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CAP-PIRO Scoring System's Performance in Predicting Prognosis and Severity of Community-Acquired Pneumonia: A Single-Center Prospective Study

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Background: Community-acquired pneumonia (CAP) is a significant global health issue, leading to high morbidity and mortality rates. Despite the existence of various severity scoring systems, accurately predicting patient outcomes remains challenging. The CAP-PIRO (Predisposition, Insult, Response, and Organ dysfunction) scoring system offers a comprehensive approach to evaluating CAP severity and prognosis.

Objective: This study aimed to assess the effectiveness of the CAP-PIRO scoring system in predicting the prognosis and severity of CAP patients, focusing on the development of acute respiratory distress syndrome (ARDS) and 28-day mortality.

Methods: A total of 875 CAP patients were prospectively enrolled from the emergency department of Beijing Chao-yang Hospital between November 2017 and December 2023. Clinical data, including patient demographics, medical history, vital signs, and laboratory findings, were collected within 6 hours of admission. CAP-PIRO, CURB-65, and PSI scores were calculated. Patients were stratified based on ARDS development, 28-day mortality, and PaO2/FiO2 categories (≤100 mmHg, 100–200 mmHg, 200–300 mmHg).

Results: Significant differences were observed in PCT, blood lactate (Lac), CURB-65, PSI, and CAP-PIRO scores between patients with and without ARDS, as well as between survivors and non-survivors at 28 days ($P<0.05$). CAP-PIRO and Lac were identified as independent predictors for ARDS development and 28-day mortality. The area under the ROC curve (AUC) for CAP-PIRO was higher than that for CURB-65 and PSI in predicting 28-day mortality. The combination of CAP-PIRO and Lac demonstrated improved predictive accuracy for ARDS. Notably, significant differences in CAP-PIRO scores were observed across different PaO2/FiO2 groups.

Conclusion: CAP-PIRO demonstrates strong predictive ability for adverse outcomes and, when combined with lactate, shows enhanced predictive power. These findings underscore the value of CAP-PIRO for clinical risk stratification in CAP patients.

Keywords: CAP, CAP-PIRO scoring system, prognosis prediction, ARDS, risk stratification

Background

Community-acquired pneumonia (CAP) is a prevalent infectious disease that poses a significant threat to human health, with an incidence rate ranging from 5.16 to 6.11 cases per 1000 adults, this disease is responsible for over 3 million deaths worldwide annually.[1] In China, the incidence of community-acquired pneumonia (including children) ranges from approximately 29.8 to 221.0 cases per 10,000 individuals.[2] Early assessment of CAP severity, appropriate selection of treatment settings, and timely implementation of targeted therapeutic strategies are essential for improving patient

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outcomes.[3,4] Given the complex presentation of CAP, reliable severity assessment tools are crucial to guide clinical decisions, optimize resource use, and improve prognosis.

Multiple scoring systems, such as CURB-65 and PSI, are commonly used; however, each has limitations in certain patient subgroups or specific settings. CURB-65's limitation is its categorization of patients only as severe or non-severe, which overlooks individuals with a low mortality risk who could be candidates for early discharge or home care.[5,6] PSI has been effective in promoting outpatient treatment for CAP and is recommended,[7] but its complexity and heavy reliance on age and comorbidities limit its utility in busy emergency settings.[8] These limitations underscore. In 2009, Jordi Rello developed the community-acquired pneumonia - predisposition, insult, deleterious response, and organ failure (CAP-PIRO) scoring system for patients with CAP based on the PIRO concept[9]. Similar to PIRO, CAP-PIRO evaluates four key aspects: predisposition, infection/insult, deleterious response, and organ failure. Specifically, the CAP-PIRO system allocates 2 points each to predisposition (including comorbidities such as chronic obstructive pulmonary disease or alcoholism and age over 70 years), infection/insult (including bacteremia and multilobar opacities on chest radiographs), deleterious response (including shock and severe hypotension), and organ failure (including acute respiratory distress syndrome and acute renal failure), summing to a total of 8 points. Since the PIRO score incorporates essential symptoms, vital signs of sepsis, and major risk factors for CAP, it is expected to provide improved predictive performance for CAP severity.

Studies have demonstrated CAP-PIRO's effectiveness in severity stratification for patients with severe community-acquired pneumonia (SCAP) and its strong predictive capability for 28-day mortality[10,11], thus validating its clinical value. Additionally, CAP-PIRO employs a simplified yes/no assessment pattern, facilitating ease of use. However, research on the CAP-PIRO system remains limited, and it is rarely used in clinical practice. The present study thus aims to explore the association between the CAP-PIRO score and CAP patient prognosis, focusing on outcomes such as ARDS and 28-day mortality.These findings are expected to provide potential strategies for the early identification, severity stratification, and timely treatment of CAP.

Materials and Methods

This prospective study included CAP patients treated in the emergency department (rescue room, observation room, and intensive care unit) at Beijing Chao-yang Hospital, Capital Medical University, from November 2017 to December 2023. Patients were categorized based on ARDS development and 28-day mortality and stratified into three ARDS severity groups according to PaO2/FiO2 levels (≤100 mmHg, 100–200 mmHg, and 200–300 mmHg). Data on age, gender, medical history, and vital signs were collected. Laboratory tests, including white blood cell count, blood gas analysis, biochemical indices, and chest X-rays, were conducted within 6 hours of admission. CAP-PIRO, CURB-65, and PSI scores were calculated using this clinical data. The primary endpoints were ARDS incidence and 28-day mortality.

