed lung ultrasonography in 48 patients with COVID-19 using a 12-zone method. Characteristic findings included thickening pleural line with irregularity; focal, multifocal and confluent B lines (B-pattern); consolidations; and A lines and pleural effusions. Xing et al. in 2020 demonstrated that lesions were most commonly distributed peripherally in the lung, and were easily detectable by lung ultrasonography (14). The predominant pattern comprised thickened pleural line, varying degrees of interstitial syndrome, and alveolar consolidation.

Our results were consistent with previous studies (15), and the features were similar to comparison with chest CT findings characterized by thickened pleura, ground glass shadow and effusion, pulmonary infiltrating shadow, and subpleural consolidation, respectively (16). Therefore, with the advantages of lung ultrasonography, our study could reveal pathologic features of COVID-19 pneumonia. To the best of our knowledge, this is the biggest case series to date to explore the features and predictive values of lung ultrasonography in COVID-19.

The presence of B lines represented an impaired aeration of lung and alveolar septum thickening. When the disease deteriorated, further severe damage in aeration occurred involving the lesions on the alveoli when white lung sign was detected on lung ultrasonography. When the disease was further aggravated together with more involved alveoli and collapsed alveoli, the consolidations and pleural effusions were detected on lung

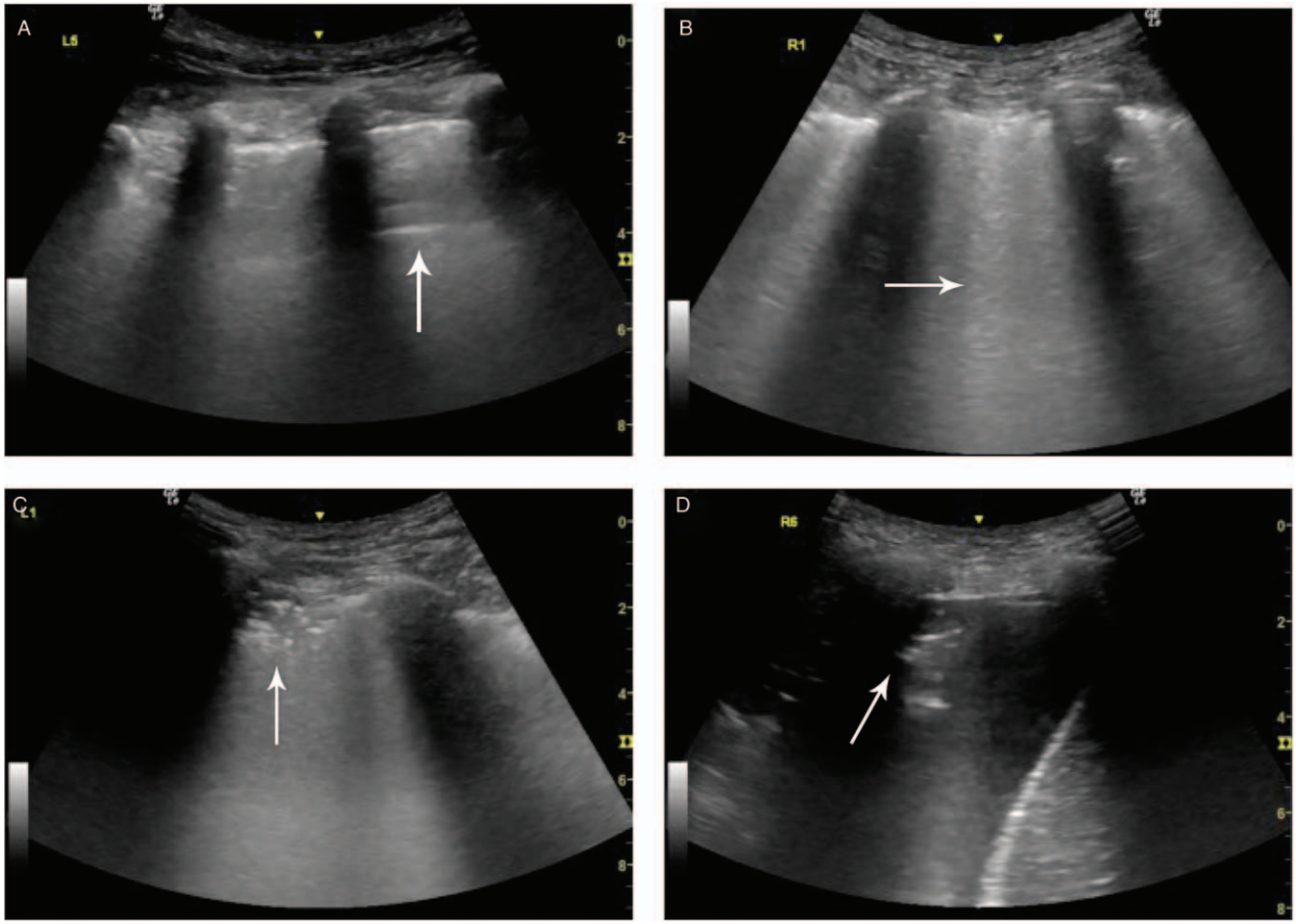


Fig. 1. **Four characteristic ultrasound findings of COVID-19 pneumonia: (A) thickening of the pleural line with A lines. (B) Confluent B lines. (C) Multifocal small consolidations. (D) Consolidations and pleural effusions.**

ultrasonography. These findings on lung ultrasonography were consistent with the pathological manifestations of COVID-19 pneumonia. The alveolar epithelial cells were involved in the early stage of the disease. Interstitial plasma cell infiltration, alveolar septum thickening, proliferation of interstitial cells, and infiltration were all observed.

