







# C-reactive protein, procalcitonin, and neutrophil-to-lymphocyte ratio as mortality predictors in elderly women with pneumonia

Irawaty Djaharuddin<sup>1,2\*</sup> , Dewi Rizki Nurmala<sup>2</sup> , Imam Nurjaya<sup>1</sup> , Rasiha Rasiha<sup>3</sup> , Demak Lumban Tobing<sup>4</sup>

<sup>1</sup>Department of Pulmonology and Respiratory, Faculty of Medicine, Hasanuddin University, Makassar 90245, Indonesia

<sup>2</sup>Dr. Wahidin Sudirohusodo Hospital, Makassar 90245, Indonesia

<sup>3</sup>Faculty of Medicine, Hasanuddin University, Makassar 90245, Indonesia

<sup>4</sup>Department of Clinical Pathology, Dharmas National Cancer Hospital, Jakarta 11420, Indonesia

**\*Correspondence:** Irawaty Djaharuddin, Department of Pulmonology and Respiratory, Faculty of Medicine, Hasanuddin University, Makassar 90245, Indonesia. [irawatydjaharuddin@unhas.ac.id](mailto:irawatydjaharuddin@unhas.ac.id)

**Academic Editor:** Narinder K. Mehra, Indian Council of Medical Research, India

**Received:** June 5, 2025 **Accepted:** March 31, 2026 **Published:** April 23, 2026

**Cite this article:** Djaharuddin I, Nurmala DR, Nurjaya I, Rasiha R, Tobing DL. C-reactive protein, procalcitonin, and neutrophil-to-lymphocyte ratio as mortality predictors in elderly women with pneumonia. *Explor Immunol.* 2026;6:1003250. <https://doi.org/10.37349/ei.2026.1003250>

## Abstract

**Aim:** Pneumonia is the leading cause of morbidity and mortality among elderly individuals. This has led to the search for reliable tools such as inflammatory biomarkers, including C-reactive protein (CRP), procalcitonin (PCT), and neutrophil-to-lymphocyte ratio (NLR), to predict disease severity and prognosis. However, the prognostic value of inflammatory biomarkers in elderly women is not fully understood, as the population is often underrepresented in clinical studies.

**Methods:** This retrospective study was conducted at Wahidin Sudirohusodo Hospital, Indonesia. The samples used were elderly women aged  $\geq 60$  years who were hospitalized with community-acquired pneumonia (CAP) between January and December 2023. CRP, PCT, and NLR levels collected within 24 hours of admission were evaluated and correlated with pneumonia severity index (PSI) scores and in-hospital mortality (IHM). Subsequently, receiver operating characteristic (ROC) curve analysis, logistic regression, and Kaplan-Meier survival analysis were performed.

**Results:** A total of 262 patients (median age 66 years) were included, of whom 83.2% had mild CAP, and 87.0% survived. Among inflammatory biomarkers, CRP showed the highest, with limited discriminatory ability for mortality [area under the curve (AUC) 0.543], followed by NLR (AUC 0.495), and PCT (AUC 0.466). All markers had high sensitivity (91.2%) but low specificity, and  $\text{CRP} \geq 14.5$  mg/L was significantly associated with reduced survival ( $p = 0.018$ ).

**Conclusions:** CRP shows a modest prognostic value in predicting mortality among elderly women with CAP, while NLR and PCT have limited utility. These results show the need for gender- and age-specific studies to improve risk stratification and outcomes in the vulnerable population.



## Keywords

CRP, PCT, NLR, elderly women, pneumonia

---

## Introduction

Pneumonia is the leading cause of morbidity and mortality among elderly individuals [1]. This has led to the search for reliable tools such as inflammatory biomarkers, including C-reactive protein (CRP), procalcitonin (PCT), and the neutrophil-to-lymphocyte ratio (NLR), to predict disease severity and prognosis [2]. However, existing literature has mainly focused on general populations, leaving a knowledge gap on how the biomarkers function specifically in elderly women, a group that is often underrepresented in clinical studies [3].

