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Feasibility and predictive power of scoring systems in evaluating patients with pneumonia

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Abstract:

BACKGROUND AND AIM: International guidelines recommend several scoring systems to assess community-acquired pneumonia (CAP) severity, which play a crucial role in guiding treatment decisions. This study aims to compare the performance of these scores in predicting mortality in patients hospitalized with CAP.

METHODS: Patients admitted to Trakya University Faculty of Medicine Hospital between January 2018 and December 2019 with CAP were retrospectively reviewed through the hospital database. Recorded data included patients' demographics, comorbidities, disease severity scores (Pneumonia Severity Index (PSI), CURB-65 (Confusion, Urea, Respiratory rate, Blood pressure, 65 years or older), Acute Physiology and Chronic Health Evaluation (APACHE), Sequential Organ Failure Assessment (SOFA)), laboratory findings, and outcomes (intensive care unit (ICU) and hospital length of stay, hospital mortality). Patients were grouped and compared according to their admission location (ward or ICU).

RESULTS: The median age was 69.5 (54.2 - 80.0). PSI, CURB-65, APACHE II, Simplified Acute Physiology Score III (SAPS-3), and SOFA scores were higher in ICU patients than in those admitted to the ward. The overall hospital mortality was 22%. Regarding mortality, the Area Under the Curve (AUC) values for the PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores in hospitalized patients were 0.854 ($p<0.001$), 0.785 ($p<0.001$), 0.807 ($p<0.01$), 0.821 ($p=0.01$), and 0.773 ($p<0.01$), respectively. In the subgroup analysis of ICU patients, the AUC values and their respective CI for the PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores related to mortality were: 0.758 ($p<0.001$), 0.667 ($p=0.02$), 0.684 ($p=0.03$), 0.744 ($p=0.001$), and 0.643 ($p=0.04$), respectively.

CONCLUSIONS: The PSI and SAPS-3 scores are valuable in helping clinicians identify patients at high risk of mortality and in tailoring treatment for patients hospitalized with CAP, including those admitted to the ICU.

Keywords:

Community aquired pneumonia, infectious diseases, pulmonary and critical care, respiratory infections, scores

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Introduction

Community-acquired pneumonia (CAP) is a significant respiratory illness affecting people of all ages and is a leading cause of hospitalization and mortality, especially in vulnerable groups like the elderly and those with weakened immune systems.[1] The severity of CAP can be assessed using various scoring systems, which also help guide treatment. These scoring systems guide treatment decisions, resource allocation, and clinical research, providing essential information to healthcare providers. This enables them to make informed decisions about patient care, such as ward or intensive care unit (ICU) admissions.

The Pneumonia Severity Index (PSI) uses demographic (age) and clinical factors (comorbidities, abnormal physical findings, and laboratory results) to predict the risk of death in patients with CAP.[2] In contrast, the CURB-65 (Confusion, Urea, Respiratory rate, Blood pressure, 65 years or older) assesses the severity of CAP and the need for hospitalization.[3] CURB-65 has higher specificity for mortality prediction than PSI.[4] However, PSI has higher sensitivity in predicting ICU requirements.[4,5] The Acute Physiology and Chronic Health Evaluation II (APACHE II) score is commonly used to predict the mortality risk for ICU patients.[6] It considers various physiological parameters, with higher scores indicating higher mortality risk. The performance of the APACHE II scoring system in predicting 28-day and hospital mortality in patients with CAP is similar to that of PSI and CURB-65.[7]

The Simplified Acute Physiology Score (SAPS) is a scoring system widely used in critical care settings to predict ICU mortality. SAPS-3, the latest version, incorporates physiological and non-physiological variables for a comprehensive assessment and has been validated in various clinical settings.[8] Therefore, SAPS-3 is an essential tool for risk stratification and clinical decision-making in ICU patients.

The Sequential Organ Failure Assessment (SOFA) score evaluates organ systems (central nervous system, respiratory, coagulation, liver, cardiovascular, and renal). It was developed to assess the severity of organ dysfunctions in sepsis patients but has since been widely used in the ICU setting to evaluate the severity of other illnesses.[9] In the context of pneumonia, the SOFA score effectively evaluates the severity of organ dysfunction in ICU patients with pneumonia, particularly those requiring ICU admission.[10,11]

The aim of this study was to compare the performance of these scores in predicting mortality in patients hospitalized with CAP.