Inclusion and Exclusion Criteria

The inclusion criteria included: (1) patients aged 18 years or older; (2) patients who met the diagnostic criteria of CAP. The exclusion criteria included: (1) patients with advanced diseases, including malignant tumors (advanced or metastatic tumors) and end-stage liver disease or kidney disease; (2) patients hospitalized within 14 days before the occurrence of symptoms; (3) patients with cystic fibrosis, active pulmonary tuberculosis, severe immunosuppression, coagulopathy, or systemic anticoagulation therapy; (4) patients who had received pretreatment in another hospital; (5) patients or their families who declined to participate in the study.

Diagnostic Criteria

Community-acquired pneumonia (CAP) is defined as pneumonia acquired outside of a hospital setting or in patients who have not been hospitalized within 48 hours prior to diagnosis.[12] CAP was diagnosed based on the presence of new infiltrative shadows on chest radiographs, accompanied by at least one of the following symptoms: (1) cough; (2) expectoration; (3) dyspnea; (4) body temperature >38.0°C; (5) abnormal breath sounds or rales in auscultation.[13]

According to the OI, the Berlin criteria for the diagnosis of ARDS included: (1) mild: 200mmHg<PaO_2/FIO2≤300mmHg; (2) moderate: 100mmHg<PaO_2/FIO2≤200mmHg; (3) severe: PaO_2/FIO2≤100mmHg. The four

adjunctive indexes for severe ARDS included radiographic severity, respiratory compliance (≤40 mL/cm H2O), positive end-expiratory pressure (PEEP, ≥10 cm H2O), and corrected exhaled volume per minute (≥10 L/min).[14]

Laboratory Tests

Firstly, 5–10mL of blood was collected within 6 hours of admission and placed into a test tube containing heparin, after which the sample was stored at −80°C. For white blood cell (WBC) counting, the automated hematology analyzer Sysmex XS-500i (Sysmex Corporation, Kobe, Japan) was utilized. Lac levels were measured using the ABL90FLEX automatic blood gas analyzer (Radiometer, Denmark), which directly analyzed arterial blood samples. Additionally, arterial blood gas values, including pH, partial pressure of oxygen, partial pressure of carbon dioxide, oxygen saturation, and lactate, were recorded to calculate the oxygenation index (OI = PaO2/FiO2). The reference range for Lac in the present study was 0.5–1.6 mol/L. PCT levels were assessed with the Roche Cobas E601 immunoanalyzer (Thermo Fisher Scientific, Birmingham, Germany), with a normal reference range of <0.05 ng/mL.

Statistical Analysis

All statistical analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA). The normally distributed data were expressed as mean ± standard deviation (SD), and the non-normally distributed data were expressed as median (P25, P75). The Mann–Whitney *U*-test was employed to compare two groups, while the Kruskal–Wallis univariate analysis was used for comparisons among multiple groups. Additionally, WBC counts, Lac levels, PCT levels, CAP-PIRO scores, PSI scores, and CURB-65 scores were calculated to analyze ARDS and 28-day mortality in the patients. ROC curves were plotted to determine the AUC for these measures. In addition, the sensitivity and specificity were also calculated. Compared with AUC, the Z value was calculated as per Z=(A1-A2)/(SE12+SE22) 1/2 (Z0.05=1.96, Z0.01=2.58). Moreover, binary logistic regression analysis was conducted to identify the independent predictors of ARDS and 28-day mortality. All statistical analyses were performed based on two-tailed tests. $P<0.05$ was considered statistically significant.

Results

Baseline Data of Patients with CAP in the Study: Table 1

A total of 966 CAP patients met the inclusion criteria and provided written informed consent upon admission to the emergency department. Of these, 65 patients or their families declined participation, 23 were lost to follow-up after transfer, and 3 withdrew midway, resulting in a final cohort of 875 patients. The cohort was divided into two groups based on 28-day mortality: 323 patients in the death group and 552 in the non-death group. For ARDS occurrence, there were 246 patients in the ARDS group and 629 in the non-ARDS group. Based on ARDS severity, patients were further stratified into three subgroups: 36 in the PaO2/FiO2 ≤100 mmHg group, 78 in the 100–200 mmHg group, and 132 in the 200–300 mmHg group (Figure 1).

In this study, the statistical analysis revealed significant differences between the death group and the non-death group in terms of chronic obstructive pulmonary disease (COPD) (P≤0.001), congenital heart defect (CHD) (P=0.005), respiratory rate (RR) (P<0.001), heart rate (HR) (P=0.008), lactate (Lac) (P<0.001), PaO2 (P<0.001), PaO2/FiO2 (P<0.001), CURB-65 score (P=0.01), PSI score (P<0.001), and CAP-PIRO score (P<0.001) (Table 1).

