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ORIGINAL RESEARCH

Analysis of the predictive value of platelet parameters for the prognosis of elderly patients with severe pneumonia

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Abstract

Background: The aim of this study was to evaluate the ability of platelet parameters to predict outcomes in elderly patients with severe pneumonia. **Methods**: We retrospectively analyzed the clinical data of 197 elderly patients with severe pneumonia. The patients were divided into two groups based on their survival in 28 days: the survival group (148 cases) and the death group (49 cases). **Results**: The Acute Physiology and Chronic Health Evaluation (APACHE II) scores were significantly higher in the death group compared to the survival group ($p < 0.05$). Platelet count (PLT) was significantly lower ($p < 0.05$), while platelet distribution width (PDW), mean platelet volume (MPV), and platelet-large cell ratio (P-LCR) were significantly higher in the death group than the survival group ($p < 0.05$). Receiver operating characteristic (ROC) curve analysis revealed that the platelet parameters PLT, PDW, MPV and P-LCR had area under curve (AUC) values of 0.834, 0.760, 0.847 and 0.842, respectively, for predicting 28-day mortality in elderly patients. The combined AUC for these four platelet parameters was 0.964, which was significantly higher than that of any individual parameter ($p < 0.05$). Kaplan-Meier analysis also demonstrated that PLT, PDW, MPV and P-LCR were all associated with the 28-day prognosis of patients ($p < 0.05$). Multivariable logistic regression analysis identified APACHE II score, PDW, MPV and P-LCR as independent risk factors for poor prognosis in elderly patients with severe pneumonia ($p < 0.05$). **Conclusions**: Our findings suggest that PLT, PDW, MPV and P-LCR could be utilized as prognostic indicators for elderly patients with severe pneumonia as these parameters were notably different between the death and survival groups of these patients. Integrating changes in various platelet parameters hold the potential for improving the prognostic evaluation of elderly individuals with severe pneumonia.

Keywords

Platelet parameters; Severe pneumonia; Prognosis; Predictive value

1. Introduction

Elderly individuals are at high-risk for pneumonia, with factors such as advanced age, frailty and complex comorbidities exacerbating the incidence and complicating treatment [1]. Delays in receiving prompt and appropriate treatment for pneumonia can lead to severe lung damage, multi-organ dysfunction or failure, and even pose a life-threatening risk to elderly patients [2]. Therefore, finding indicators that can accurately predict the prognosis of elderly patients with severe pneumonia is essential for developing personalized treatment plans and improving the quality of patient survival.

Platelets (PLT), as an important component of blood, are not only involved in hemostasis and thrombosis but also modulate inflammatory response and immune regulation through the release of a variety of bioactive substances [3]. Increased evidence suggests that platelet parameters are strongly associated with the prognosis of several diseases [4, 5]. It has been reported that elevated initial platelet distribution width (PDW) and mean platelet volume (MPV) during hospitalization in patients with community-acquired pneumonia are associated with more severe clinical features and higher mortality. Monitoring trends in these metrics can help inform patient prognosis [6]. A single-center retrospective study also reported that elevated hematological markers MPV, PDW and MPV/PLT in patients with severe COVID-19 were associated with the risk of death [7]. However, whether platelet parameters can be used as predictors of prognosis in elderly patients with severe pneumonia remains unclear. In order to determine the predictive value of platelet count (PLT), platelet distribution width (PDW), mean platelet volume (MPV), and platelet-large cell ratio (P-LCR) for mortality within 28 days of hospital

admission in elderly patients with severe pneumonia, we retrospectively analyzed the clinical data of 197 such patients. The purpose of this study is to establish a novel foundation for improving the prognosis in elderly individuals with severe pneumonia.

2. Materials and methods

2.1 Patients

The clinical data of 197 elderly patients with severe pneumonia admitted to our hospital during the period were retrospectively analyzed. Inclusion criteria: (1) meeting the diagnostic criteria of severe pneumonia [8]; (2) age $\geq$60 years. Exclusion Criteria: (1) patients with other serious underlying diseases and those who have recently received treatments affecting platelet function; (2) those with malignant tumors or liver and kidney dysfunction; (3) those with other respiratory diseases such as respiratory failure; (4) those with deaths that were not caused by severe pneumonia; and (5) those with psychiatric disorders.