Although men are generally reported to have a 13% higher in-hospital mortality (IHM) from pneumonia, some studies show conflicting results [4, 5]. For example, a large Spanish study found a 5% higher risk of death in women, indicating the complexities of gender differences in pneumonia outcomes [4]. Potential factors contributing to variation in results include gender-related biases in healthcare delivery, with women often presenting late to hospitals and receiving delayed treatment. These delays can worsen the condition, leading to poorer outcomes, particularly in pneumonia. There is also an initial presentation with milder symptoms that contributes to underreporting of cases and delay in seeking care [5–7].

Based on the description above, this study aims to evaluate the prognostic value of CRP, PCT, and NLR in predicting mortality in elderly women diagnosed with community-acquired pneumonia (CAP). By focusing exclusively on this population, the results are expected to provide targeted insights into the role of inflammatory biomarkers in predicting adverse outcomes in elderly women with CAP. This study also hypothesizes that inflammatory biomarkers can provide valuable information for early risk stratification, potentially improving clinical decision-making for the vulnerable group.

## Materials and methods

### Study design and participants

This retrospective study was conducted using data collected from January 2023 to December 2023 at Wahidin Sudirohusodo Hospital, a tertiary hospital in eastern Indonesia. The inclusion criteria were female patients diagnosed with pneumonia and aged  $\geq 60$  years. Patients were excluded if they were male, had hospital-acquired or ventilator-associated pneumonia, or had incomplete laboratory data (CRP, PCT, and NLR), as shown in Figure 1.

CAP was diagnosed based on typical lower respiratory tract symptoms and the presence of a new infiltrate on chest X-ray, in the absence of an alternative explanation. Treatment and hospital discharge decisions were made by medical staff. Subsequently, all patients were followed up until IHM or discharge as the outcome of interest.

### Laboratory data

All laboratory data were recorded in medical records, followed by blood sample collection in the first 24 hours of admittance. CRP, PCT, white blood cell (WBC) counts, and differential counts (neutrophils and lymphocytes) were measured from these samples, and NLR was calculated as the ratio of neutrophils to lymphocytes.

Counts of WBC, neutrophils, and lymphocytes were made using a BC-6800 Plus hematology analyzer (Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). Serum levels of CRP and PCT were measured using immunoassay methods on the Architect Plus ci4100 analyzer (Abbott Laboratories, USA).

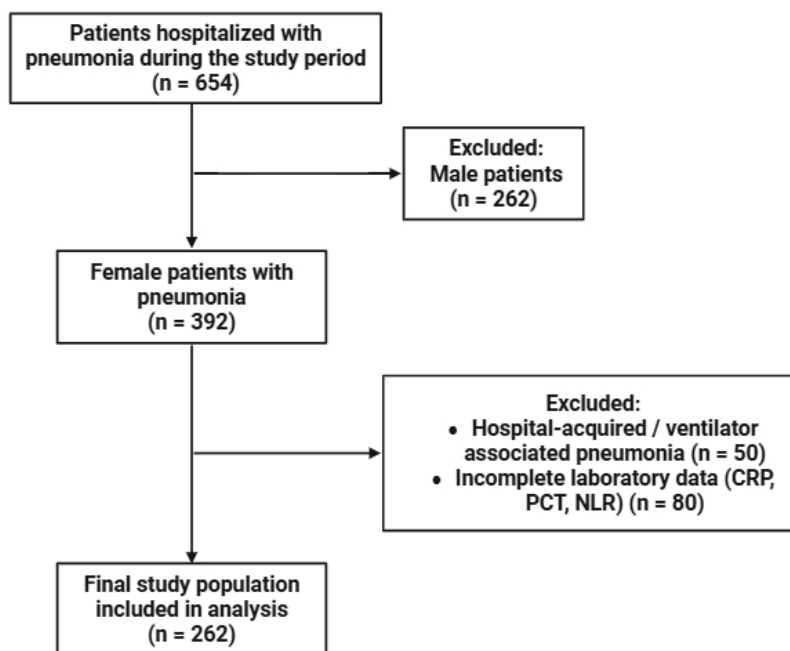


Figure 1. Flowchart of patient selection.