Materials and Methods

This single-center, retrospective cohort study was conducted in the Medical Intensive Care Units of Trakya University Hospital and enrolled patients admitted between January 2018 and December 2019. The Clinical Research Ethics Committee (TUTF-BAEK 2020/436) granted approval for the study. Written informed consent was obtained from the participants' parent/legal guardian/next of kin for participation in the study. In accordance with the regulatory procedures of the study clinic, patients or legally authorized relatives provided written informed consent for the "processing and publishing of patients' medical records (with names disclosed) for scientific purposes."

The study enrolled individuals aged 18 years and older who were admitted to the emergency room and diagnosed with CAP. Inclusion criteria for CAP included the presence of lower respiratory tract infection symptoms (cough, sputum production, shortness of breath, pleuritic chest pain, fever or hypothermia, dyspnea, confusion), along with the identification of new infiltrates on a chest radiograph and the absence of any alternative diagnosis.[12] Exclusion criteria were patients who did not meet the above criteria for CAP, were younger than 18 years old, had been hospitalized within the last month, had immunosuppression, developed pneumonia 48 hours after admission, or had incomplete data.

Patients' data were retrospectively scanned through the hospital database. This included patients' demographics, comorbidities, disease severity scores (PSI, CURB-65, APACHE-II, SAPS-3, SOFA), laboratory findings (hemogram, C-reactive protein (CRP)) and types of respiratory support (conventional oxygen therapy, non-invasive mechanical ventilation (NIV), invasive mechanical ventilation (IMV)) at admission, as well as outcomes (ICU and hospital length of stay, hospital mortality).

Out of the 213 patients diagnosed with CAP, 50 patients admitted to the ward and 50 patients admitted to the ICU were recruited into two groups by the stratified randomization method.

Table 1: Baseline characteristics and outcomes of patients according to place of admission

	All (n=100)		Ward (n=50)		ICU (n=50)		p
	n	%	n	%	n	%	
Age	69.5 (54.2–80.0)		65.5 (48.7–73.0)		74.5 (62–83)		0.002
Gender (male)*	73	73	40	80	33	66	0.17
PSI class*							<0.01
Class I	8	8	8	16	0	0	
Class II	16	16	16	32	0	0	
Class III	17	17	13	26	4	8	
Class IV	25	25	12	24	13	26	
Class V	34	34	1	2	33	66	
PSI score	122.0 (85–171)		83 (54–112)		166 (131–184)		<0.001
CURB-65	2 (1–3)		2 (1–2)		3 (2–3)		<0.001
APACHE II score	13.0 (7–22)		8 (5–12)		21 (16–33)		<0.001
SAPS 3 score	56 (46–66)		46 (42–52)		66 (60–79)		
SOFA score	3 (2–6)		2 (1–3)		6 (4–9)		<0.001
WBC (10^9/L)	12.2 (9.2–17.5)		12.5 (9.2–17.0)		11.05 (8.7–17.6)		0.44
CRP (mg/dL)	13.5 (8.3–23.1)		15.3 (8.2–22.3)		12.7 (8.1–22.5)		0.79
Hospital LOS (days)	10 (7–17)		9 (7–14)		14 (7–21)		0.04
Hospital mortality	22	22	3	6	19	38	<0.001

*: n (%) Data expressed in median (interquartile range), and n (%). Numerical variables were analyzed using the Mann-Whitney U test. The Fisher exact test was used for comparing hospital mortality in Chi-square analysis. The comparison of gender and PSI class in groups was conducted using the Pearson Chi-square test. ICU: Intensive care unit, PSI: Pneumonia severity index, CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, Age >65, APACHE-II: The Acute Physiology and Chronic Health Evaluation, SAPS-3: Simplified Acute Physiology Score, SOFA: Sequential Organ Failure Assessment, WBC: White blood cell, CRP: C-reactive protein, LOS: Length of stay

IBM Statistical Package for the Social Sciences (SPSS) software version 26.0 (IBM Corporation, Armonk, NY) was used for the randomization process and statistical analyses. Descriptive analyses were presented as a count (percentage) for categorical variables or median (25^{th}-75^{th} percentile) for numerical variables. Baseline characteristics, scores, and outcomes were compared between ward and ICU admissions using appropriate statistical tests, including Chi-square analysis or Fisher's exact test for categorical variables and the Mann-Whitney U test for numerical variables. Receiver operating characteristic (ROC) curves were generated to assess the predictive prognostic efficacy of the PSI, CURB-65, APACHE-II, and SAPS-3 scores regarding mortality. Optimal cut-off values and the area under the curves (AUC) were calculated using MedCalc software (MedCalc Software Ltd, Ostend, Belgium). To compare ROC curves, the method described by DeLong et al.[13] was utilized. A 5% type-I error level was used to infer statistical significance.