The statistical analysis showed significant differences between the ARDS group and the non-ARDS group in terms of chronic obstructive pulmonary disease (COPD) (P<0.001), high blood pressure (HBP) (P=0.017), diabetes mellitus (DM) (P=0.003), mean arterial blood pressure (MABP) (P<0.001), body temperature (T) (P=0.039), heart rate (HR) (P=0.023), procalcitonin (PCT) (P<0.001), lactate (Lac) (P<0.001), PaO2 (P<0.001), PaO2/FiO2 (P<0.001), CURB-65 score (P<0.001), PSI score (P<0.001), and CAP-PIRO score (P<0.001) (Table 1).

Correlation between the CAP-PIRO Score and Other Indexes: (Table 2)

CAP-PIRO is significantly correlated with PCT (R = 0.122, P < 0.001), Lac (R = 0.213, P < 0.001), CURB-65 (R = 0.506, P < 0.001), and PSI (R = 0.503, P < 0.001). No significant correlation was found between CAP-PIRO and WBC (R = 0.052, P = 0.127).

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Table 1 Basic Information of the Study Cohort

	All Patients (n=875)	Survivors (n=552)	Non-survivors (n=323)	P	ARDS (n=246)	Non-ARDS (n=629)	P
Age, years	68.1 (62–78)	71 (61–78)	72 (63–78)	0.104	72 (63–78)	72 (59–78)	0.473
Male, sex%	525 (60)	341 (61.8)	184 (57)	0.161	390 (62)	135 (55.3)	0.074
COPD(%)	27.4	22.6	35.6	<0.01	50	24.8	<0.01
Cerebrovascular disease(%)	20.2	23.7	24.5	0.806	23.6	27.2	0.305
Hypertension(%)	47	43.8	52.3	0.017	51.6	44.7	0.129
Diabetes mellitus(%)	30.1	33.0	36.2	0.003	39.8	32.0	0.032
Chronic heart failure(%)	41.7	41.5	48.3	0.057	51.2	40.7	0.005
Chronic renal dysfunction(%)	11.5	11.8	15.5	0.673	17.1	14.0	0.247
Tumor(%)	10.4	10.5	14.2	0.105	14.2	12.4	0.501
MAP mmHg	90(77–103)	90(80–104)	87(72–102)	<0.001	88(77–103)	89(78–102.5)	0.496
Respiratory rate beats/minutes	30(26–34)	32(28–35)	32(28–38)	0.149	30(26–36)	28(25–32)	<0.001
Temperature °C	37.5(36.5–38.5)	37.3(36.5–38.5)	37(36.4–38.3)	0.039	37.2(36.5–38.5)	37.1(36.5–38.3)	0.509
Heart rate beats/minutes	110(95–123)	108(95–120)	111(96–128)	0.023	110(96–124.5)	105(93–120)	0.008
Lactate (mmol/L)	1.6(1–3.1)	1.5(1–2.6)	2.2(1.2–5.2)	<0.001	1.6(1.0–2.7)	2.3(1.1–5.35)	<0.001
PCT (ng/mL)	0.46(0.09–3.26)	0.27(0.06–1.88)	1.3 (0.22–8.5)	<0.001	0.46 (0.1–3.33)	0.41 (0.05–2.75)	0.142
WBC (× 109/L)	11.9(8.2–16.4)	11.5(8.0–16.1)	12.4(8.5–17.4)	0.11	11.65(8.15–16.3)	12.42(8.805–17.8)	0.099
PaO2, mmHg	76.7(62.3–96.8)	78(64–97)	72(62–97)	0.108	89(78–102.5)	72(62–97)	<0.001
PaO2/FiO2	235(175–312	247(182–317)	222(157–304)	<0.001	200.5(149.5–246)	369(327–448)	<0.001
CURB65	2 (1–3)	2 (1–3)	2 (2–3)	<0.001	2 (1–3)	2 (1–3)	0.01
PSI	130(114–146)	126 (111–140)	138 (122–155)	<0.001	126 (116–148)	126 (110.5–141)	<0.001
CAP-PIRO	4(3–5)	4(3–5)	5 (4–6)	<0.001	4(3–4)	4(3–5)	<0.001

Abbreviations: COPD: chronic obstructive pulmonary disease; MAP: mean arterial pressure; PCT: procalcitonin; WBC White blood cell; CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, and age ≥ 65; PSI Pneumonia Severity Index, CAP-PIRO: Community-Acquired Pneumonia-Predisposition, Insult, Response, Organ dysfunction.

