Predictive Value of SOFA Score, CURB-65 Score, and PSI Score for 28-Day Mortality in Patients with Severe Pneumonia: Postprint

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Abstract

Background Severe pneumonia (SP) is a common acute and critical respiratory illness with high mortality and heavy social burden. Early and accurate assessment of the condition and prognosis of patients with severe pneumonia facilitates clinical decision-making. The Pneumonia Severity Index (PSI) score, CURB-65 score, and Sequential Organ Failure Assessment (SOFA) score can reflect the severity of pneumonia from different aspects and have been widely used to evaluate the severity of pneumonia patients.

Objective To investigate the predictive value of the SOFA score, CURB-65 score, and PSI score for short-term prognosis in patients with severe pneumonia.

Methods This multicenter, prospective observational study enrolled hospitalized patients with severe pneumonia from 11 hospitals including the First Affiliated Hospital of Henan University of Chinese Medicine between December 2017 and March 2022. Patients were divided into survival and death groups based on whether they died within 28 days after diagnosis of severe pneumonia, and clinical characteristics and risk scores were compared between the two groups. Logistic regression analysis was used to evaluate the relationship between different risk scores and 28-day mortality, and the predictive performance of risk scores was assessed using the area under the receiver operating characteristic (ROC) curve (AUC), Hosmer-Lemeshow test, and calibration plots.

Results A total of 240 eligible patients with severe pneumonia were finally included, with a mean age of (65.5$±$15.3) years, 170 males (70.8%), and 57 deaths within 28 days (23.8%). All three scores were higher in the death group than in the survival group (all $P<0.05$), and all three risk scores were independent risk factors for 28-day mortality in patients with severe pneumonia (adjusted odds ratio >1, $P<0.05$). The AUC of the SOFA score (0.741, 95%CI:

0.663~0.820) was higher than that of the other two risk scores (both AUCs <0.70, P<0.01). Both the Hosmer-Lemeshow test and calibration plots indicated good accuracy of the SOFA score. The 28-day mortality rates in the low-, medium-, and high-risk groups stratified by SOFA score were 12.0%, 28.8%, and 65.6%, respectively (Log-rank P<0.001).

Conclusion The SOFA score, CURB-65 score, and PSI score all have certain roles in predicting 28-day mortality in patients with severe pneumonia, among which the SOFA score has greater clinical application value.

Full Text

Preamble

Title: Predictive Value of SOFA Score, CURB-65 Score, and PSI Score for 28-Day Mortality in Patients with Severe Pneumonia

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Abstract

Background: Severe pneumonia (SP) is a common critical illness of the respiratory system with high mortality and substantial social burden. Early and accurate assessment of disease severity and prognosis in patients with severe pneumonia facilitates clinical decision-making. The Pneumonia Severity Index (PSI), CURB-65 score, and Sequential Organ Failure Assessment (SOFA) score

reflect pneumonia severity from different perspectives and have been widely used to evaluate disease severity in pneumonia patients.

Objective: To investigate the predictive value of SOFA, CURB-65, and PSI scores for short-term prognosis in patients with severe pneumonia.

Methods: This multicenter, prospective observational study enrolled hospitalized patients with severe pneumonia from 11 hospitals, including the First Affiliated Hospital of Henan University of Chinese Medicine, between December 2017 and March 2022. Patients were divided into survival and death groups based on whether they died within 28 days of severe pneumonia diagnosis. Clinical characteristics and risk scores were compared between groups. Logistic regression analysis was used to evaluate the association between different risk scores and 28-day mortality. The predictive performance of risk scores was assessed using area under the receiver operating characteristic curve (AUC), Hosmer-Lemeshow test, and calibration plots.

