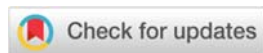


ORIGINAL ARTICLE

Ultrasound-Derived Lung Aeration Score for Predicting Recovery in Severe Community-Acquired Pneumonia

AKHTAR ALI¹, HINA AWAN², MUNTAQA BUTT³, NOOR E SEHER⁴, HAMZA AKRAM⁵, MUHAMMAD KASHIF⁶¹Assistant Professor, Pulmonology, Shalamar Institute of Health Sciences.²Medicine Speciality Registrar Shalamar institute of health sciences. **Email:** dr.hinaawan1234@gmail.com³Medicine Speciality Registrar Shalamar institute of health sciences. **Email:** dr.hinaawan1234@gmail.com⁴Department of Biological Science, Keele University, Keele, Staffordshire ST5 5BG, United Kingdom. **Email:** nooreseher7989@gmail.com⁵Master in Management, Business School Hertfordshire University, Hatfield, AL10 9AB, United Kingdom.**Email:** chhamzajal0300@gmail.com⁶Master of Science in Management University of Hertfordshire Hatfield, AL10 9AB United Kingdom**Email:** Muhammadrashid02183@gmail.com**Correspondence to:** Akhtar Ali, **Email:** drakhtarshah@gmail.com

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ABSTRACT

Background: Severe community-acquired pneumonia is linked to respiratory failure, long hospital intensive care and significant mortality. Patients not likely to recover can be identified early to provide better surveillance and management. The present study assessed the utility of serial ultrasound-derived lung aeration scores for early clinical recovery prediction.

Methods: This was a prospective observational cohort study of 80 adults with severe community-acquired pneumonia (CAP) from June 2025 to March 2026 at Shalamar Hospital Lahore. Lung ultrasound was done within 24 hours of admission, and assessed after 72 hours with a standardized 12-zone protocol. The scores for each region ranged from 0 to 3 and the scores for all regions were summed, resulting in a total score of 0–36. The primary outcome was clinical recovery at day 7. Receiver operating characteristic analysis and multivariable logistic regression were used to assess predictive performance.

Results: Clinical recovery occurred in 52 patients (65.0%), whereas 28 patients (35.0%) failed to recover. Non-recovered patients had higher admission scores than recovered patients (22.4 ± 4.6 vs 16.8 ± 4.3 ; $p < 0.001$) and markedly higher day-3 scores (20.1 ± 5.0 vs 10.7 ± 4.6 ; $p < 0.001$). A day-3 score of >16 had a sensitivity of 82.1%, a specificity of 84.6% and an area under the curve of 0.91, predicting non-recovery. For every 1-point improvement on day-3 score, there was a 31% increase in the odds of non-recovery. It can be used to add to traditional clinical and oxygenation severity assessment.

Conclusion: Loss of lung aeration at 72 hours was highly associated with delayed clinical recovery. Serial lung ultrasound could prove to be a useful bedside tool for early risk-stratification in severe community-acquired pneumonia.

Keywords: community-acquired pneumonia; lung ultrasound; lung aeration score; clinical recovery; respiratory failure; prognosis

INTRODUCTION

Community-acquired pneumonia is a major cause of hospitalization, respiratory failure, intensive care admission, and mortality among adults¹. It can have mild

infections or be life-threatening with severe hypoxia, septic shock, acute respiratory distress syndrome, multi-organ failure, and mechanical ventilation. In severe CPD, early recognition of response to therapy is important as failure to recognise deterioration may result in ongoing

respiratory support, treatment failure and worse clinical outcomes².

In severe pneumonia, recovery is usually determined by a reduction in respiratory rate, oxygen need, body temperature, and hemodynamic stability, as well as improvement in arterial blood gases, inflammatory markers and organ dysfunction scores³. These parameters have clinical value but are not directly related to the changes in regional lung aeration. Laboratory markers can be persistently elevated even with good treatment, and physiologic measurements can be affected by ventilator settings, fluid balance, cardiac function, and other extrapulmonary factors. Thus, there is a need for further bedside equipment for a more direct assessment of pulmonary improvement⁴.