Results

Baseline characteristics, disease severity score points, and outcomes of 100 patients according to the admission place are shown in Table 1. The median age was 69.5 (54.2–80.0). Men (73%) were in the majority. The median PSI score point of the patients was 122.0 (85.5–171.5). According to the PSI, 59% of the patients were in Class IV and V. The median CURB-65 score was 2 (1–3). Median APACHE-II and SAPS-3 scores were 13.0 (7–22) and 56.5 (46–66), respectively. Conventional O2 therapy, NIV, and IMV were provided to 65%, 4%, and 31% of the patients, respectively. All the patients requiring NIV and IMV were admitted to the ICU.

Patients were grouped and compared according to the place of admission (Table 1). Patients admitted to the ICU were older, with a median age of 74.5 years (62–83), compared to those admitted to the ward, who had a median age of 65.5 years (48.7–73.0). There were no significant differences between the groups in terms of gender, white blood cell (WBC) count, or CRP levels. PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores were higher in ICU patients than in those admitted to the ward. The two groups differed significantly in terms of PSI category ($p<0.01$), with the PSI category of the patients admitted to the ICU being at least III.

Out of the patients admitted to the ICU, 62% (31 patients) required intubation and received invasive mechanical ventilation, while only 8% (4 patients) received non-invasive mechanical ventilation. The remaining patients were given low-flow oxygen therapy methods such as nasal cannulas, diffuser masks, and non-rebreathing reservoir masks. None of the patients admitted to the ward required invasive or non-invasive mechanical ventilation; however, all ward patients needed low-flow oxygen therapies. Hospital length of stay (LOS) was longer for ICU patients (median of 14 days (7–21)) than for ward patients (median of 9.5 days (7–14)) (p=0.04). Hospital mortality was 22% overall. The standardized mortality ratio was 0.76 (95% CI: 0.60–0.92) according to the APACHE-II predicted mortality (28.9%).

The ROC curves were utilized to examine the predictive accuracy of five scoring systems [Fig. 1a,b] in relation to mortality. Since only three of the randomly selected ward patients died, analyses were conducted for all hospitalized patients and the group of patients admitted to the ICU. For all hospitalized patients, the AUC values and corresponding confidence intervals (CI) for the PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores were as follows: 0.854 (95% CI: 0.766 – 0.919) (p<0.001), 0.785 (95% CI: 0.692 – 0.861) (p<0.001), 0.807 (95% CI: 0.716–0.879) (p<0.01), 0.821 (95% CI: 0.732–0.890) (p=0.01), and 0.773 (95% CI: 0.678 – 0.851) (p<0.01), respectively (Table 2). Table 2 presents the optimal cut-off values and corresponding sensitivity and specificity for each scoring system in relation to mortality among hospitalized patients. Notably, the PSI score exhibited the highest sensitivity (81.8%), and the greatest specificity (70.4%). For the subgroup of patients admitted to the ICU, the AUC values and their respective confidence intervals (CI) for the PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores in relation to mortality were: 0.758 (95% CI: 0.616–0.868, p<0.001), 0.667 (95% CI: 0.515–0.820, p=0.02), 0.684 (95% CI: 0.520–0.848, p=0.03), 0.744 (95% CI: 0.594–0.895, p=0.001), and 0.643 (95% CI: 0.479–0.806, p=0.04), respectively (Table 3). In the ICU subgroup, the CURB-65 score displayed the highest sensitivity (89.5%), while the SAPS-3 score had the greatest specificity (71%).

No differences were detected in pairwise comparisons of ROC curves for all hospitalized patients (Appendix 1) and the subgroup of patients admitted to the ICU (Appendix 2).