Results: A total of 240 eligible patients with severe pneumonia were included, with a mean age of (65.5$±$15.3) years, 170 (70.8%) males, and 57 (23.8%) deaths within 28 days. All three scores were significantly higher in the death group than in the survival group (all $P<0.05$), and each score was an independent risk factor for 28-day mortality (adjusted odds ratio >1, $P<0.05$). The AUC of the SOFA score (0.741, 95% CI: 0.663–0.820) was higher than those of the other two scores (both AUCs <0.70, $P<0.01$). Both the Hosmer-Lemeshow test and calibration plots indicated good accuracy for the SOFA score. Risk stratification based on the SOFA score yielded 28-day mortality rates of 12.0%, 28.8%, and 65.6% for low-, intermediate-, and high-risk groups, respectively (Log-rank $P<0.001$).

Conclusion: SOFA, CURB-65, and PSI scores all demonstrate predictive value for 28-day mortality in patients with severe pneumonia, with the SOFA score showing superior clinical utility.

Keywords: Severe pneumonia; SOFA score; CURB-65 score; PSI score; Prognosis

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Introduction

Community-acquired pneumonia (CAP) is one of the most common causes of death worldwide [1]. Severe pneumonia (SP) represents a critical progression of pulmonary inflammation that leads to organ dysfunction and life-threatening respiratory failure, characterized by rapid disease progression and high mortality [2]. Early and accurate assessment of disease severity and prognosis in patients with severe pneumonia is essential for informed clinical decision-making [3]. The Pneumonia Severity Index (PSI) [4], CURB-65 score [5], and Sequential Organ Failure Assessment (SOFA) [6] reflect pneumonia severity from different dimensions and have been widely employed to evaluate prognosis in pneumonia

patients. However, consensus regarding the optimal risk score for predicting severe pneumonia outcomes remains elusive, with substantial variation among different scoring systems in assessing disease severity [7, 8]. This study focuses on patients with severe pneumonia to validate the predictive performance of these three scoring systems for short-term prognosis and to inform clinical decision-making.

Methods

Study Design

This multicenter, prospective observational study enrolled hospitalized patients with severe pneumonia from 11 hospitals, including the First Affiliated Hospital of Henan University of Chinese Medicine, between December 2017 and March 2022. Patients were stratified into survival and death groups based on 28-day mortality following severe pneumonia diagnosis to evaluate the predictive value of SOFA, PSI, and CURB-65 scores for 28-day mortality. All procedures involving human participants complied with the Declaration of Helsinki (2013 revision). The study was approved by the Ethics Committee of the First Affiliated Hospital of Henan University of Chinese Medicine (Approval No. 2017HL-002-01).

Study Population

The study population comprised hospitalized patients with severe pneumonia admitted to intensive care units (ICU) and respiratory/critical care departments across 11 hospitals, including the First Affiliated Hospital of Henan University of Chinese Medicine, the First Affiliated Hospital of Zhengzhou University, and Henan Provincial People' s Hospital. Inclusion criteria were: (1) age $ $18 years; (2) diagnosis according to the "Guidelines for the Diagnosis and Treatment of Community-Acquired Pneumonia (2016 Edition)" [9]. Exclusion criteria included: (1) pregnant or lactating women; (2) patients with COVID-19; (3) malignancy; (4) fungal pneumonia, HIV-associated pneumocystis pneumonia, or tuberculosis; (5) severe immunosuppression; (6) refusal to provide informed consent.

Data Collection

A standardized case report form was used to collect clinical data at the time of severe pneumonia diagnosis and 28-day outcomes. Data included: (1) baseline demographics: sex, age, clinical signs, laboratory tests, and comorbidities; (2) mortality risk scores: calculated using the SOFA, CURB-65, and PSI scoring systems based on data extracted from patient records. When data were missing at admission, the first available values after admission were used.

Statistical Analysis

Descriptive statistics were performed using SPSS 26.0. Categorical variables were expressed as frequencies and percentages, with between-group comparisons using the ^{2} test. Normally distributed continuous variables were presented as mean ± standard deviation (±s) and compared using independent samples t-tests. Non-normally distributed continuous variables were expressed as median and interquartile range (IQR) and compared using Mann-Whitney U tests. The association between risk scores and 28-day mortality was evaluated using logistic regression analysis. Discrimination was assessed using receiver operating characteristic (ROC) curve analysis. Calibration was evaluated using the Hosmer-Lemeshow test and calibration plots. Optimal cut-off values for risk stratification were determined using X-tile v3.6, and Kaplan-Meier survival curves were generated with Log-rank tests for comparison. Statistical significance was set at $P<0.05$. ROC curves and Kaplan-Meier survival curves were generated using GraphPad Prism v8.0, and calibration plots were created using Stata 15.1.