With disease progression, inflammatory cells and a large amount of cellulose-like exudate in the alveolar cavity (characterized with diffuse alveolar damage) were observed. When the lung injury continued to exacerbate, necrosis of alveolar epithelial cells, inflammatory cell infiltration in alveoli and interstitial areas, collapse of alveoli, pulmonary interstitial fibrosis, and alveolar septum thickening were detected (17, 18). In summary, severity of the pathologic features of COVID-19 could be reflected in different features of the lung ultrasonography findings.

LUS is an efficient measurement tool to assess the severity of pulmonary illness. Our study was the first to evaluate the prognostic value of LUS in COVID-19 pneumonia. Some studies have shown that lung ultrasonography on ICU admission contributes to predicting the outcome. Bedsides lung ultrasonography score, which is simple and easily available, the degree of severity of ARDS and the prognosis can also be evaluated (19).

Our study concluded that LUS on ICU admission was significantly correlated with 28-day mortality and LUS was the independent risk factor for worse outcome. We also confirmed that LUS was significantly negatively correlated with $PaO_2/FiO_2$ ($P < 0.05$) and positively correlated with APACHE II score ($P < 0.05$). When LUS was greater than 22.5, the sensitivity and specificity were 0.833 and 0.722, respectively, for predicting the mortality. While the $PaO_2/FiO_2$ could only reflect functional changes, lung ultrasonography could reveal the pathologic features of the disease. Therefore, it makes sense that LUS was the only indicator to predict the risk of death compared to conventional measures such as $PaO_2/FiO_2$.

It could be useful to associate LUS with the severity of disease, as changes in lung aeration cannot be recognized at the early stage. Some studies claimed that aeration changes could be detected bedside by lung ultrasonography score before the changes in $PaO_2/FiO_2$ (20). Analysis of the correlation between LUS and disease severity in this study invites future studies in using lung ultrasonography for predicting the severity of lung injury and assessing mortality and prognosis. Furthermore, the correlation may be utilized to grade the severity of diseases, which could be combined with traditional parameters such as oxygenation index. It could also be used to predict the severity