## Statistical analysis

All continuous variables were expressed as the median and interquartile range because of their abnormal distribution. The association between inflammatory markers and pneumonia severity index (PSI) was evaluated by Spearman correlation. Furthermore, composite biomarkers were generated using bivariate logistic regression models that included CRP, PCT, and NLR. Diagnostic accuracy for each biomarker, alone and in combination, was evaluated using receiver operating characteristic (ROC) curve analysis and area under the curve (AUC) values. Multicollinearity among CRP, PCT, and NLR was assessed using the variance inflation factor (VIF) obtained from linear regression analysis.

For each biomarker, sensitivity and specificity values were obtained from ROC coordinates, and the optimal cut-off point was determined using the Youden index. The cut-off values were applied to survival analysis using Kaplan-Meier, and the data obtained were analyzed using SPSS 26.0 for Windows. The correlation graph was extracted using GraphPad Prism 10, and the level of significance for all statistical tests was defined as a two-sided  $p < 0.05$ .

## Results

### Baseline characteristics

A total of 262 pneumonia patients were included in this study, with a median age of 66 years (60–91). The results showed that most cases were mild (83.2%), with a median PSI of 73.00 (50–320). The majority of patients (93.5%, general wards) received in-hospital treatment, and 87.0% survived. Furthermore, the median in-hospital days was 10.00 days (1–44), with values of 5.06, 69.00 mg/L, and 1.30 ng/mL for NLR, CRP, and PCT, respectively (Table 1).

Table 1. Baseline characteristics.

Characteristics	N = 262
Age [median (min–max)]	66 (60–91)
Pneumonia severity	
Mild	218 (83.2%)
Severe	44 (16.8%)
Pneumonia severity index (PSI)	73.00 (50–320)

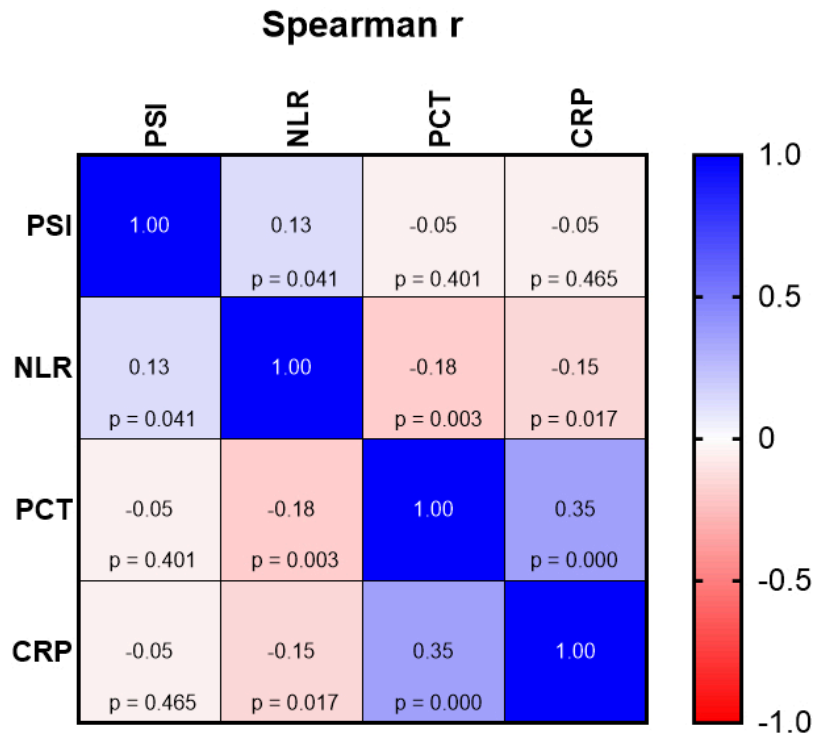
**Table 1. Baseline characteristics. (continued)**