2.2 Data collection

Clinical data of the patients were collected, including basic information such as age, gender, body mass index, smoking history, hypertension, diabetes mellitus, acute physiology and chronic health evaluation II (APACHE II) score, albumin (ALB), serum creatinine (Scr), glomerular filtration rate (GFR), hemoglobin A1c (HbA1c). Platelet-related parameters: 5 mL of venous blood was collected from all patients within 24 h of admission according to aseptic standards. The specimens were sent to the laboratory department within 1 h. The blood was analyzed by a fully automated blood cell analyzer. PLT, PDW, MPV and P-LCR parameters were detected using a fully automated hemocyte analyzer (HST-N201 model, Hyson Micron, Kobe, Japan).

2.3 Follow-up

Patients with severe pneumonia were divided into a survival group (148 cases) and a death group (49 cases) according to their survival within 28 days of admission.

2.4 Statistical analysis

The data for this investigation were processed using SPSS 25.0 (IBM Corp., SPSS Statistics, Armonk, NY, USA). The χ^2 test was used, and count results were reported as n (%). When analyzing continuous variables with a normal distribution, the Students' *t*-test was used to report the data as mean $\pm$ standard deviation. The predictive value of PLT, PDW, MPV and P-LCR for death within 28 days in elderly patients with severe pneumonia was analyzed by plotting the ROC curve. Multivariate logistic regression analysis was used to explore the independent influencing factors of death within 28 days in elderly patients with severe pneumonia. Subgrouping of the indicators was performed according to the ROC curve to obtain the best cutoff value. Survival curves were generated using the Kaplan-Meier method, and the relationship between each index and the prognosis of elderly patients with severe pneumonia within 28 days was analyzed using the Log-rank method. $p < 0.05$ was considered as a statistically significant difference.

3. Results

3.1 Comparison of clinical data

There was no significant difference between patients in the survival and death groups in terms of gender composition, age, body mass index, smoking history, hypertension, percentage of diabetes mellitus, ALB, Scr, GFR and HbA1c ($p > 0.05$, Table 1). Patients in the death group had higher APACHE II scores than those in the survival group ($p < 0.05$, Table 1).

3.2 Comparison of platelet parameters

Compared with the survival group, PLT was significantly lower in the death group ($p < 0.05$), while PDW, MPV and P-LCR were significantly higher ($p < 0.05$, Table 2).

3.3 Analysis of the clinical value of each platelet parameter and APACHE II score in predicting the prognosis of elderly patients with severe pneumonia

The ROC results showed that the area under the curve (AUC) values for PLT, PDW, MPV, P-LCR and APACHE II score in predicting death within 28 days in elderly patients with severe pneumonia were 0.834, 0.760, 0.847, 0.842, 0.859, respectively; corresponding sensitivity were 75.51%, 71.43%, 79.59%, 81.63%, 79.59%, respectively, and a specificity of 84.46%, 73.65%, 85.14%, 80.41%, 77.30%, respectively. The above four platelet parameters were then included in the logistic regression model. The combined value was calculated using the regression coefficient calculated as: Combine = $-27.053 + (-0.021) \times$ PLT $+ 0.52 \times$ PDW $+ 1.025 \times$ MPV $+ 0.307 \times$ P-LCR. The ROC analysis for the combined model yielded an AUC of 0.964, which was higher than PLT ($Z = 3.790$, $p = 0.0002$), PDW ($Z = 4.857$, $p < 0.0001$), MPV ($Z = 3.963$, $p = 0.0001$), P-LCR ($Z = 3.624$, $p = 0.0003$), and APACHE II score ($Z = 3.029$, $p = 0.0025$) alone (Table 3, Fig. 1), respectively.