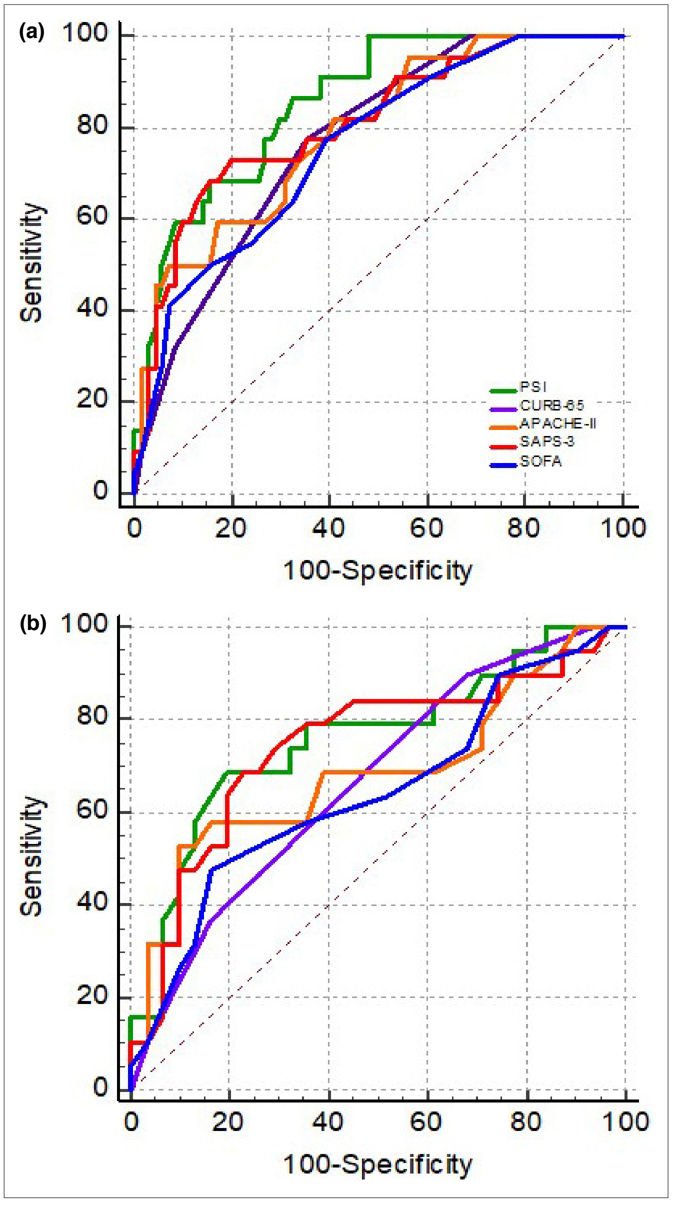

Figure 1: ROC curve analysis for mortality. (a) ROC curve analysis for hospitalized patients, (b) ROC curve analysis for patients admitted to the ICU

PSI: Pneumonia severity index, CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, Age >65, APACHE-II: The Acute Physiology and Chronic Health Evaluation, SAPS-3: Simplified Acute Physiology Score, SOFA: Sequential Organ Failure Assessment

Discussion

The results of this study indicate that patients admitted to the ICU were older and had higher severity scores compared to those admitted to the ward. Additionally, ICU patients had longer hospital LOS and higher mortality rates. The mortality predictive power of five scoring systems (PSI, CURB-65, APACHE II, SAPS-3, and SOFA) was compared separately in patients hospitalized and admitted to the ICU. The results showed that the PSI, APACHE-II, and SAPS-3 scoring systems had good predictive ability for hospitalized pneumonia patients, with the PSI score showing the highest AUC value. However, in ICU patients, the PSI and SAPS-3 scores predicted mortality moderately, whereas the CURB-65, APACHE-II, and SOFA scores had poor predictive ability.

Table 2: AUC values and corresponding confidence intervals (CI) for PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores; optimal cut-off values and corresponding sensitivity and specificity for each scoring system in predicting mortality among hospitalized patients

Score	AUC (95% CI)	p	Cut-off	Sensitivity (%)	Specificity (%)
PSI	0.854 (0.766–0.919)	<0.001	134	81.8	70.4
CURB-65	0.785 (0.692–0.861)	<0.001	2	77.2	67.9
APACHE II	0.807 (0.716–0.879)	<0.001	15	72.7	69.2
SAPS-3	0.821 (0.732–0.891)	0.001	59	72.7	67.9
SOFA	0.773 (0.678–0.851)	<0.001	3	77.2	62.8

AUC: Area under the curve

Table 3: AUC values and corresponding confidence intervals (CI) for PSI, CURB-65, APACHE II, SAPS-3, and SOFA scores; optimal cut-off values with corresponding sensitivity and specificity for each scoring system in predicting mortality among patients admitted to the ICU