Chest radiography is still widely used in the diagnosis and follow up of pneumonia⁵. However, the sensitivity of portable chest radiographs may be compromised due to sub optimal image quality, patient position, overlapping structures and difficulty in identifying posterior or small peripheral lesions. There may also be radiographic abnormalities which persist after clinical improvement and limit the usefulness of radiographs to monitor early response to treatment. CT is more detailed, but cannot be used for frequent evaluation due to the use of ionizing radiation, need for transport of a critically ill patient, extra expense, and potential disruption of respiratory or hemodynamic support⁶.

Lung ultrasound has become an increasingly used bedside imaging modality for the assessment of pulmonary disease, which is non-invasive, repeatable, fast and without radiation⁷. The sonographic features of pneumonia may be typical, such as focal B lines, subpleural lesions, tissue-like consolidation, air bronchograms and pleural effusion. Lung ultrasound can be repeated at the bedside and can be particularly helpful when patients are unstable or difficult to move⁸.

Lung ultrasound can also be used to assess the presence of pulmonary abnormalities and semiquantitatively assess the loss of aeration⁹. The thorax is subdivided into pre-defined regions and each region is scored based on the worst ultrasound pattern seen. Normal aeration gets the lowest score, separated B-lines get the next score, confluent B-lines and tissue-like consolidation get higher scores. Regional values are then added together to calculate the total lung aeration score, which represents the extent of the loss of aeration¹⁰.

The serial assessment may be more useful as a prognostic tool than a single assessment at admission¹¹. The first score represents the initial level of pulmonary involvement while the score following treatment shows the direction and extent of change. The reduction of B-lines and reduction in size of consolidation and restoration of

normally aerated lung may be markers of a good response. However, continued or worsening loss of aeration could indicate continued infection, insufficient antimicrobial treatment, fluid overload, atelectasis, pleural issues, or worsening of acute respiratory distress syndrome¹².

Prediction of patients who are likely to die in the early treatment phase may enhance clinical decision making¹³. A persistently elevated lung aeration score may be a reason for closer monitoring, further microbiological evaluation, re-evaluation of antimicrobial coverage, evaluation for empyema or pulmonary necrosis, and optimization of respiratory support. However, if there is a significant drop in score this can be objective evidence of pulmonary recovery and thus help to de-escalate care¹⁴.

Although the use of lung ultrasound is in a progressive process in practice within respiratory and critical care, the prognostic value in severe community-acquired pneumonia still needs to be better defined¹⁵. The majority of previous studies have been based on the diagnosis, and the usefulness of the serial aeration score in the initial days of the treatment needs to be further evaluated¹⁶.

This study was thus designed to test whether a lung aeration score obtained from ultrasound was predictive of early clinical recovery in severe community-acquired pneumonia (CAP) in adults¹⁷. It also evaluated if the score after 72 hours of treatment and change from baseline score offered better prognosis than the admission scores alone¹⁸.

MATERIALS AND METHODS

Study Design and Setting: The study was a prospective observational cohort study in the Department of Pulmonology and Critical Care Medicine at Shalamar Hospital Lahore from June 2025 to March 2026. This study assessed the prognostic significance of a lung aeration score obtained by ultrasound for early clinical recovery in adult patients with severe CAP. Participants were selected consecutively after the confirmation of the eligibility.

Study Population: Eighty adult patients with severe CPE were studied. Patients were selected within 24 hours of their admission in the hospital. Severe community-acquired pneumonia (CAP) was defined by the presence of acute respiratory signs or symptoms, clinical findings compatible with the diagnosis of CAP, new onset pulmonary infiltrate on chest radiograph or computed tomography scan, and severe physiological or organ dysfunction which required high-dependency or intensive care unit (ICU) care.

Inclusion Criteria: Patients were eligible for inclusion if they had fever, cough, sputum production, dyspnea, pleuritic chest pain, or other features of lower respiratory tract

infection in combination with the presence of a new pulmonary infiltrate on chest radiography or computed tomography (CT). Patients had to be at least severely ill with pneumonia, as defined by the presence of severe hypoxia, respiratory distress, hemodynamic instability, altered mental status, multiple pulmonary lobes involved or need for non-invasive or invasive ventilatory support.