Characteristics	N = 262
<b>Types of care</b>	
Ward	245 (93.5%)
HCU	11 (4.2%)
ICU	6 (2.3%)
<b>Outcome</b>	
Survive	228 (87.0%)
Non-survivor	34 (13.0%)
<b>In-hospital days</b>	10.00 (1–44)
<b>NLR</b>	5.06 (0.07–162.00)
<b>CRP (mg/L)</b>	69.00 (0.05–220.00)
<b>PCT (ng/mL)</b>	1.30 (0.01–50.00)

HCU: high care unit; ICU: intensive care unit; NLR: neutrophil-to-lymphocyte ratio; CRP: C-reactive protein; PCT: procalcitonin.

### Correlation between inflammatory biomarkers and pneumonia severity (PSI score)

A Spearman rank-order correlation was performed to evaluate the relationships among PSI, NLR, PCT, and CRP (Figure 2).

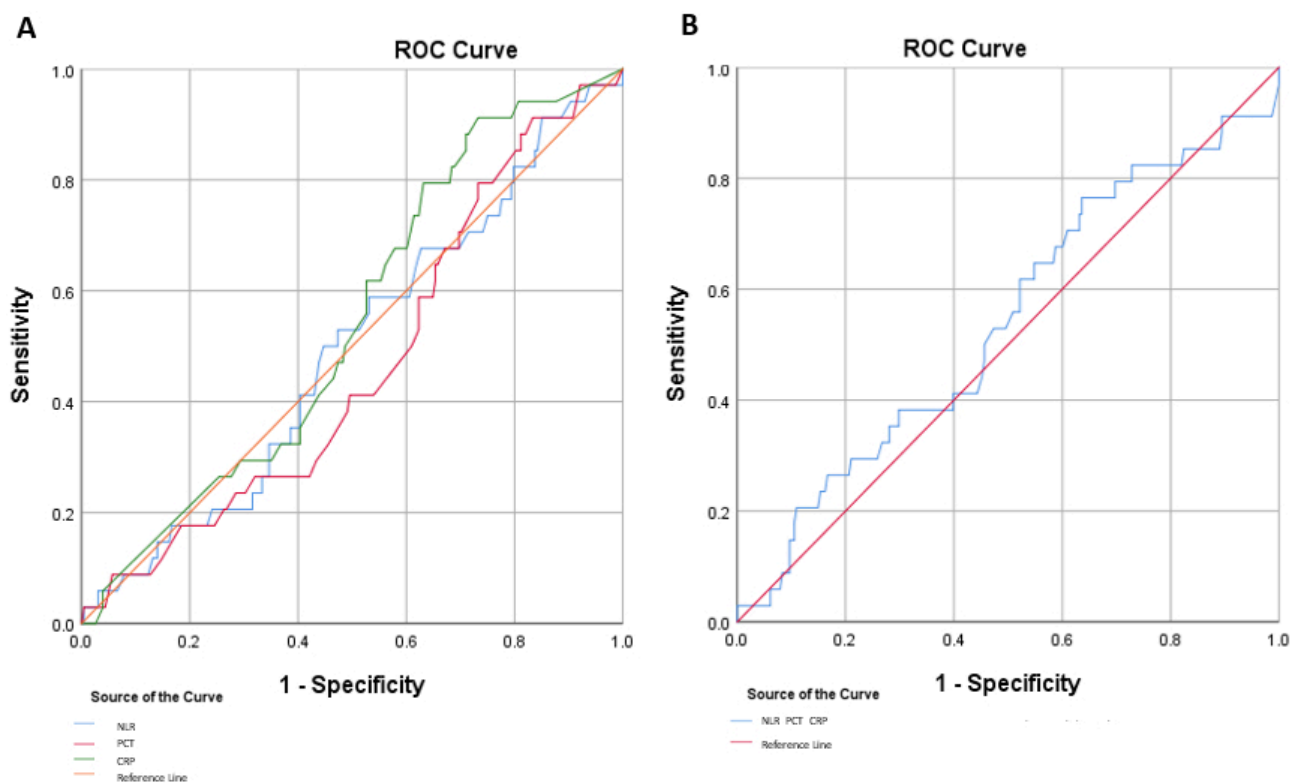


**Figure 2. Spearman correlation matrix of PSI, NLR, PCT, and CRP levels.** Spearman correlation heatmap shows the relationships between PSI, NLR, PCT, and CRP levels. Correlation coefficients (Spearman’s  $r$ ) are shown in each cell, with corresponding  $p$ -values presented below. The color scale represents the magnitude and direction of the correlation, ranging from  $-1$  (red, strong negative correlation) to  $+1$  (blue, strong positive correlation). Statistically significant correlations ( $p < 0.05$ ) are observed between NLR and PSI, PCT and NLR, PCT and CRP, and CRP and NLR. CRP: C-reactive protein; NLR: neutrophil-to-lymphocyte ratio; PCT: procalcitonin; PSI: pneumonia severity index.

The analysis showed a weak but statistically significant positive correlation between PSI and NLR ( $r = 0.13$ ,  $p = 0.041$ ). NLR showed a statistically significant negative correlation with both PCT ( $r = -0.18$ ,  $p = 0.003$ ) and CRP ( $r = -0.15$ ,  $p = 0.017$ ). Furthermore, a moderate and statistically significant positive correlation was observed between PCT and CRP ( $r = 0.35$ ,  $p < 0.001$ ). In comparison, the correlations between PSI and PCT ( $r = -0.05$ ,  $p = 0.401$ ) as well as PSI and CRP ( $r = -0.05$ ,  $p = 0.465$ ) were weak and not statistically significant.