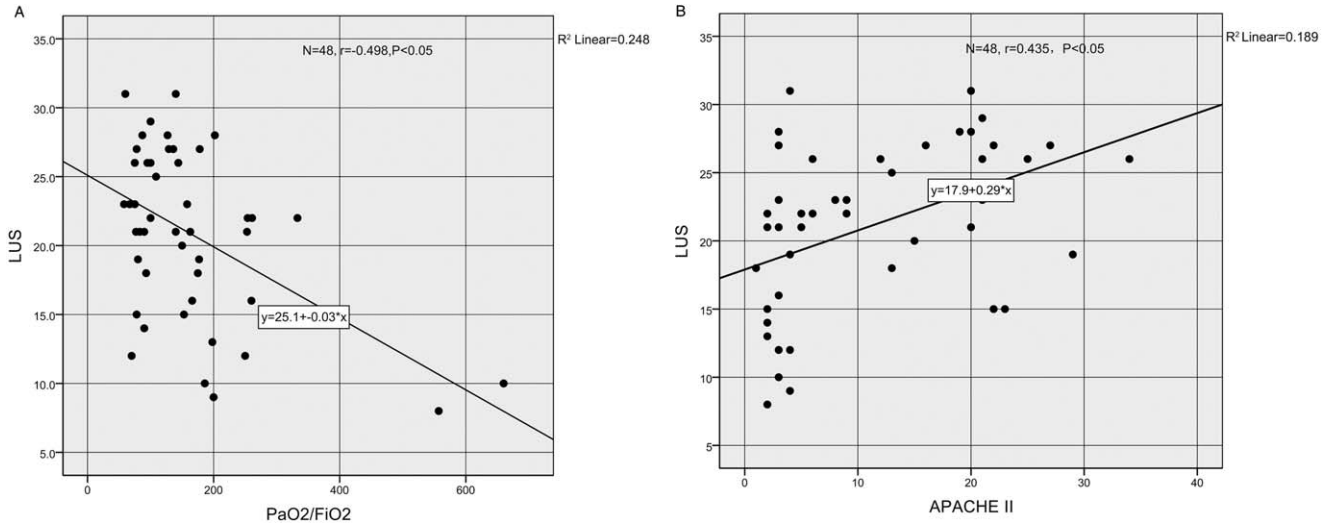


FIG. 2. **Correlations between lung ultrasonography score (LUS), $PaO_2/FiO_2$, and APACHE II score. LUS was significantly negatively correlated with $PaO_2/FiO_2$ (n = 48, $r = -0.498$, $P < 0.05$) and positively correlated with APACHE II score (n = 48, $r = 0.435$, $P < 0.05$).**

and prognosis of the disease earlier than the oxygenation index, and used for guiding the treatment therapy.

As it is noninvasive, easily available, rapid, gives no radioactive exposure, and gives reproducible data collection at the bedside, ultrasound is better than other diagnostic methods. Moreover, by comparing with other monitoring or imaging equipment, the ultrasound device can visually focus on the lung pathology at the bedside, which highlights its unique value. Thus, it is important to encourage use of lung ultrasonography when patients are admitted to the ICU with COVID-19 pneumonia.

This study has some limitations. First, it is a Observational study. Although we assigned two operators to double check the data and identify the variables strictly according to the standard and guidelines, the results still might be affected by inherent

TABLE 2. **Associations between LUS, $PaO_2/FiO_2$, SOFA, APACHEII, baseline physical examination, comorbidity, baseline laboratory results, and 28-day mortality**