3.4 Multivariate regression analysis of death within 28 days in elderly patients with severe pneumonia

Survival of patients within 28-day of admission was used as the dependent variable, and APACHE II score, PLT, PDW, MPV and P-LCR were included as independent variables in a multifactorial logistic regression model. The results showed that APACHE II score, PDW, MPV and P-LCR were independent risk factors for poor prognosis in elderly patients with severe pneumonia ($p < 0.05$, Table 4).

3.5 Kaplan-Meier analysis of indicators and prognosis of elderly patients with severe pneumonia within 28 days

PLT, PDW, MPV, P-LCR and APACHE II score were subgrouped based on their respective cut-off values. Kaplan-Meier showed that patients in the PLT $\leq 160 \times 10^9$/L group

TABLE 1. Comparison of clinical data.

Parameters	Death group (n = 49)	Survival group (n = 148)	t/χ^2	*p*-value
Gender (n (%))				
Male	25 (51.02)	79 (53.38)	0.082	0.774
Female	24 (48.98)	69 (46.62)		
Age (yr)	68.80 ± 5.59	68.11 ± 5.14	0.786	0.433
Body mass index (kg/m^2)	22.90 ± 1.30	23.10 ± 1.24	0.977	0.330
Smoking history (n (%))				
Yes	24 (48.98)	57 (38.51)	1.666	0.197
No	25 (51.02)	91 (61.49)		
APACHE II score	18.98 ± 1.88	15.86 ± 2.15	9.077	<0.001
Hypertension (n (%))				
Yes	20 (40.82)	43 (29.05)	2.341	0.126
No	29 (59.18)	105 (70.95)		
Diabetes (n (%))				
Yes	18 (36.73)	39 (26.35)	1.930	0.165
No	31 (63.27)	109 (73.65)		
ALB (g/L)	40.69 ± 4.61	41.89 ± 5.03	1.474	0.142
Scr (μmol/L)	102.63 ± 14.35	106.21 ± 15.50	1.426	0.156
GFR (mL/min)	83.98 ± 8.62	85.66 ± 9.22	1.125	0.262
HbA1c (%)	4.99 ± 0.89	5.23 ± 0.90	1.652	0.100

APACHE: Acute Physiology and Chronic Health Evaluation; ALB: albumin; Scr: serum creatinine; GFR: glomerular filtration rate; HbA1c: hemoglobin A1c.

TABLE 2. Comparison of platelet parameters.

Group	n	PLT (×10^9/L)	PDW (%)	MPV (fL)	P-LCR (%)
Dead Group	49	156.04 ± 32.14	17.21 ± 2.13	11.30 ± 1.61	38.82 ± 4.77
Survival group	148	189.72 ± 30.95	15.39 ± 1.65	8.98 ± 1.34	32.02 ± 4.88
t		6.540	6.217	10.013	8.499
p		<0.001	<0.001	<0.001	<0.001

PLT: Platelet count; PDW: platelet distribution width; MPV: mean platelet volume; P-LCR: platelet-large cell ratio.

TABLE 3. Predictive value of each platelet parameter in the prognosis of elderly patients with severe pneumonia.

Parameters	AUC	95% CI	Youden index	Cut-off value	*p*	Sensitivity (%)	Specificity (%)
PLT	0.834	0.775–0.883	0.600	≤160.0	<0.001	75.51	84.46
PDW	0.760	0.694–0.818	0.451	>16.3	<0.001	71.43	73.65
MPV	0.847	0.789–0.895	0.647	>10.2	<0.001	79.59	85.14
P-LCR	0.842	0.784–0.890	0.620	>35.5	<0.001	81.63	80.41
APACHE II score	0.859	0.803–0.905	0.566	>17.0	<0.001	79.59	77.30
Combine	0.964	0.927–0.985	0.810	—	<0.001	91.84	89.19

PLT: Platelet count; PDW: platelet distribution width; MPV: mean platelet volume; P-LCR: platelet-large cell ratio; APACHE: Acute Physiology and Chronic Health Evaluation; AUC: area under curve; CI: confidence interval.