Score	AUC (95% CI)	p	Cut-off	Sensitivity (%)	Specificity (%)
PSI	0.758 (0.616–0.868)	<0.001	163	78.9	64.5
CURB-65	0.667 (0.515–0.820)	0.02	2	89.5	32.3
APACHE II	0.684 (0.520–0.848)	0.03	21	68.4	61.3
SAPS-3	0.744 (0.594–0.895)	0.001	66	73.7	70.9
SOFA	0.643 (0.479–0.806)	0.04	6	57.9	64.5

Community-acquired pneumonia can lead to severe complications and even death, particularly in individuals with underlying health conditions or immunosuppression. The mortality rate for CAP varies depending on the patient's age, overall health status, and severity of the pneumonia. Generally, the mortality rate in hospitalized patients for CAP ranges from 5–10%.[14,15] However, this rate is higher when ICU admission is necessary. In the ICU setting, patients with CAP are typically those with severe or life-threatening infections that require advanced medical interventions, such as mechanical ventilation and hemodynamic support. The mortality rate for ICU patients with CAP can range from 30% to 54%.[16,17] In our study, the actual mortality was 22%, which was lower than that predicted by the APACHE-II score (28.9%, with a Standardized Mortality Ratio (SMR) of 0.76 (95% CI: 0.60–0.92)). Fifty percent of the population consisted of ICU patients, suggesting the potential impact of randomization on patient outcomes should be taken into account.

Various predictive rules and severity scores have been developed to assess mortality and ICU requirements for patients with CAP. The PSI and CURB-65 are commonly used scoring systems for assessing severity and determining the site of care. These scores can also be utilized to assess the risk of mortality. A study conducted by Carlos et al.[18] analyzed the effectiveness of CURB-65 in predicting mortality rates in both the short and long term. The study found that this score is reliable in predicting mortality and rehospitalization within six months following hospitalization. English et al.[19] conducted a study on a significant patient population and discovered that the PSI's specificity for in-hospital mortality was 98.9%, and its positive predictive value was 0.941. The mortality prediction performances of these scores have also been found to be similar in cases of CAP related to the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2).[20] According to the Clinical Practice Guideline of the American Thoracic Society and Infectious Diseases Society of America, PSI is preferred over the CURB-65 scoring system for determining the need for hospitalization.[12] Studies by Aujesky et al.[21] and Zhang et al.[22] have also found that PSI outperforms CURB-65 in predicting mortality, with PSI showing higher discriminatory power and sensitivity for 28-day mortality. In a meta-analysis of 23 studies involving 22,753 participants, Loke et al.[23] found that PSI had higher sensitivity than CURB-65 for mortality prediction. In our study, PSI performed better than CURB-65, with a higher area under the curve (AUC) and sensitivity in hospitalized patients, in accordance with the literature. The discriminative function of CURB-65 was limited, as its AUC was under 0.80 in both hospitalized and ICU patients.

Several ICU scoring systems, such as APACHE II, SOFA, and SAPS-3, are used to predict mortality in ICU patients upon admission, but their validity in CAP patients is not well understood. In the Prowess study's subgroup analyses, Richards et al.[7] compared PSI (fifth category), CURB-65 (≥3), and APACHE II (≥25) in predicting 28-day mortality of CAP. They found that the three scoring systems had similar performance, as their respective AUCs of the scores were 0.65, 0.66, and 0.64. Aydoğdu et al.[24] evaluated the performance of pneumonia scores (PSI, CURB-65) and ICU scores (APACHE II and SOFA) in predicting mortality in CAP patients. While PSI and CURB-65 were not found to be valuable in predicting mortality, a high APACHE II score (> 20) was associated with an increased risk of mortality. Unlike their study, which focuses exclusively on patients who required mechanical ventilation and were admitted to the ICU, our study included both hospitalized and ICU patients. We found that among the intensive care scoring systems, the SAPS-3 score was comparable to PSI and stronger than APACHE-II and SOFA scores in predicting mortality.