| | Univariable analysis | | Multivariable analysis | |
|---|---|---|---|---|
| Variables | OR (95% CI) | *P* | OR (95% CI) | *P* |
| LUS (per 5) | 0.429 (0.204–0.902) | 0.026 | 2.331 (1.109–4.896) | 0.026 |
| Repeated LUS (per 5) | 6.475 (0.6–69.877) | 0.124 | | 0.101 |
| $PaO_2/FiO_2$ (per 5) | 1.013 (0.975–1.052) | 0.515 | — | 0.423 |
| SOFA (per 5) | 0.84 (0.367–1.922) | 0.68 | — | 0.585 |
| APACHEII (per 5) | 1.46 (1.015–2.098) | 0.041 | — | 0.227 |
| PaO2 (per 5) | 0.895 (0.746–1.074) | 0.233 | — | 0.401 |
| PaCO2 (per 5) | 1.214 (0.979–1.504) | 0.077 | — | 0.103 |
| PEEP (per 5) | 1.857 (0.663–5.204) | 0.239 | — | 0.248 |
| Repeated PEEP (per 5) | 1.146 (0.247–5.31) | 0.862 | — | 0.477 |
| Respiratory rate (per 5) | 2.179 (0.914–5.193) | 0.079 | — | 0.102 |
| PH (per 5) | 0.168 (0–7.8066E+14) | 0.923 | — | 0.969 |
| Heart rate (per 5) | 0.951 (0.784–1.154) | 0.611 | — | 0.68 |
| Systolic blood pressure (per 5) | 1.042 (0.902–1.203) | 0.578 | — | 0.979 |
| Diastolic blood pressure (per 5) | 1.119 (0.85–1.471) | 0.423 | — | 0.379 |
| Temperature (per 5) | 2.662 (0.059–120.84) | 0.615 | — | 0.513 |
| White blood cells (per 5) | 1.937 (0.995–3.773) | 0.052 | — | 0.067 |
| Lymphocytes (per 5) | 0.39 (0.001–229.936) | 0.773 | — | 0.445 |
| PLT (per 5) | 1 (0.956–1.046) | 0.995 | — | 0.926 |
| Creatinine (per 5) | 0.99 (0.93–1.054) | 0.756 | — | 0.306 |
| Troponin-I (per 5) | 0.999 (0.994–1.004) | 0.684 | — | 0.772 |
| Brain natriuretic peptide (per 5) | 1.005 (0.988–1.024) | 0.557 | — | 0.717 |
| Age (years) | 0.944 (0.756–1.178) | 0.363 | 0.996 (0.957–1.036) | 0.825 |
| Gender (male/female) | 0.758 (0.222–2.592) | 0.659 | 0.929 (0.189–4.56) | 0.928 |
| Ischemic heart disease | 0.921 (0.199–4.262) | 0.916 | 0.898 (0.181–4.448) | 0.895 |
| COPD | 0.983 (0.126–7.684) | 0.987 | 2.276 (0.216–24) | 0.494 |
| Chronic kidney disease | 2.067 (0.264–16.152) | 0.489 | 2.507 (0.261–24.095) | 0.426 |
| Diabetes | 1.72 (0.456–6.49) | 0.424 | 2.31 (0.562–9.489) | 0.245 |
| Smoking | 1.79 (0.475–6.75) | 0.39 | 3.075 (0.701–13.5) | 0.137 |
| Hypertension | 2.533 (0.74–8.671) | 0.139 | 4.217 (0.947–18.778) | 0.059 |

OR indicates odds ratio; CI, confidence interval; —, no data available; LUS, lung ultrasound score.

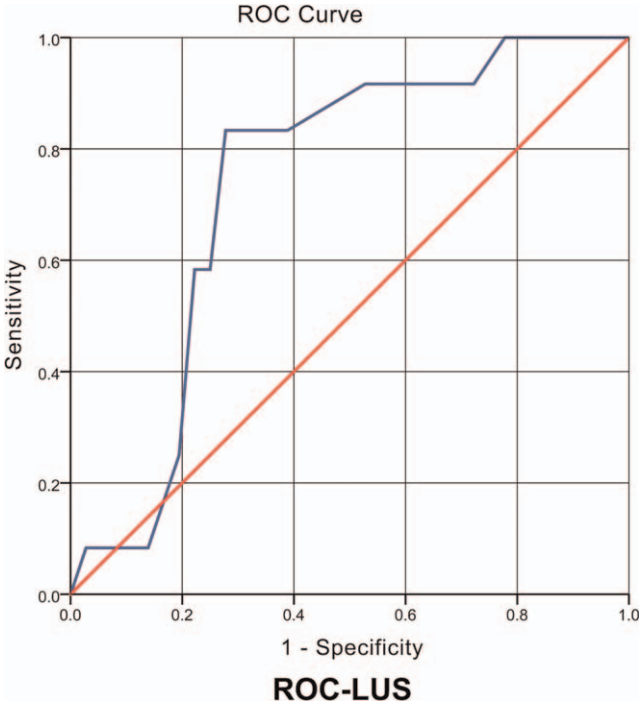


FIG. 3. **Receiver operating characteristic curves of LUS for mortality. Note: The area under the curve was 0.735; 95% confidence interval [CI] was 0.586–0.844; *P* = 0.016 for LUS.**

errors and bias. Second, the patients came from a single center in Wuhan, China, which might affect the representativeness of the patients population. Lastly, the sample size was small, which affected the study's statistical power.

Despite these limitations, this study provided significant information on LUS for evaluating COVID-19 pneumonia and the characteristics assessed by lung ultrasonography. These data were valuable for the clinical diagnosis, therapeutic decision-making, and subsequent design of future clinical trials related to lung ultrasonography. A well-designed prospective study is needed to address the limitations mentioned above.

## CONCLUSIONS

Based on our study, lung ultrasonography could be used to assess the severity of COVID-19 pneumonia and reveal the pathological signs of the disease. The LUS was independently related to the 28-day mortality, and an elevated LUS on ICU admission was associated with worse outcome.

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