Results

Patient Characteristics

A total of 258 patients with severe pneumonia were initially enrolled, with 18 excluded during follow-up, yielding a final analytical cohort of 240 patients (Figure 1 [Figure 1: see original paper]). The mean age was (65.5$±$15.3) years, with 170 (70.8%) males. Fifty-seven patients (23.8%) died within 28 days. Compared with the survival group, the death group had significantly older age (69.5 vs. 64.3, P=0.009) and lower platelet counts (155.5 vs. 202.5, P=0.031, Table 1).

Relationship Between Risk Scores and Prognosis

All three risk scores—SOFA, CURB-65, and PSI—were significantly higher in the death group than in the survival group (all $P<0.01$, Table 2). After adjusting for age, platelet count, and sex (factors showing statistical significance in Table 1), logistic regression analysis revealed that SOFA score (OR: 1.34; 95% CI: 1.18–1.52, $P<0.001$), CURB-65 score (OR: 1.43; 95% CI: 1.01–1.98, P=0.028), and PSI score (OR: 1.01; 95% CI: 1.01–1.02, P=0.042) were all independent risk factors for 28-day mortality (Table 3).

Predictive Performance of Risk Scores

Discrimination of Different Risk Scores The SOFA score achieved an AUC of 0.741 (95% CI: 0.663–0.820) for predicting 28-day mortality, compared with 0.627 (95% CI: 0.544–0.710) for CURB-65 and 0.621 (95% CI: 0.539–0.703)

for PSI. All three scores demonstrated AUCs >0.6, indicating acceptable predictive value for 28-day mortality (all P<0.001), with the SOFA score showing the strongest discriminative performance (Figure 2 [Figure 2: see original paper], Table 4).

Calibration of Different Risk Scores The Hosmer-Lemeshow test yielded P>0.05 for all three scores (Table 5), suggesting adequate calibration. Model comparison using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) showed lower values for the SOFA score compared with the other two scores (Table 6), indicating superior accuracy. The calibration plot for SOFA score demonstrated observed versus predicted mortality risks aligned along the 45° line (E:O=0, intercept=0, slope=1, Figure 3 [Figure 3: see original paper]), confirming excellent calibration.

Risk Stratification Based on Predictive Models Using optimal cut-off values determined by X-tile software, SOFA scores were stratified into low-risk (0–5 points), intermediate-risk (6–8 points), and high-risk (9–18 points) groups. Kaplan-Meier survival analysis revealed progressively increasing mortality rates with higher SOFA scores, with 28-day mortality rates of 12.0%, 28.8%, and 65.6% for low-, intermediate-, and high-risk groups, respectively (Log-rank P<0.001, Figure 4 [Figure 4: see original paper]).

Discussion

This study evaluated the predictive value of different risk scores for short-term prognosis in severe pneumonia, demonstrating that SOFA, CURB-65, and PSI scores all possess acceptable predictive value for 28-day mortality, with the SOFA score exhibiting the strongest performance and highest accuracy.

Severe pneumonia manifests primarily as systemic inflammatory response and frequently leads to sepsis, septic shock, and multiple organ dysfunction syndrome [10]. The mortality rate for severe pneumonia requiring ICU admission approaches 50% [11]. Although advances in antibiotics, mechanical ventilation, and corticosteroid therapy have improved outcomes to some extent [12], mortality remains unacceptably high. Therefore, early and accurate prognostic assessment is crucial for guiding clinical decision-making. SOFA, CURB-65, and PSI scores are widely used predictive models for severe pneumonia prognosis, yet no well-designed comparative study has evaluated their relative predictive performance.