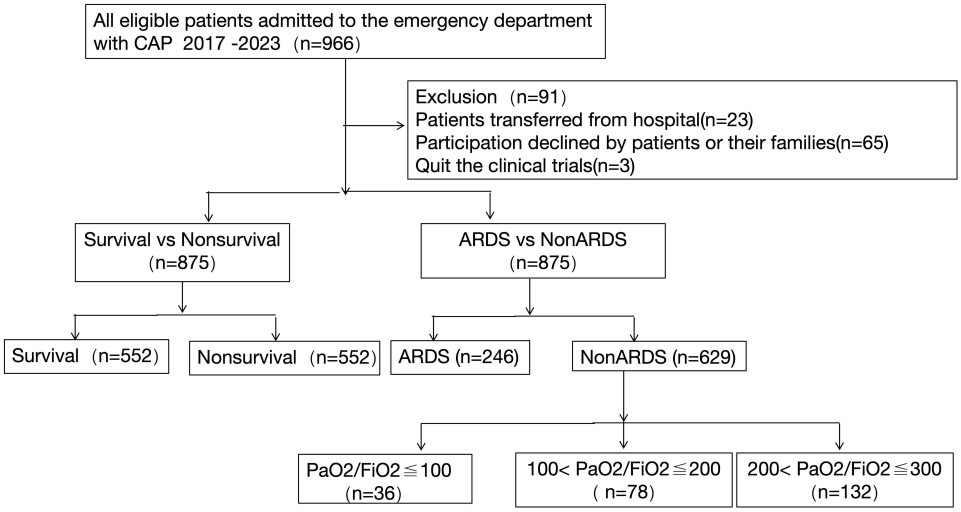

Figure 1 Flowchart of the study population.

Logistic Regression Analysis of Each Variable for the Prognosis of Patients with CAP (Table 3)

In the present study, the independent predictors for CAP were analyzed using multivariate logistic regression. As listed in Table 3, the results show that PCT (P=0.028, OR=1.009, 95% CI: 1.001–1.017), Lac (P<0.001, OR=1.799, 95% CI: 1.608–2.012) and CAP-PIRO score (P<0.001, OR=1.643, 95% CI: 1.437–1.877) were independent risk factors for the co-occurrence of ARDS in patients with CAP; while, Lac (P<0.001, OR=1.158, 95% CI: 1.092–1.228) and CAP-PIRO score (P<0.001, OR=1.786, 95% CI: 1.56–2.044) were independent risk factors for 28-day mortality in patients with CAP.

Prediction of the Prognosis of Patients with CAP (Table 4 and Figure 2)

The results of CAP-PIRO and other variables and their combinations for the prediction of ARDS and 28-day mortality in patients with CAP are shown in Table 4 and Figure 2.

The AUC values for predicting ARDS were as follows: PCT 0.658 (95% CI: 0.62–0.695, $P < 0.001$), lactate (Lac) 0.634 (95% CI: 0.594–0.674, $P < 0.001$), PSI score 0.651 (95% CI: 0.613–0.69, $P < 0.001$), CURB-65 score 0.636 (95% CI: 0.597–0.674, $P < 0.001$), and CAP-PIRO score 0.732 (95% CI: 0.698–0.766, P < 0.001). The AUC for CAP-PIRO+PCT was 0.753 (95% CI: 0.721–0.786, $P < 0.001$), and that for CAP-PIRO+Lac was 0.754 (95% CI: 0.72–0.787, $P < 0.001$).

The AUC values for predicting 28-day mortality were as follows: PCT 0.719 (95% CI: 0.683–0.755, $P < 0.001$), Lac 0.84 (95% CI: 0.811–0.87, $P < 0.001$), PSI score 0.702 (95% CI: 0.664–0.741, $P < 0.001$), CURB-65 score 0.707 (95% CI: 0.669–0.744, $P < 0.001$), and CAP-PIRO score 0.746 (95% CI: 0.71–0.782, $P < 0.001$). The AUC for CAP-PIRO+PCT was 0.794 (95% CI: 0.761–0.827, $P < 0.001$), and that for CAP-PIRO+Lac was 0.876 (95% CI: 0.85–0.901, $P < 0.001$).

Table 2 Spearman Correlations Analysis Between CAP-PIRO and Other Indicators

Variables	WBC	PCT	Lac	CURB-65	PSI
Spearman correlation	0.052	0.122	0.213	0.506	0.503
P	0.127	<0.001	<0.001	<0.001	<0.001

Note: CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, and age ≥ 65;
Abbreviations: WBC:White blood cell; PCT:procalcitonin; Lac:Lactic acid; PSI, Pneumonia Severity Index.

Table 3 Multivariate Logistic Regression Analysis of 28-Day Mortality and ARDS in CAP Patients

	Variables	B	SE	Wald	P	OR (95% CI)
ARDS	PCT	0.009	0.004	4.817	0.028	1.009 (1.001–1.017)
	Lac	0.587	0.057	105.651	<0.001	1.799 (1.608–2.012)
	CURB-65	0.032	0.135	0.057	0.812	1.033 (0.792–1.346)
	PSI	0.011	0.006	2.725	0.099	1.011 (0.998–1.023)
	CAP-PIRO	0.613	0.085	52.288	<0.001	1.846 (1.563–2.179)
	Constant	−6.64	0.735	81.565	<0.001	
28-day mortality	PCT	0.002	0.003	0.418	0.518	1.002 (0.996–1.008)
	Lac	0.147	0.03	23.958	<0.001	1.158 (1.092–1.228)
	CURB-65	−0.087	0.109	0.642	0.423	0.917 (0.74–1.134)
	PSI	0.006	0.005	1.238	0.266	1.006 (0.996–1.016)
	CPA-PIRO	0.58	0.069	70.596	<0.001	1.786 (1.56–2.044)
	Constant	−4.086	0.547	55.8	<0.001	

Abbreviations: PCT:procalcitonin; Lac:Lactic acid; CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, and age≥65; PSI: Pneumonia Severity Index; CAP-PIRO: Community-Acquired Pneumonia-Predisposition, Insult, Response, Organ dysfunction.