### ROC curve analysis and accuracy of inflammatory markers in predicting mortality

To evaluate the predictive performance of inflammatory biomarkers for mortality in patients with CAP, ROC curve analysis was conducted for NLR, PCT, and CRP. Among these biomarkers, CRP showed the highest AUC, but with limited discriminatory ability (AUC 0.543; 95% CI 0.449–0.636). NLR showed an AUC of 0.495 (95% CI 0.394–0.596), while PCT had 0.466 (95% CI 0.367–0.564) (Figure 3A). These results indicated that none of the evaluated inflammatory biomarkers provided strong discrimination for mortality prediction in CAP. A logistic regression model combining NLR, PCT, and CRP showed an AUC of 0.538 (95% CI 0.432–0.644). However, the combined model did not show significant improvement in predictive accuracy compared to the individual biomarkers (Figure 3B).



**Figure 3. ROC curves of inflammatory biomarkers for mortality prediction.** ROC curve analyses evaluating the diagnostic performance of NLR, PCT, and CRP. (A) ROC curves for NLR, PCT, and CRP in predicting mortality outcome. (B) Combined ROC analysis of the three biomarkers (NLR, PCT, CRP) to assess their collective predictive value. The reference line (red) represents a test with no discriminative power (AUC = 0.5). Sensitivity is plotted against 1 – specificity to visualize diagnostic accuracy. Biomarkers with curves closer to the upper left corner demonstrate better diagnostic performance. AUC: area under the curve; CRP: C-reactive protein; NLR: neutrophil-to-lymphocyte ratio; PCT: procalcitonin; ROC: receiver operating characteristic.