Exclusion Criteria: Patients were excluded if pneumonia was diagnosed after 48 hours of admission, if they were admitted to the hospital in the previous 14 days, or if they had an established diagnosis of HAP or VAP. Patients with suspected pulmonary tuberculosis, advanced interstitial lung disease, active pulmonary malignancy, recent major thoracic surgery, severe chest wall deformity, extensive subcutaneous emphysema or poor quality ultrasound windows were also excluded. Patients who died or were transferred before the repeat lung ultrasound examination were excluded from the final analysis as were pregnant patients.

Sampling Technique: A non-probability consecutive sampling technique was used. All patients who met the selection criteria during the study period were approached to enroll in the study until 80 patients were obtained.

Clinical Assessment: A structured form for data collection was employed for the demographic and clinical data. Age, sex, smoking history, body mass index, comorbidities, duration of symptoms, respiratory rate, heart rate, blood pressure, temperature, level of consciousness and oxygen saturation were collected. Data on the use of oxygen therapy, non-invasive ventilation, invasive mechanical ventilation, vasopressor support, antimicrobial therapy, and intensive care unit admissions were also recorded.

Laboratory tests were performed, such as complete blood count, serum electrolyte, renal and liver function tests, C-reactive protein, serum procalcitonin, arterial blood gas analysis, blood cultures, sputum examination, and microbiological tests as clinically indicated. The ratio of arterial oxygen tension to inspired oxygen fraction was used to evaluate the severity of oxygenation impairment. Sequential Organ Failure Assessment score at the time of admission was used to assess organ dysfunction.

Lung Ultrasound Examination: In all the cases, a portable ultrasound machine with convex or phased-array transducer was used for lung ultrasound examination. The first examination was done within 24 hours of admission and the second examination was done after 72 ± 6 hours of treatment. Patients were examined in the supine, semi-recumbent, lateral and sitting position depending on their clinical condition and ability to tolerate movement.

Each hemithorax was divided into six regions: anterior-superior, anterior-inferior, lateral-superior, lateral-inferior, posterior-superior, and posterior-inferior regions. Thus, in each patient, 12 lung regions were analyzed. The probe was positioned both longitudinally and transversely inside each region, to determine which of the ultrasound patterns was the worst.

Lung Aeration Scoring: Aeration scores were given for each lung region, ranging from 0 to 3. A score of 0 indicated no restriction of aeration with preserved lung sliding and horizontal A-lines and no more than 2 isolated B-lines. Moderate aeration loss was defined as a score of 1, with three or more visible B-lines. If the loss of aeration was severe with multiple coalescent B-lines, a markedly irregular pleural line, or small abnormalities in the subpleural space, it was given a score of 2. A score of 3 indicated total loss of aeration and pulmonary consolidation in tissue pattern (with or without air bronchograms).

This total lung aeration score was calculated by adding together the regional values, and ranged from 0 to 36. The greater the total score, the more significant the loss of pulmonary aeration. The difference of lung aeration scores between the admission and day-3 scores was calculated. A positive value indicated pulmonary reaeration and improvement, while a value close to zero or negative value, indicated persistent or worsening aeration loss.

Operator Training and Reliability: All examinations were carried out by point-of-care lung ultrasound trained clinicians who had previously undertaken supervised examinations before being involved in the study. Standardized scanning protocol and scoring criteria were applied in order to minimize observer-related variability. A randomly selected proportion of patients had ultrasound clips stored and these were independently assessed by a second trained investigator. When a disagreement arose they were worked out through discussion and by mutual examination of the recorded images.

Treatment Protocol: All patients were managed as per institutional guidelines for severe CAP. Initial antimicrobial therapy was chosen as per disease severity, suspected organisms, local resistance patterns, comorbidities and previous antimicrobial exposure. Supportive therapies including supplemental oxygen, high-flow nasal oxygen, non-invasive ventilation, invasive mechanical ventilation, intravenous fluid, vasopressors, steroids, thromboprophylaxis and other supportive therapies were administered based on clinical needs. All therapeutic choices were left to the treating physicians.

Primary Outcome: The main outcome was clinical recovery at day 7. Clinical recovery was defined as survival with progressive improvement in respiratory and hemodynamic parameters, no need for invasive mechanical ventilation, or successful extubation for at least 48 hours or less, respiratory rate ≤ 24 breaths/min, and oxygen saturation $\geq 92\%$ with an inspired oxygen fraction ≤ 0.35 , or low-flow oxygen by nasal cannula.