Table 4 Statistical Data of ROC Curve in Predicting 28-Day-Mortality and ARDS in sCAP Patients

	Variables	AUCs	SE	P-value	95% CI	Cut off	Sensitivity	Specificity
ARDS	PCT	0.719	0.018	< 0.001	0.683–0.755	0.45	73.7	60.5
	Lac	0.84	0.015	< 0.001	0.811–0.87	2.35	73	82.4
	PSI	0.702	0.02	< 0.001	0.664–0.741	139.5	57.6	76.2
	CURB-65	0.707	0.019	< 0.001	0.669–0.744	2.5	57.9	75
	CAP-PIRO	0.746	0.018	< 0.001	0.71–0.782	4.5	67.6	70.9
	CAP-PIRO+PCT	0.794	0.017	< 0.001	0.761–0.827		78.4	84
	CAP-PIRO+Lac	0.876	0.013	< 0.001	0.85–0.901		64	81.9
28-day mortality	PCT	0.658	0.019	< 0.001	0.62–0.695	0.36	71.1	56.1
	Lac	0.634	0.02	< 0.001	0.594–0.674	2.35	49.5	72.4
	PSI	0.651	0.02	< 0.001	0.613–0.69	139.5	49.8	75.3
	CURB-65	0.636	0.02	< 0.001	0.597–0.674	2.5	48.9	71.8
	CAP-PIRO	0.732	0.017	< 0.001	0.698–0.766	4.5	63	70.6
	CAP-PIRO+PCT	0.753	0.017	< 0.001	0.721–0.786		81	60
	CAP-PIRO+Lac	0.754	0.017	< 0.001	0.72–0.787		66.6	71.7

Abbreviations: PCT:procalcitonin; Lac: Lactic acid; CURB-65: Confusion, Urea, Respiratory rate, Blood pressure, and age ≥ 65;PSI: Pneumonia Severity Index; CAP-PIRO: Community-Acquired Pneumonia-Predisposition, Insult, Response, Organ dysfunction.

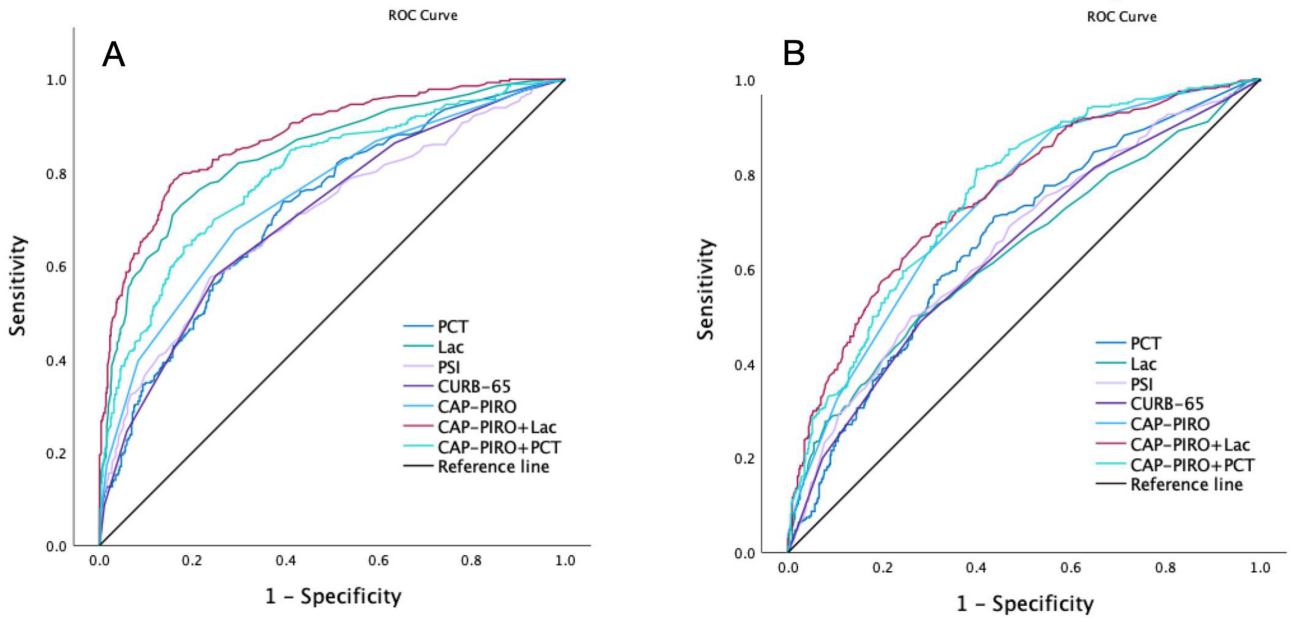

Figure 2 (**A**) The ROC curves of variables for predicting ARDS,(**B**) the ROC curves of of variables for predicting 28-day mortality.

The ability of CAP-PIRO and other variables to predict the prognosis of CAP patients was analyzed by comparing the AUC values. The results reveal no significant differences between CAP-PIRO and PSI (Z=1.635, *P*=0.102), CAP-PIRO and CURB-65 (Z=1.49, *P*=0.136), and CAP-PIRO and CAP-PIRO+PCT (Z=1.94, *P*=0.053) in predicting the co-occurrence of ARDS. Nevertheless, there were significant differences in predicting the co-occurrence of ARDS between CAP-PIRO and CAP-PIRO+Lac (Z=5.854, *P*<0.001).