The diagnostic accuracy of individual biomarkers was further assessed using the optimal cut-off values identified from ROC analysis. The results showed that all biomarkers shared the same sensitivity value of 91.2% with a low specificity value, indicating a strong ability to identify non-survivors. Specifically, NLR, CRP, and PCT had a cut-off value of 1.72, 14.50 mg/L, and 0.115 ng/mL with a specificity of 14.9%, 26.8%, and 16.7%. These results showed that although inflammatory biomarkers were sensitive for detecting mortality, the low specificity limited standalone clinical utility (Table 2). The VIF values ranged from 1.004 to 1.052 for CRP, PCT, and NLR, indicating no evidence of significant multicollinearity among the biomarkers.

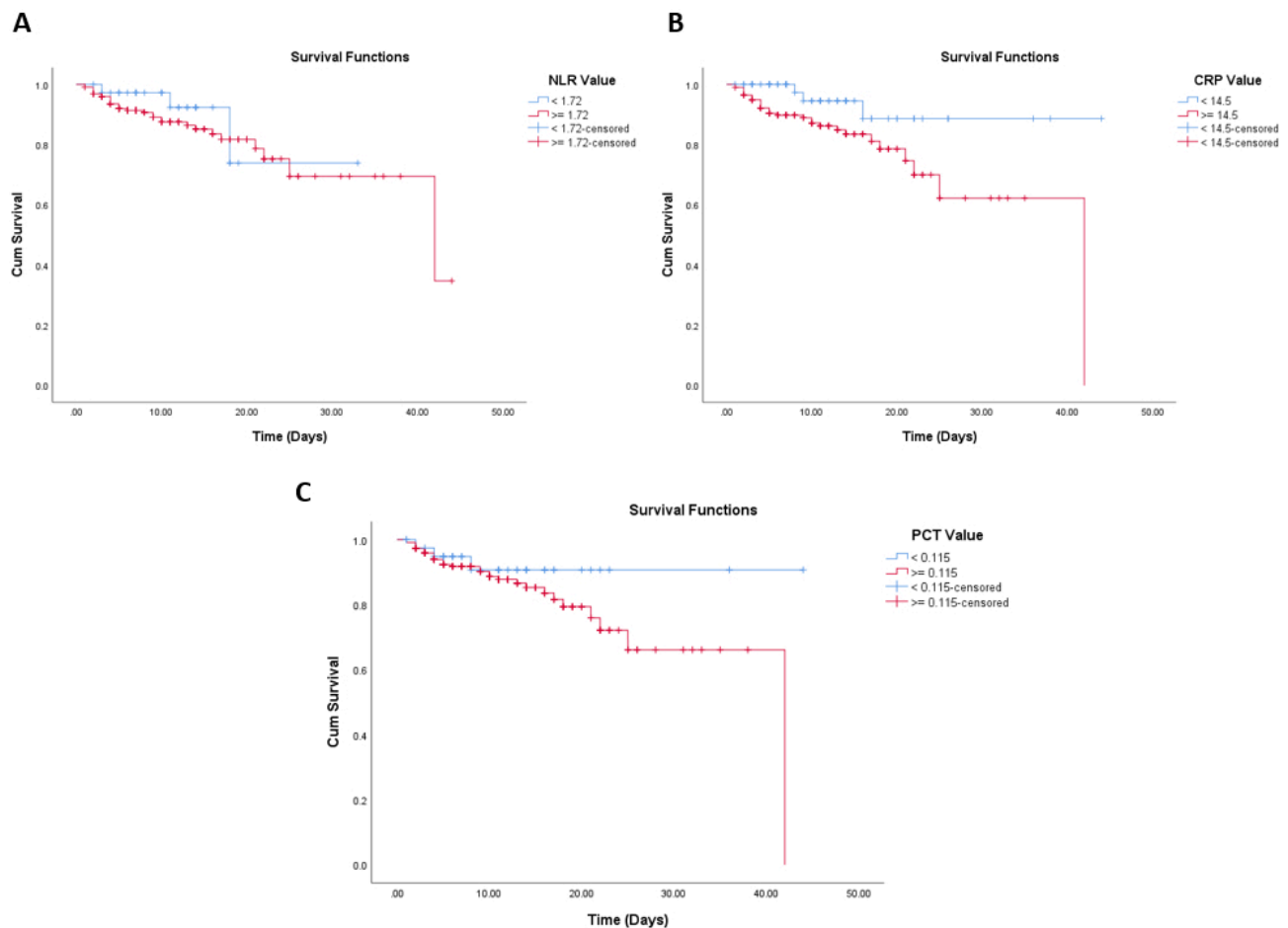
**Table 2. Diagnostic performance of inflammatory biomarkers for predicting mortality outcome.**