Patients who remained dependent on invasive ventilation, or who required escalation of oxygen or vasopressor use or increasing organ dysfunction, or who required expansion of antimicrobial therapy due to clinical deterioration, or who died before day 7 were classified as failure to recover.

Secondary Outcomes: Secondary outcomes were the need for invasive mechanical ventilation after enrollment, length of time on mechanical ventilation, vasopressor requirement, intensive care unit length of stay, total hospital length of stay, acute respiratory distress syndrome, pleural complications, and 28-day all-cause mortality. The correlation of these results to the admission score, day-3 score and the difference between the admission score and day-3 score was also assessed.

Data Collection Procedure: Eligible patients were identified at admission and assessed after obtaining informed consent. Baseline clinical, laboratory, and radiologic data were obtained before or immediately after the initial lung ultrasound examination. During hospitalisation, patients were followed-up daily. The repeat ultrasound examination was done after ~ 72 hours, while clinical recovery outcome was assessed on day 7. Mortality and other secondary outcomes were obtained until day 28 or hospital discharge.

Statistical Analysis: Data entered and analysed by appropriate statistical software package. Data for continuous variables were presented as mean $\pm$ standard deviation or median (range), depending on the distribution of the data. For categorical data, frequency and percentage were used. The independent-samples t test or Mann-Whitney U test was used to compare continuous variables between recovered and non-recovered patients. The chi-square test or Fisher exact test was used for categorical variables.

Admission lung aeration score, day-3 score and difference between score were compared between recovered and nonrecovered patients. Using receiver operating characteristic curve analysis, the predictive accuracy of each ultrasound variable was determined. Area under the curve, optimal cut-off value, sensitivity, specificity, positive predictive value, negative predictive value were calculated.

All variables associated with non-recovery were included in a univariable logistic regression model and those variables were then placed in a multivariable logistic regression model. Adjusted odds ratios (AOR) with 95% confidence intervals (CI) were presented. A p value < 0.05 was taken as statistically significant.

Ethical Considerations: The Institutional Review Board of the institution participated in this study provided ethical approval. All subjects or their legal representatives signed informed consent prior to enrolment. For confidentiality, each patient had an identification code, and all personal identifiers were deleted from the study database. The study was carried out in compliance with the generally accepted rules of medical investigations on human subjects.

RESULTS

Participant Enrollment and Clinical Recovery: During the study period, 92 patients with suspected severe community-acquired pneumonia were assessed for eligibility. Twelve patients were excluded, including four with HAP, three with suspected pulmonary TB, two with advanced interstitial lung disease, two that were transferred prior to repeat ultrasound and one with an inadequate sonographic window. In the final analysis 80 patients were included.

Fifty-two patients (65.0%) were clinically recovered by day 7. Twenty-eight (35.0%) were deemed to be failure to recover by persistent respiratory failure, continued vasopressor requirement, escalation of ventilatory support, worsening organ dysfunction or death.

Baseline Characteristics: The mean age of the patients was 59.4 ± 15.2 years, with 45 patients being male. The non-recovering patients had a significantly higher age than the recovering patients. There was no significant difference between the number of males and females participating in the two groups.

Diabetes mellitus was significantly higher in the group that had not been able to recover. Chronic obstructive pulmonary disease and chronic kidney disease were also more prevalent in the non-recovery group, but not statistically significant.

Patients with no recovery had higher Sequential Organ Failure Assessment (SOFA) scores, lower arterial oxygen tension to inspired oxygen fraction ($\text{PaO}_2/\text{FIO}_2$) ratio, and higher C-reactive protein and procalcitonin (PCT). Other factors associated with non-recovery, as seen in Table 1, included the presence of multilobar pulmonary involvement, the requirement for invasive mechanical ventilation and the use of vasopressors during the first 24 hours.

Serial Lung Ultrasound Findings: The mean admission lung aeration score for all was 18.8 ± 5.2 . Patients who did not recover were also significantly higher on admission score compared to patients who recovered. This difference was more marked at the second examination (after 72 hours).