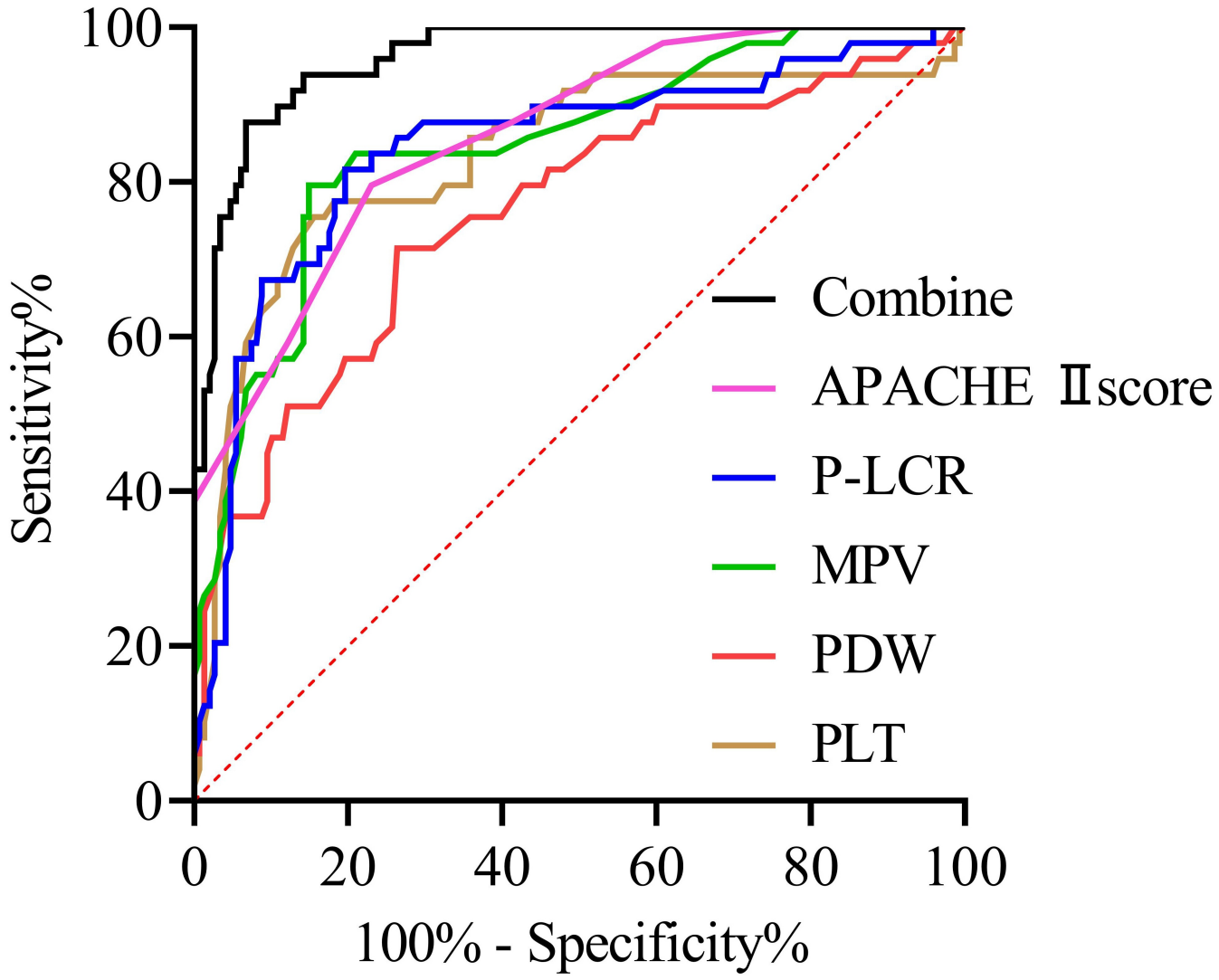

FIGURE 1. ROC curve of parameters to predict prognosis in elderly patients with severe pneumonia. PLT: Platelet count; PDW: platelet distribution width; MPV: mean platelet volume; P-LCR: platelet-large cell ratio; APACHE: Acute Physiology and Chronic Health Evaluation.

TABLE 4. Multivariate regression analysis of death within 28 days in elderly patients with severe pneumonia.