The CURB-65 score comprises five components: confusion, urea nitrogen, respiratory rate, blood pressure, and age $ $65 years [13]. Due to its simplicity and excellent predictive accuracy, CURB-65 is widely used to assess mortality and ICU admission risk in CAP patients [14-15]. However, studies show that while

CURB-65 accurately predicts 30-day mortality after hospital discharge, it performs poorly in predicting in-hospital mortality [16]. Kolditz et al. found that CURB-65 is better suited for identifying low-risk patients suitable for outpatient management but less effective for identifying severely ill patients [17]. The PSI score reflects pneumonia severity index and stratifies risk into five grades based on patient history, age, comorbidities, clinical signs, laboratory findings, and imaging results, providing a comprehensive assessment of pneumonia severity [18]. The 2020 American Thoracic Society guidelines indicate that PSI demonstrates higher discriminative ability than CURB-65 for mortality prediction but may underestimate disease severity in younger patients [19].

The SOFA score incorporates six criteria reflecting organ system function (respiratory, cardiovascular, hepatic, coagulation, renal, and neurological systems) and serves as a risk model for organ dysfunction in critically ill patients [20]. Multiple organ failure is a common complication of severe pneumonia, and early assessment of organ dysfunction is prognostically significant [21]. A European multicenter prospective study found that SOFA score significantly outperformed other scores in correctly identifying severe CAP [6]. Research indicates that SOFA score is superior to CURB-65 for predicting 30-day mortality in hospital-acquired pneumonia [22]. Baek et al. demonstrated that in ICU patients over 80 years old with severe pneumonia, SOFA score showed better predictive performance for in-hospital mortality than CURB-65 and PSI scores [23]. Our findings confirm that SOFA score provides superior discrimination and calibration for predicting 28-day mortality in severe pneumonia compared with CURB-65 and PSI. Previous studies have shown that in ICU patients with suspected infection, a SOFA score increase of $ $2 points accurately predicts in-hospital mortality [24]. Using optimal cut-off values determined by X-tile software (5 and 8), we stratified patients into low-, intermediate-, and high-risk groups, revealing that each SOFA score increment doubled mortality risk. Thus, continuous dynamic assessment using SOFA score can optimize clinical decision-making.

This multicenter prospective study investigated the predictive value of different scores for severe pneumonia prognosis. Several limitations should be acknowledged. First, due to the complex and dynamic nature of severe pneumonia, some laboratory results included in the scores could not be obtained within 24 hours of diagnosis, potentially introducing temporal inconsistency in data collection. Second, as a multicenter study, different clinical decisions made by physicians at various centers may have influenced patient outcomes. Third, the cohort included both general ward and ICU patients, and different levels of care may have affected prognosis.

In conclusion, SOFA, PSI, and CURB-65 scores all predict short-term prognosis in severe pneumonia, with SOFA score demonstrating superior discrimination and calibration. Risk stratification based on SOFA score enables individualized treatment strategies for patients across different risk categories.