The mean day-3 lung aerations score was 10.7 ± 4.6 in recovered patients and 20.1 ± 5.0 in patients who did not recover. The mean reduction from baseline for the recovery group was 6.1 ± 3.2 points while the reduction for the non-recovery group was only 2.3 ± 2.8 points.

There was also a lower number of areas with consolidation on admission and day 3 in the recovered patients. 17.3% of patients who recovered had persistent bilateral posterior consolidation, while 67.9% had no recovery. Also more commonly found in the non-recovery group was pleural effusion and new or increasing pulmonary consolidation, as shown in Table 2.

Predictive Accuracy of Lung Aeration Scores: ROC curve analysis revealed the lung aeration score at day-3 was the most accurate in predicting failure of clinical recovery. The area under its curve was 0.91, while that for the admission aeration score was 0.82 and that for the reduction in aeration score was 0.87.

A score of >16 on day-3 had a sensitivity of 82.1% and a specificity of 84.6% for predicting non-recovery. It had a positive predictive value of 74.2% and negative predictive value of 89.8%.

Predictive accuracy was lower with an admission aeration score > 20 . Failure to improve by fewer than four points in the first 72 hours was also a factor in failure to recover. Table 3 illustrates the relative predictive ability of the variables examined.

Independent Predictors of Non-Recovery: Multivariable logistic regression was used to analyze variables associated with non-recovery in the initial analysis. The day-3 lung aeration score was independently associated with failure to

achieve clinical recovery, after adjusting for organ dysfunction and oxygenation impairment.

For every point increment in the lung aeration score on day-3, there was a corresponding 31% rise in adjusted odds of non-recovery. Another independent association with poor outcome was a higher Sequential Organ Failure Assessment score. Conversely, for every 10 mmHg improvement in the ratio of arterial oxygen tension to the fraction of inspired oxygen, there was a 12% decrease in the odds of not recovering, as shown in Table 4.

Secondary Clinical Outcomes: 23 patients (28.8%) needed invasive mechanical ventilation during their hospital stay. 17 patients did need vasopressor therapy and 19 patients did develop acute respiratory distress syndrome. Overall mortality was 12.5% (10 patients died within 28 days).

Patients who had a day-3 lung aeration score > 16 had worse outcomes than those with a day-3 lung aeration score ≤ 16 . 58.1% of patients with a score > 16 required invasive mechanical ventilation as opposed to 10.2% with a score < 16 . The high score group was also significantly more likely to require vasopressor and acute respiratory distress syndrome.

Patients with a day-3 score of >16 had a median intensive care unit stay of 9 days, and patients with a day-3 score of ≤ 16 had a median intensive care unit stay of 4 days. High score group also had significantly longer median total hospital stay. In Table 5, 9 patients with a score greater than 16 were in the deaths group within 28 days compared to one with a score of 16 or less.

The amount of aeration loss and the early ultrasound change were both significantly related to recovery. However, the lung aeration score obtained at day 3 showed the best prognostic value. A persistently elevated score above 16 was an independent predictor of failure to recover and was correlated with the need for mechanical ventilation and vasopressor support, longer intensive care and hospital length of stay, development of acute respiratory distress syndrome and 28-day mortality.

Table 1: Baseline characteristics according to day-7 clinical recovery

Characteristic	Total (n=80)	Recovered (n=52)	Not recovered (n=28)	p value
Age, years	59.4 ± 15.2	56.8 ± 14.2	64.2 ± 15.8	0.034
Male sex	45 (56.3%)	30 (57.7%)	15 (53.6%)	0.724
Female sex	35 (43.8%)	22 (42.3%)	13 (46.4%)	0.724
Current or former smoking	31 (38.8%)	18 (34.6%)	13 (46.4%)	0.302
Diabetes mellitus	33 (41.3%)	18 (34.6%)	15 (53.6%)	0.047
Chronic obstructive pulmonary disease	20 (25.0%)	10 (19.2%)	10 (35.7%)	0.104
Chronic kidney disease	12 (15.0%)	5 (9.6%)	7 (25.0%)	0.066
Sequential Organ Failure Assessment score	6.0 ± 3.0	5.0 ± 2.3	7.8 ± 3.1	<0.001
Arterial oxygen tension to inspired oxygen fraction ratio, mmHg	175 ± 65	195 ± 57	137 ± 60	<0.001
C-reactive protein, mg/L	161 ± 73	141 ± 61	198 ± 78	<0.001
Procalcitonin, ng/mL	$2.5 (0.8-5.9)$	$1.7 (0.6-3.8)$	$4.0 (1.5-8.5)$	0.004
Multilobar pulmonary involvement	56 (70.0%)	31 (59.6%)	25 (89.3%)	0.006
Invasive ventilation within 24 hours	23 (28.8%)	8 (15.4%)	15 (53.6%)	<0.001
Vasopressor support within 24 hours	17 (21.3%)	5 (9.6%)	12 (42.9%)	<0.001