Parameters	β	S.E.	Wald	OR	95% CI	p
APACHE II score	1.345	0.327	16.915	3.839	2.022–7.288	<0.001
PDW	0.449	0.223	4.046	1.567	1.012–2.428	0.044
MPV	1.603	0.405	15.646	4.969	2.245–10.997	<0.001
P-LCR	0.509	0.126	16.301	1.663	1.299–2.130	<0.001
Constant	66.882	13.731	23.725			

PDW: platelet distribution width; MPV: mean platelet volume; P-LCR: platelet-large cell ratio; APACHE: Acute Physiology and Chronic Health Evaluation; β: regression coefficient; S.E.: standard error; OR: Odds Ratio; CI: confidence interval.

had a significantly lower survival rate within 28-day than those in the PLT >160 $\times$ 10^9/L group (37/60 *vs.* 12/137, log-rank $\chi^2 = 69.52$, $p < 0.001$, Fig. 2A). Survival within 28-days were significantly lower in patients in the PDW >16.3% group than in those in the PDW ≤16.3% group (35/74 *vs.* 14/123, log-rank $\chi^2 = 35.26$, $p < 0.001$, Fig. 2B). Similarly, patients with MPV >10.2 fL had a significantly lower survival rate within 28 days compared to those with MPV ≤10.2 fL (39/61 *vs.* 10/134, log-rank $\chi^2 = 80.09$, $p < 0.001$, Fig. 2C). Patients with P-LCR >35.5% also had a remarkably lower survival rate within 28 days compared to those with P-LCR ≤35.5% (40/69 *vs.* 9/128, log-rank $\chi^2 = 70.90$, $p < 0.001$, Fig. 2D). Additionally, patients with an APACHE II score >17 exhibited a significantly lower 28-day survival rate compared to those with an APACHE II score ≤17 (39/73 *vs.* 10/124, log-rank $\chi^2 = 53.93$, $p < 0.001$, Fig. 2E).