Moreover, CAP-PIRO exhibited significant differences in predicting the 28-day mortality compared with PSI (Z=3.086, *P*=0.002) and CURB-65 (Z=3.657, *P*≤0.001). However, CAP-PIRO had no significant differences in predicting the 28-day mortality compared with CAP-PIRO+PCT (Z=0.873, *P*=0.382) and CAP-PIRO+Lac (Z=0.915, *P*=0.360).

Comparison of Indexes and Scores Between Adjacent Groups According to the OI (PaO_2/FiO_2) (Figure 3)

Except for PSI, the $PaO_2/FiO_2 \leq 100$ mmHg (severe ARDS) group and the 100 mmHg < $PaO_2/FiO_2 \leq 200$ mmHg (moderate ARDS) group showed significant differences in all other indexes (P < 0.05), including PCT: 1.61 vs 0.6, P = 0.022; Lac: 3 vs 1.8, P = 0.003; CURB-65 score: 3 vs 2, P = 0.014; PSI: 137 vs 127, P = 0.125; CAP-PIRO score: 6 vs 5, P < 0.001; CAP-PIRO+PCT: 0.58 vs 0.37, P < 0.001; CAP-PIRO+Lac: 0.69 vs 0.34, P < 0.001.

Except for PCT, the 100 mmHg < $PaO_2/FiO_2 \leq 200$ mmHg (moderate ARDS) group and the 200 mmHg < $PaO_2/FiO_2 \leq 300$ mmHg (mild ARDS) group showed significant differences in all other indexes (P < 0.05), including PCT: 0.6 vs 0.33, P = 0.21; Lac: 1.8 vs 1.6, P = 0.02; CURB-65 score: 2 vs 2, P < 0.001; PSI: 136 vs 127, P < 0.001; CAP-PIRO score: 5 vs 4, P < 0.001; CAP-PIRO+PCT: 0.37 vs 0.23, P < 0.001; CAP-PIRO+Lac: 0.34 vs 0.14, P < 0.001.

Discussion

Our results demonstrate that the CAP-PIRO score effectively reflected both the severity and prognosis of CAP. Moreover, the CAP-PIRO scoring system's ability to predict ARDS was comparable to that of the conventional CURB-65 and PSI scoring systems. Notably, the combination of CAP-PIRO and Lac improved performance in predicting ARDS. The CAP-PIRO score also outperformed CURB-65 and PSI in predicting 28-day mortality. Additionally, significant differences were observed in CAP-PIRO scores across different PaO_2/FiO_2 groups, with higher PaO_2/FiO_2 values associated with lower CAP-PIRO scores. This further supports the CAP-PIRO scoring system's superior ability to assess the severity of CAP and pulmonary damage.