Table 2: Serial lung ultrasound findings according to clinical recovery

Ultrasound finding	Recovered (n=52)	Not recovered (n=28)	p value
Admission lung aeration score	16.8 ± 4.3	22.4 ± 4.6	<0.001
Day-3 lung aeration score	10.7 ± 4.6	20.1 ± 5.0	<0.001
Reduction in lung aeration score	6.1 ± 3.2	2.3 ± 2.8	<0.001
Lung regions with consolidation at admission	2.9 ± 1.3	4.4 ± 1.5	<0.001
Lung regions with consolidation on day 3	1.6 ± 1.2	3.9 ± 1.5	<0.001
Bilateral posterior consolidation on day 3	9 (17.3%)	19 (67.9%)	<0.001
Pleural effusion on day 3	10 (19.2%)	12 (42.9%)	0.024
New or increasing consolidation on day 3	3 (5.8%)	10 (35.7%)	<0.001

Interobserver agreement for the total lung aeration score was excellent, with an intraclass correlation coefficient of 0.90.

Table 3: Predictive performance of clinical and ultrasound variables for day-7 non-recovery

Predictor	Area under the curve (95% confidence interval)	Cutoff value	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Admission lung aeration score	0.82 (0.72–0.91)	>20	75.0%	73.1%	60.0%	84.4%
Day-3 lung aeration score	0.91 (0.84–0.97)	>16	82.1%	84.6%	74.2%	89.8%
Reduction in lung aeration score	0.87 (0.79–0.95)	<4 points	78.6%	80.8%	68.8%	87.5%
Admission Sequential Organ Failure Assessment score	0.79 (0.69–0.89)	>6	71.4%	71.2%	57.1%	82.2%

Table 4: Multivariable predictors of failure to achieve clinical recovery by day 7

Predictor	Adjusted odds ratio	95% confidence interval	p value
Day-3 lung aeration score, per one-point increase	1.31	1.16–1.48	<0.001
Sequential Organ Failure Assessment score, per one-point increase	1.22	1.02–1.46	0.031
Arterial oxygen tension to inspired oxygen fraction ratio, per 10-mmHg increase	0.88	0.79–0.98	0.019

The final regression model demonstrated strong discrimination, with an area under the curve of 0.93, and showed acceptable calibration.

Table 5: Clinical outcomes according to the day-3 lung aeration score

Clinical outcome	Day-3 score ≤16 (n=49)	Day-3 score >16 (n=31)	p value
Invasive mechanical ventilation	5 (10.2%)	18 (58.1%)	<0.001
Vasopressor requirement	4 (8.2%)	13 (41.9%)	<0.001
Acute respiratory distress syndrome	5 (10.2%)	14 (45.2%)	<0.001
Intensive care unit stay, days	4 (3–6)	9 (6–13)	<0.001
Total hospital stay, days	8 (6–11)	14 (10–19)	<0.001
28-day mortality	1 (2.0%)	9 (29.0%)	<0.001

DISCUSSION

The present study evaluated the usefulness of serial ultrasound-derived lung aeration scoring for predicting early clinical recovery in adults with severe community-acquired pneumonia¹. The major result was that patients that did not recover had significantly higher reduction of lung aeration at admission and after 72 hours of treatment. The day-3 score had significantly more predictive power than the admission score for outcome. These findings suggest that the sonographic abnormalities seen at the time of early treatment period may be more clinically informative than the amount of pulmonary involvement alone².

65.0% of the study population was clinically recovered by day 7³. Patients who did not recover were older with more severe physiological impairment. Their Sequential Organ Failure Assessment score was higher, oxygenation was poorer, inflammatory activity was greater and there was more frequent involvement of more than one lobe.