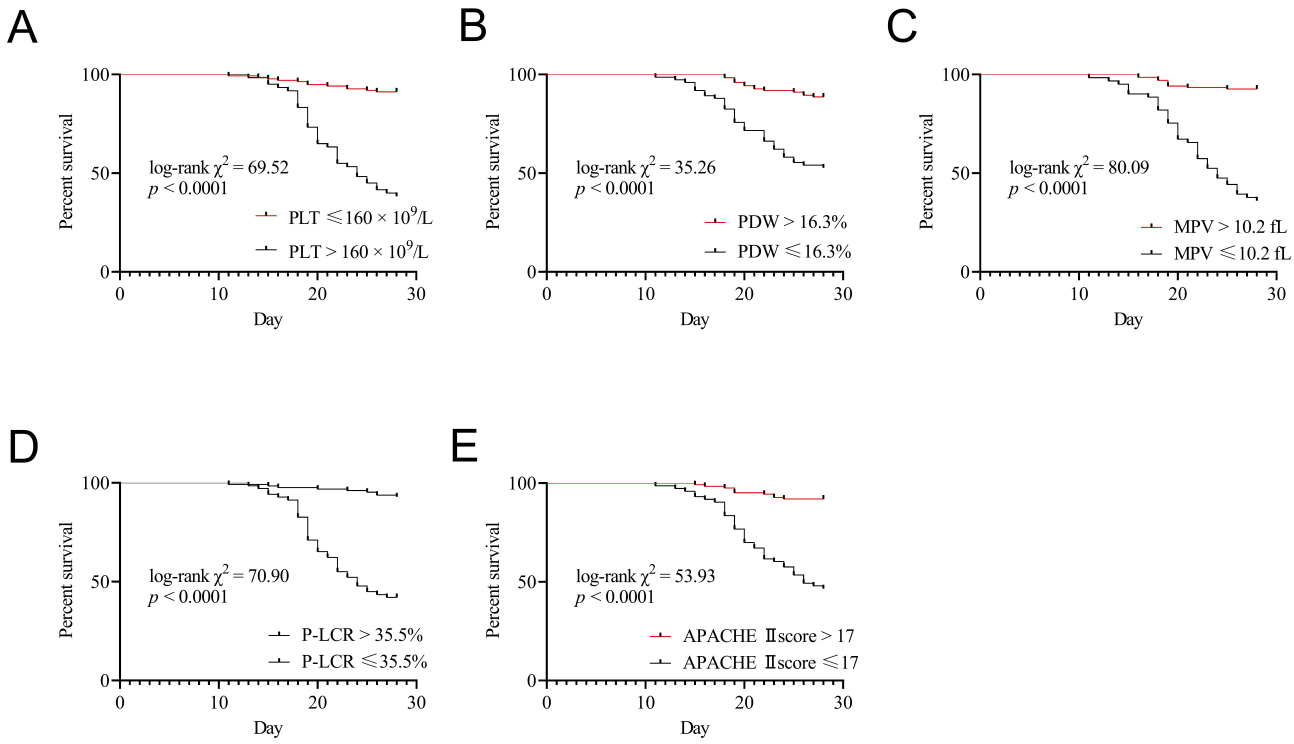

FIGURE 2. Kaplan-Meier analysis of each index and prognosis within 28 days in elderly patients with severe pneumonia. (A) PLT; (B) PDW; (C) MPV; (D) P-LCR; (E) APACHE II score. PLT: Platelet count; PDW: platelet distribution width; MPV: mean platelet volume; P-LCR: platelet-large cell ratio; APACHE II: Acute Physiology and Chronic Health Evaluation.

4. Discussion

Elderly people with severe pneumonia often experience physiologic decline and weakened immune systems due to the effects of aging. As a result, older individuals with severe pneumonia frequently have compromised immune systems, leading to more rapid disease progression. They are also at increased risk of complications, including multiple organ failure, which can result in a poor prognosis [9]. Therefore, early identification and assessment of the prognostic risk of patients is essential for active and effective interventions.

Platelets, as a crucial component of blood, play a key role in disease assessment and prognosis prediction across a range of conditions, particularly severe infections, through their number, volume, and functional status [10, 11]. In addition to their involvement in hemostasis, platelets are also key players in the inflammatory response [12]. In elderly patients with severe pneumonia, pathogenic infections and the subsequent release of inflammatory factors, such as interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α), activate platelets to produce large amounts of cytokines. These cytokines further regulate the movement and migration of leukocytes, promote the release of inflammatory mediators, and exacerbate tissue injury [13]. Meanwhile, activated platelets can directly recognize and bind pathogens, releasing mediators that disrupt bacterial cell membranes, thereby participating in the anti-infection process [14]. In elderly patients with severe pneumonia, the systemic inflammatory response triggered by infection is often accompanied by platelet activation and depletion, leading to a decrease in PLT levels [15]. Low PLT may reflect excessive inflammatory response, abnormal coagulation function and immunosuppressive state of the body, which is an important marker of poor prognosis [16]. Abnormal increases in PDW, MPV and P-LCR; on the other hand, may be related to platelet activation, abnormal function and enhanced bone marrow hematopoietic response, further exacerbating the disease process. PDW reflects the heterogeneity of platelet volume size in the blood. Increased levels of PDW usually imply an uneven distribution of platelet volume and may signal platelet activation, functional abnormalities, or release of neoplastic platelets [17, 18]. PDW is an important assessment of platelet activation, and this index can also effectively suggest the overall function of platelets. In patients with severe pneumonia, an abnormally elevated PDW often indicates that the disease is deteriorating and is associated with a significant increase in patient mortality [19]. Severe pneumonia is often accompanied by severe infections that release large amounts of inflammatory mediators to activate the coagulation system, causing platelet adhesion, aggregation, and activation. A decrease in platelet count can further cause compensatory proliferation of bone marrow, while an abnormal increase in platelet count can lead to elevated MPV [20]. This compensatory hyperplasia may be accompanied by a decrease in platelet quality, such as abnormal function or reduced activity, which can be detrimental to the patient's prognosis. Dixit *et al.* [21] found that blood parameters such as PDW and MPV were significantly higher in non-survivors than in survivors of postoperative sepsis patients, and the increase