Several studies have demonstrated the utility of SAPS-3 in predicting patient outcomes, including hospital mortality and LOS.[8,25] Carmo et al.[26] compared the performance of severity scores developed for the ICU (SAPS-3, Quick Sequential Organ Failure Assessment (qSOFA)) with a pneumonia-specific score (CURB-65). In their study, none of the severity scores reached an AUC threshold of 0.80, indicating a limitation in accurately detecting patients at the highest risk of death who were admitted to the ICU with pneumonia. Another study evaluated the predictive power of SAPS II, SOFA, and CURB-65 scores in determining mortality among hospitalized patients with severe CAP. These scores were found to have similar predictive capacities regarding mortality.[27]

While they serve similar purposes, there are differences between SAPS-3, APACHE-II, and SOFA scores. SAPS-3 includes 20 physiological variables and considers the presence of chronic health conditions as an additional factor in predicting patient outcomes, whereas APACHE-II and SOFA scores include fewer physiological variables and do not directly consider chronic health conditions in their scoring systems. This is significant as chronic health conditions are associated with the mortality of pneumonia patients.[28]

It is important to note that this study has some limitations, including its retrospective nature and the fact that it was conducted at a single center. Additionally, the sample size was relatively small.

These findings have important clinical implications for managing patients with respiratory infections. Specifically, the results suggest that older patients with higher severity scores are more likely to require ICU admission and experience poorer outcomes, emphasizing the importance of accurate risk stratification. Furthermore, PSI and SAPS-3 scores can help clinicians identify patients at high risk for mortality and tailor treatment accordingly. Despite variations in their respective predictive abilities, no significant differences were observed among the scoring systems, implying that any of them could be effectively employed in clinical practice for our local population.

By incorporating these scores into their decision-making processes, younger attending physicians can enhance their ability to identify high-risk pneumonia patients who may require intensive care admission. The implementation of such scoring systems has the potential to improve patient outcomes, optimize resource allocation, and guide appropriate hospitalization decisions. Further studies are needed to validate these results and explore other potential predictors of mortality in this patient population.

Conflicts of interest

There are no conflicts of interest.

Ethics Committee Approval

The study was approved by the Trakya University Faculty of Medicine Scientific Research Ethics Committee (No: 2020/436, Date: 07/12/2020).

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Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept – A.U.; Design – V.İ., P.H.; Supervision – V.İ.; Materials – V.İ.; Data collection &/or processing – A.U., P.H.; Analysis and/or interpretation – P.H.; Literature search – P.H.; Writing – P.H.; Critical review – V.İ.

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Appendix 1. Pairwise comparison of ROC curves in hospitalized patients

Compared scores	Difference between areas	Standard error	%95 Confidence interval	Z statistic	p
PSI-CURB-65	0.083	0.050	–0.015–0.183	1.660	0.09
PSI-APACHE-II	0.063	0.052	–0.039–0.166	0.208	0.22
PSI-SAPS-3	0.044	0.050	–0.054–0.143	0.876	0.38
PSI-SOFA	0.094	0.058	–0.020–0.210	1.617	0.10
CURB-65-APACHE II	0.020	0.042	–0.062–0.103	0.486	0.62
CURB-65- SAPS-3	0.039	0.040	–0.038–0.118	0.993	0.30
CURB-65-SOFA	0.010	0.039	–0.066–0.087	0.277	0.78
APACHE II-SAPS-3	0.019	0.034	–0.048–0.086	0.558	0.57
APACHE II-SOFA	0.031	0.027	–0.023–0.085	1.539	0.12
SAPS-3-SOFA	0.050	0.032	–0.013–0.115	1.539	0.12

ROC: Receiver operating characteristic, PSI: Pneumonia severity index, CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, Age>65, APACHE-II: Acute Physiology and Chronic Health Evaluation II, SAPS-3: Simplified Acute Physiology Score-3, SOFA: Sequential organ failure assessment

Appendix 2. Pairwise comparison of ROC curves in ICU patients

Compared Scores	Difference between areas	Standard error	%95 Confidence interval	Z statistic	p
PSI-CURB-65	0.0908	0.101	–0.108–0.290	0.896	0.37
PSI-APACHE-II	0.0739	0.111	–0.114–0.292	0.665	0.50
PSI-SAPS-3	0.0136	0.098	–0.179–0.206	0.138	0.89
PSI-SOFA	0.115	0.115	–0.110–0.341	1.004	0.31
CURB-65-APACHE II	0.017	0.076	–0.133–0.167	0.222	0.82
CURB-65- SAPS-3	0.077	0.073	–0.066–0.221	1.052	0.29
CURB-65-SOFA	0.024	0.066	–0.106–0.155	0.370	0.71
APACHE II-SAPS-3	0.060	0.066	–0.070–0.191	0.901	0.36
APACHE II-SOFA	0.041	0.042	–0.042–0.126	0.969	0.33
SAPS-3-SOFA	0.102	0.058	–0.013–0.217	1.732	0.08

ICU: Intensive care unit