References

[1] Torres A, Cilloniz C, Niederman M S, et al. Pneumonia[J]. Nat Rev Dis Primers, 2021,7(1):25.
[2] Nair G B, Niederman M S. Updates on community acquired pneumonia management in the ICU[J]. Pharmacol Ther, 2021,217:107663.
[3] Cilloniz C, Torres A, Niederman M S. Management of pneumonia in critically ill patients[J]. BMJ, 2021,375:e65871.
[4] Wang D, Willis D R, Yih Y. The pneumonia severity index: Assessment and comparison to popular machine learning classifiers[J]. Int J Med Inform, 2022,163:104778.
[5] Ilg A, Moskowitz A, Konanki V, et al. Performance of the CURB-65 Score in Predicting Critical Care Interventions in Patients Admitted With Community-Acquired Pneumonia[J]. Ann Emerg Med, 2019,74(1):60-
[6] Ahnert P, Creutz P, Horn K, et al. Sequential organ failure assessment score is an excellent operationalization of disease severity of adult patients with hospitalized community acquired pneumonia - results from the prospective observational PROGRESS study[J]. Crit Care, 2019,23(1):110.
[7] Waterer G. Severity Scores and Community-acquired Pneumonia. Time to Move Forward[J]. Am J Respir Crit Care Med, 2017,196(10):1236-1238.
[8] Ranzani O T, Prina E, Menendez R, et al. New Sepsis Definition (Sepsis-3) and Community-acquired Pneumonia Mortality. A Validation and Clinical Decision-Making Study[J]. Am J Respir Crit Care Med, 2017,196(10):1287-1297.
[9] 瞿介明, 曹彬. 中国成人社区获得性肺炎诊断和治疗指南 (2016 年版)[J]. 中华结核和呼吸杂志, 2016,39(04):253-279.
[10] Bartos H, Dzupova O. Severe community-acquired pneumonia in intensive care[J]. Epidemiol Mikrobiol Imunol, 2020,69(4):159-163.
[11] Ferreira-Coimbra J, Sarda C, Rello J. Burden of Community-Acquired Pneumonia and Unmet Clinical Needs[J]. Adv Ther, 2020,37(4):1302-1318.
[12] Wang J, Song Y L. Advances in severe community-acquired pneumonia[J]. Chin Med J (Engl), 2019,132(16):1891-1893.
[13] Lim W S, van der Eerden M M, Laing R, et al. Defining community acquired pneumonia severity on presentation to hospital: an international derivation and validation study[J]. Thorax, 2003,58(5):377-382.
[14] Lv C, Chen Y, Shi W, et al. Comparison of Different Scoring Systems for Prediction of Mortality and ICU Admission in Elderly CAP Population[J]. Clin Interv Aging, 2021,16:1917-1929.
[15] Brabrand M, Henriksen D P. CURB-65 Score is Equal to NEWS for Identifying Mortality Risk of Pneumonia Patients: An Observational Study[J]. Lung, 2018,196(3):359-361.
[16] Sharp A L, Jones J P, Wu I, et al. CURB-65 Performance Among Admitted and Discharged Emergency Department Patients With Community-acquired Pneumonia[J]. Acad Emerg Med, 2016,23(4):400-405.
[17] Kolditz M, Ewig S, Hoffken G. Management-based risk prediction in community-acquired pneumonia by scores and biomarkers[J]. Eur Respir J,

2013,41(4):974-984.
[18] Aujesky D, Fine M J. The pneumonia severity index: a decade after the initial derivation and validation[J]. Clin Infect Dis, 2008,47 Suppl 3:S133-S139.
[19] Olson G, Davis A M. Diagnosis and Treatment of Adults With Community-Acquired Pneumonia[J]. JAMA, 2020,323(9):885-886.
[20] Lambden S, Laterre P F, Levy M M, et al. The SOFA score-development, utility and challenges of accurate assessment in clinical trials[J]. Crit Care, 2019,23(1):374.
[21] Kolditz M, Braeken D, Ewig S, et al. Severity Assessment and the Immediate and Long-Term Prognosis in Community-Acquired Pneumonia[J]. Semin Respir Crit Care Med, 2016,37(6):886-896.
[22] Wen J N, Li N, Guo C X, et al. Performance and comparison of assessment models to predict 30-day mortality in patients with hospital-acquired pneumonia[J]. Chin Med J (Engl), 2020,133(24):2947-2952.
[23] Baek M S, Park S, Choi J H, et al. Mortality and Prognostic Prediction in Very Elderly Patients With Severe Pneumonia[J]. J Intensive Care Med, 2020,35(12):1405-1410.
[24] Raith E P, Udy A A, Bailey M, et al. Prognostic Accuracy of the SOFA Score, SIRS Criteria, and qSOFA Score for In-Hospital Mortality Among Adults With Suspected Infection Admitted to the Intensive Care Unit[J]. JAMA, 2017,317(3):290-300.

Note: Figure translations are in progress. See original paper for figures.