in these parameters was significantly associated with patient mortality. P-LCR is the percentage of large platelets in the blood, which usually have greater activity and function [22]. In elderly patients with severe pneumonia, elevated P-LCR may imply that the body is actively responding to the infection by increasing the release of large platelets to enhance coagulation and immune defense. The prognosis of the patient may be impacted by persistently high P-LCR, which might potentially be a sign of issues with bone marrow hematopoiesis, which results in aberrant platelet production and release [23]. In this study, it was found that the PLT level of elderly severe pneumonia in the death group was significantly lower than that of the survival group, while the levels of PDW, MPV and P-LCR were significantly higher than those of the survival group, suggesting that each platelet parameter may play an important role in the disease progression of pneumonia. The ROC results showed that the AUC of PLT, PDW, MPV and P-LCR for predicting death within 28 days in elderly patients with severe pneumonia was greater than 0.7, and all of them had a certain predictive value for patient prognosis. Therefore, monitoring platelet parameters may be a valuable biomarker for predicting the clinical prognosis of elderly patients with severe pneumonia. The sensitivity and specificity of various serologic indicators vary, and it is typically challenging to fulfil clinical objectives with a single indicator. To overcome the limitations of relying on one marker, multiple indicators are often used together [24]. In this study, a predictive model for the combination of each platelet parameter was obtained by multivariate logistic regression analysis. According to this model, clinicians can visualize the prognostic risk of a patient by substituting each platelet parameter of the patient into the formula and calculating a specific value. In addition, the model can reflect the morphology and function of platelets from different perspectives. By jointly analyzing each platelet parameter, healthcare professionals can more comprehensively assess the patient's condition and prognosis, and to some extent improve the accuracy of predicting the prognosis of elderly patients with severe pneumonia. In the clinical setting, elderly patients with severe pneumonia who also had low PDW + low MPV + low P-LCR + high PLT were less likely to die within 28 days of admission. However, special attention or aggressive treatment should be given to elderly patients with severe pneumonia who develop some concomitant high PDW + high MPV + high P-LCR + low PLT. This finding could provide valuable insights for improving the prognosis of elderly patients with severe pneumonia.

However, this study s has several limitations. The sample size of patients included in this study was relatively small and the study was conducted at a single-center, and may lack reliability. Future research should involve a larger, multicenter cohort or further validate the predictive value of platelet parameters for the prognosis of elderly patients with severe pneumonia. The APACHE II score is a tool commonly used to assess the severity of a patient's disease. A higher APACHE II score usually means that the patient's condition is more severe and the probability of poor prognosis is higher [25]. According to Pan *et al.* [26], a high APACHE II score is an independent risk factor for in-hospital mortality in intensive care units (ICUs) patients with severe pneumonia and a column-line graph model based on APACHE II score and other influencing factors has high accuracy and clinical applicability in predicting the risk of in-hospital mortality in patients with pneumonia. The results of this study also found that the APACHE II score is an influential factor for poor prognosis in elderly patients with severe pneumonia. However, the predictive model obtained by the combination of multiple platelet parameters performed significantly better than the APACHE II score in predicting the prognosis of elderly patients with severe pneumonia. There is a need to expand the sample size in future studies and to construct a predictive model to predict the prognosis of elderly patients with severe pneumonia based on the APACHE II score and platelet parameters.

5. Conclusions

PLT, PDW, MPV and P-LCR, as comprehensive indicators reflecting the number, size, distribution and function of platelets, can be used as valuable predictors of prognosis in elderly patients with severe pneumonia. Combining changes in several platelet parameters is promising in the prognostic assessment of elderly patients with severe pneumonia.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

LJ and LS—designed the study and carried them out. LJ, LS, JQC, JC, JHY, XX and WZ—supervised the data collection; analyzed the data; interpreted the data. LJ, LS, WG and YS—prepared the manuscript for publication and reviewed the draft of the manuscript. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Sir Run Run Hospital Nanjing Medical University (Approval no. 2022-SR-004). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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