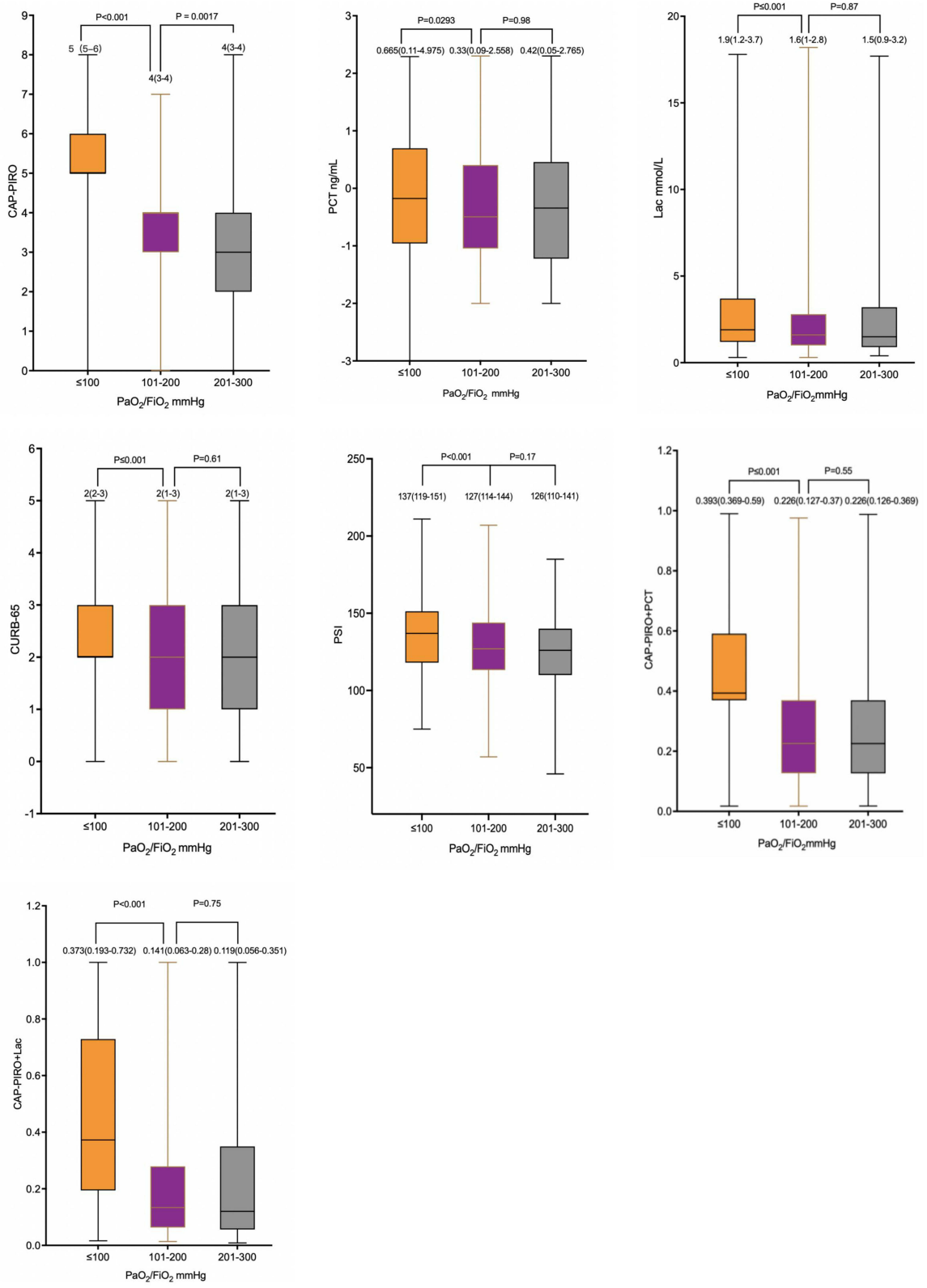

Figure 3 Variables in the comparison between different PaO2 / FiO2 group.

CAP remains a significant cause of disease and mortality globally, particularly among the elderly and immunocompromised individuals. Despite advancements in antibiotic treatment and vaccination, CAP continues to pose a major public health challenge due to its high morbidity and mortality rates. Accurate prognosis prediction, early severity risk stratification, and appropriate antimicrobial treatment are crucial for improving patient outcomes with CAP.[15,16] These aspects have become key areas of focus for both clinicians and researchers. The conventional CURB-65 and PSI scoring systems have favorable performance in predicting the prognosis of CAP, and these scoring systems are widely used in the stratification of patients.[17,18] As suggested in several studies, CURB-65 and PSI exhibit good performance in predicting the mortality of patients with CAP.[19,20] Nonetheless, recent studies and guidelines have raised concerns about their predictive accuracy, particularly for elderly patients. Inconsistencies in their performance for predicting CAP prognosis in this age group have been noted, indicating that these systems may not be as reliable for older individuals.[21] Chun-Ming Ma found that CURB-65 and PSI had poor predictive performance for the 28-day mortality in CAP patients with diabetes mellitus (DM) compared with those without DM.[22] According to the official clinical practice guidelines of the American Thoracic Society (ATS) and the Infectious Diseases Society of America (IDSA), the PSI and CURB-65 scoring systems are not recommended for assessing the condition of patients with community-acquired pneumonia (CAP) or for determining the need for ICU treatment.[15] The results of the present study indicate that CURB-65, PSI, and CAP-PIRO can all predict the 28-day mortality of CAP patients from the emergency department, and CURB-65 and PSI display a positive correlation with CAP-PIRO (r=0.506, $P<0.01$; r=0.503, $P<0.01$). Yet, the multiple regression analysis results suggest that CURB-65 and PSI were not independent risk factors for predicting the 28-day mortality of patients with CAP; whereas CAP-PIRO was an independent risk factor for predicting the 28-day mortality of patients with CAP. Additionally, it was found that CAP-PIRO had a stronger ability to predict the 28-day mortality compared with CURB-65 and PSI ($Z=3.657$, $P\leq0.001$; $Z=3.086$, $P=0.002$). In terms of the evaluation criteria, the PSI scoring system contains many scoring items and requires more laboratory tests, which results in relatively complicated operation procedures. The CAP-PIRO scoring system, being relatively straightforward and requiring fewer tests, is more accessible to clinicians. As a result, it was concluded that the CAP-PIRO scoring system outperforms the conventional CURB-65 and PSI scoring systems in predicting 28-day mortality in patients with CAP.