This group also had significantly more requirements for invasive ventilation and for vasopressors. These differences illustrate that, in severe pneumonia, treatment failure depends upon the severity of the pulmonary disease and the systemic dysfunction⁴.

Patients who did not recover had significantly higher admission lung aeration score⁵. This finding indicates that a lot of aeration loss at presentation is indicative of more extensive alveolar and interstitial involvement. Widespread consolidation, confluent B-lines, inflammatory exudation, and atelectatic changes or a mixture of all of these may be represented by higher scores. More extensive initial pulmonary involvement may lead to disturbance of gas exchange, increased respiratory effort and a higher risk for ventilatory support. However, the admission score alone is not sufficient to predict a quick response of the involved lung to anti-microbial and supportive care⁶.

The lung aeration score on day-3 was more discriminative between patients who recovered and not⁷. Patients with recovery had significant decreases in their

scores, with patients without recovery showing small improvements. This difference is an argument for the need of serial assessment. A single examination will show the severity of the disease at one moment in time and the repeated examination will reflect the direction and amount of the pulmonary response. Improvement in aeration can be manifested as the reduction in the consolidation, disappearance of confluent B-lines, reappearance of normally aerated lung, and the decrease in the involvement of affected regions⁸.

When aeration doesn't return following 72 hours, it may be a sign of continued alveolar inflammation, failure to control infection, failure to resolve consolidation, fluid overload, atelectasis, or evolution into ARDS⁹. It can also indicate that there are complications, including parapneumonic effusion, empyema, necrotizing infection or that the initial antimicrobial treatment is ineffective. The day-3 examination thus seems to be a clinically relevant time-point to assess the early treatment response¹⁰.

The area under the receiver operating characteristic curve for the day-3 score was 0.91, suggesting good discrimination between recovered and non-recovered patients¹¹. The sensitivity of a cutoff value of >16 was 82.1% and the specificity was 84.6%. It has a high negative predictive value implying that patients with a score of 16 or less were likely to have a favorable clinical course. In practice, a lower score may offer further confidence when deciding to reduce respiratory support or move to a lower level of care, when all else is going well¹².

A score higher than 16, however, identified a sub-population with a significantly heightened risk of poor outcomes¹³. These patients had higher rates of duration of intensive care and hospital stays, 28-day mortality, use of invasive mechanical ventilation, vasopressor use and acute respiratory distress syndrome. Findings like this indicate that the score will need to be carefully reassessed if it is not going down. Possible interventions include reevaluation of antimicrobial therapy, re-investigation of microbiology, fluid balance assessment, exclusion of pleural involvement, computed tomography, and a reassessment of the necessity for escalation of respiratory and/or hemodynamic support¹⁴.

The lung aeration score reduction also showed a good predictability¹⁵. Those who recovered were able to cut down on a mean of over six points, while those who did not recover could cut down on a mean of just over two points. Fewer than a 4-point decrease was correlated with a poor outcome. This is a dynamic measure that might be useful especially since it considers individual variation of baseline severity. Patients with the same admission score can have very different clinical courses with varying degrees of reaeration during therapy¹⁶.

Aeration score day-3 was still independently associated, after adjusting for organ dysfunction and oxygenation¹⁷. For every one-point increase, there was a 31% increase in the adjusted odds of treatment failure. This discovery indicates that lung ultrasound gives information which is more than the common physiological measurements for prognosis. Inspired oxygen concentration, ventilatory settings, hemodynamic status, cardiac function, and pulmonary perfusion all can have an impact on oxygenation. By contrast, the aeration score is an immediate reflection of the extent and severity of sonographic lung abnormalities¹⁸.

The relationship between Sequential Organ Failure Assessment scores and survival outcomes highlights a role for systemic illness¹⁹. The presentation of severe community-acquired pneumonia does not necessarily include a pulmonary infection and may be complicated by circulatory, renal, neurological, hepatic and haematological dysfunction. Thus, the simultaneous assessment of lung aeration and organ failure can offer a more comprehensive indication of the severity of disease than either of these alone²⁰.

The ratio between arterial oxygen tension and inspired oxygen fraction was also independently related to non-recovery⁶. This is an expected observation as worsening oxygenation demonstrates impaired gas exchange due to consolidation, alveolar filling, ventilation-perfusion mismatch and intrapulmonary shunting. The high discrimination of the day-3 lung aeration score, however, indicates that structural evaluation of pulmonary involvement could prove useful in addition to the traditional oxygenation scores¹³.

If they didn't get better, they were more likely to have persistent bilateral posterior consolidation². Posterior and dependent parts of the lungs are often involved in patients who are on mechanical ventilation, have decreased mobility, or who remain in bed. Persistent posterior abnormalities may be due to secretions, gravity dependent atelectasis or extensive inflammatory consolidation. A systematic scanning protocol should therefore be used, including examination of posterior areas, because a primary anterior chest examination may underestimate the burden of the disease¹⁷.

Patients without recovery were more likely to have pleural effusion and new or greater consolidation⁹. Progressive infection, parapneumonic complications, or inadequate drainage of secretions, or superimposed atelectasis, may be responsible for these findings. These abnormalities are clinically useful if they are detected at the bedside as they may result in further imaging, diagnostic aspiration, drainage or a change in antimicrobial treatment⁴.

In severe pneumonia, LUS presents some benefits¹⁵. Portable, No ionizing radiation, repeatable and non invasive. Examinations can be conducted without the need to move the unstable patient and may be repeated as often as clinically needed. This renders it especially appropriate for intensive care units, high-dependency wards, emergency departments and health care environments where higher-level imaging is not readily available⁷.

Lung ultrasound should not be used to replace a thorough clinical evaluation or computed tomography (CT) when complications are suspected¹¹. Deep lesions, that do not extend to the pleural surface, may not be observed. There may also be overlap in sonographic appearances between pneumonia, pulmonary edema, atelectasis and acute respiratory distress syndrome. The score should thus be combined with clinical examination, laboratory investigations, microbiological results, oxygenation and conventional imaging¹⁹.

The strong inter observer agreement noted during the study suggests that lung aeration scoring is reproducible and could be done by trained clinicians using standardized criteria³. But user experience is still crucial. Implementing the score routinely will require adequate training, structured scanning, and consistent interpretation of B-lines and the consolidation patterns¹⁴.

This study is subject to a number of limitations⁸. First, the sample size of 80 patients was relatively small, which could have introduced a degree of imprecision into some of the estimates and limited the number of variables that could be incorporated into the multivariable model. Second, the study was performed in only one center, and the cutoff value may not be applicable to other hospitals and patient groups. Thirdly, the use of lung ultrasound requires a skillful operator but the use of standardized training and assessment of interobserver agreement was an effort to limit this concern¹⁶.

Fourth, the aeration score may have been affected independently from pneumonia by pulmonary edema, pre-existing chronic lung disease, ventilator-related atelectasis and fluid administration⁵. Fifth, exclusion of patients who died or were transferred prior to the repeat examination may have led to a selection bias and to underestimation of the severity of early treatment failure. Finally, clinical recovery at day 7 was a composite endpoint and needs to be validated in larger studies²⁰.

Larger, more diverse populations should be used in future multicenter investigations that should externally validate the day-3 cut-off value¹². Further research could also involve assessing different durations of scanning and different levels of detail, as well as comparing the ultrasound score with biomarkers and organ dysfunction scores. Randomized studies are required to determine if serial lung ultrasound can decrease complications,

ventilation duration, intensive care unit stay, and/or mortality¹⁸.

CONCLUSION

In adults with severe CPE, serial ultrasound-derived lung aeration scoring proved to be useful prognostic information. Admission and 72-hour scores were significantly higher in patients who did not recover, and the 72-hour score had the best predictive performance.

A day-3 lung aeration score >16 independently predicted failure to achieve clinical recovery and was associated with mechanical ventilation days, vasopressor days, acute respiratory distress syndrome (ARDS), hospitalization, and 28-day mortality. There was also a significant reduction in the score within the first 72 hours, which was associated with an unfavorable clinical course.

Lung ultrasound could thus prove to be a useful tool at the bedside to monitor the pulmonary response and select patients for closer follow-up or reassessment of treatment. But the proposed threshold should be confirmed in larger multicenter studies prior to routine clinical use.

DECLARATION

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