Acute lung injury (ALI) induced by ARDS is one of the most serious complications of CAP. Patients with pulmonary infection accompanied by ARDS have a poor prognosis.[23] According to the severity of lung injury, the mortality of patients with ARDS ranges from 34.9% to 46.1%.[24] ARDS is characterized by rapid progression and currently lacks effective biomarkers to enhance diagnostic sensitivity and specificity. At the same time, effective therapies for ARDS are limited. Identifying risk factors that can predict ARDS in patients with bacterial pneumonia is crucial, as it can guide clinicians in selecting timely and appropriate treatment strategies, ultimately improving patient outcomes. In the present study, the incidence of ARDS among CAP patients in the emergency department (including the emergency rescue room, emergency observation room, and emergency intensive care unit) was found to be 28.11%. Significant differences were observed between the ARDS and non-ARDS groups in terms of chronic obstructive pulmonary disease (COPD), heart rate (HR), and respiratory rate (RR). COPD, in particular, may exacerbate clinical symptoms and inflammatory responses in patients with CAP[25]. COPD is associated with further exacerbation of CAP and progression to ARDS.[26] HR can reflect respiratory functions, cardiac functions, and immune responses. Studies have shown that HR can be a useful marker for the early identification of infections and respiratory diseases[27,28] An elevated HR can be used to predict the risk of pneumonia progressing to ARDS to some extent, which aligns with the present findings. In addition, the results corroborate that CURB-65, PSI, CAP-PIRO, Lac, and PCT all had certain predictive effects for CAP complicated with ARDS. The multiple regression analysis results suggest that the CAP-PIRO score and Lac were independent risk factors for ARDS in CAP patients, and the combination of them had a stronger ability to predict ARDS than CAP-PIRO alone ($Z=5.854$, $P<0.001$). Further, the differences of each index were compared between the $PaO_2/FiO_2\leq100$mmHg group and the $100\text{mmHg}<PaO_2/FiO_2\leq200$mmHg group (severe and moderate ARDS), as well as the $100\text{mmHg}<PaO_2/FiO_2\leq200$mmHg group and the $200\text{mmHg}<PaO_2/FiO_2\leq300$mmHg group (moderate and mild ARDS). It was found that there were significant differences in PSI scores between patients with mild and moderate ARDS but no significant difference between those with moderate and severe ARDS. This indicates that the PSI is more effective at identifying mild ARDS. Previous research has shown that PSI is suitable for stratifying and predicting outcomes in mild CAP but

has limited predictive performance for critically ill patients.[6,15] These findings are consistent with the results of the present study. There were significant differences in Lac, CURB-65, and CAP-PIRO between patients with severe ARDS, moderate ARDS, and mild ARDS. The PaO_2/FiO_2 ratio, which measures PaO_2 relative to FiO_2, is commonly used to assess the severity of hypoxia in respiratory failure. This ratio is fundamental in diagnosing ARDS.[14] and serves as a key method for evaluating the severity of the condition. Lower Pao2/Fio2 values are associated with a worse prognosis of patients with ARDS and the severity of alveolar damage.[29] Moreover, the Pao2/Fio2 value is also a significant parameter for evaluating lung functions.[30] Therefore, Lac, CURB-65, and CAP-PIRO can not only be employed to predict the co-occurrence of ARDS in patients with CAP but also be sensitive to the severity of ARDS.

Previous studies have indicated that the CAP-PIRO scoring system is effective for stratifying the severity of patients with SCAP and demonstrates strong performance in predicting 28-day mortality in these patients [6, 7]. It has also been revealed in several studies that the predictive performance of CAP-PIRO for CAP caused by influenza is similar to that of CURB-65, PSI, and APACHE-2, but the predictive ability is limited.[31,32] Several researchers have also found that the predictive performance of CAP-PIRO for inpatients with bacterial pneumonia is inferior to that for CAP patients from the clinic or ambulance.[33] In the present study, the relationship between the CAP-PIRO score and the prognosis of CAP patients from the emergency department was explored. The results validate that the CAP-PIRO score had an independent predictive ability for 28-day mortality and the co-occurrence of ARDS in inpatients with CAP from the emergency department. The results demonstrate for the first time that combining the CAP-PIRO score with Lac significantly enhances the prediction of ARDS co-occurrence. Additionally, it was also shown for the first time that the CAP-PIRO score varies significantly among different PaO_2/FiO_2 groups, effectively predicting the severity of lung damage in patients.

Nevertheless, there were also limitations in the present study. Firstly, the present study was single-center in nature, with a small sample size. Therefore, it is necessary to further conduct multi-center studies based on a larger sample size. Secondly, the findings may have limited generalizability due to the high mortality and incidence of ARDS within the study cohort. Several factors contributed to this limitation: firstly, the cohort primarily consisted of older individuals, who were generally at higher risk for severe outcomes. Secondly, the study focused on CAP patients in the emergency department (including the emergency rescue room, emergency observation room, and emergency intensive care unit), who were likely to have more severe conditions compared to those treated in specialized departments or outpatient settings. Additionally, the inclusion of bedridden patients with recurrent lung infections from nursing homes further contributed to the higher severity of cases observed in the study.

Conclusions

The CAP-PIRO scoring system demonstrates superior performance in predicting the severity and prognosis of community-acquired pneumonia, particularly across different PaO2/FiO2 categories. It outperforms traditional scoring tools like CURB-65 and PSI, showing even higher predictive accuracy when combined with lactate levels. These findings highlight CAP-PIRO's enhanced capability for patient risk stratification, suggesting its potential for wider clinical adoption.

Ethics Approval

All procedures performed in studies involving human participant were in accordance with the ethical standards of the institutional and with the 1964 helsinki declaration and its later amendments or comparable ethical standards. Ethics approval was obtained from the Ethics Committee of Beijing Chaoyang Hospital, affiliated with Capital Medical University (approval number: 2021-KE-124). Informed consent was acquired from patients or their legal guardians before any treatments or tests, ensuring their comprehension and agreement.

Consent for Publication

Written informed consent for publication was obtained from all participants.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically

reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

All authors report no conflicts of interest in this work.

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