Biomarker	Cut-off value	Sensitivity	Specificity	AUC
NLR	1.72	91.2%	14.9%	0.495 (95% CI 0.394–0.596)
CRP	14.50 mg/L	91.2%	26.8%	0.543 (95% CI 0.449–0.636)
PCT	0.115 ng/mL	91.2%	16.7%	0.466 (95% CI 0.367–0.564)

Diagnostic accuracy of NLR, CRP, and PCT in predicting mortality outcomes. All three biomarkers demonstrated high sensitivity (91.2%), but low to moderate specificity. CRP showed the highest AUC, indicating slightly better discriminative performance compared to NLR and PCT. AUC: area under the curve; CRP: C-reactive protein; NLR: neutrophil-to-lymphocyte ratio; PCT: procalcitonin.

### Survival analysis based on the biomarker's cut-off value

To further explore the prognostic significance of biomarkers, Kaplan-Meier survival analyses were performed (Figure 4).



**Figure 4. Kaplan-Meier survival curves based on NLR, CRP, and PCT values.** Kaplan-Meier survival analysis illustrating the association between biomarker levels and patient survival over time. (A) Cumulative survival curves stratified by NLR, comparing patients with NLR < 1.72 and  $\geq 1.72$ . (B) Survival analysis based on CRP levels, comparing patients with CRP < 14.5 mg/L and  $\geq 14.5$  mg/L. (C) Survival curves based on PCT levels, with patients grouped into < 0.115 ng/mL and  $\geq 0.115$  ng/mL. CRP: C-reactive protein; NLR: neutrophil-to-lymphocyte ratio; PCT: procalcitonin.

Patients with a lower NLR (< 1.72) had a mean survival time of 28.33 days (95% CI 22.97–33.68). Meanwhile, NLR patients with  $\geq 1.72$  had a mean survival of 34.24 days (95% CI 30.74–37.74). The difference in survival distributions between groups was not statistically significant (log-rank test:  $\chi^2 = 0.632$ ,  $p = 0.427$ ).

Based on the results, patients with lower PCT levels (< 0.115 ng/mL) showed a mean survival time of 40.39 days (95% CI 36.42–44.35), compared to 32.85 days (95% CI 29.33–36.36) in those with higher

levels ( $\geq 0.115$  ng/mL). However, the difference was not statistically significant (log-rank test:  $\chi^2 = 1.592$ ,  $p = 0.207$ ).

CRP showed a significant impact on survival. Based on the results, patients with lower levels ( $< 14.5$  mg/L) had a longer mean survival time of 40.40 days (95% CI 36.39–44.41) compared to those with higher levels ( $\geq 14.5$  mg/L) at 31.85 days (95% CI 27.82–35.87). The log-rank test showed a statistically significant difference between the two groups ( $\chi^2 = 5.555$ ,  $p = 0.018$ ), suggesting that high CRP levels were associated with poorer survival outcomes.

## Discussion

### Principal findings

This study aimed to assess the prognostic value of inflammatory biomarkers, namely CRP, PCT, and NLR, in predicting IHM among elderly women with CAP. The results showed that most elderly women had mild pneumonia (83.2%), with a high survival rate of 87.0%. The median age was 66 years, and most were treated in general wards (93.5%).

PSI showed only a weak positive correlation with NLR, but no significant association with CRP or PCT. Although several reports have reported the use of NLR in predicting pneumonia severity [8], the weak correlations between PSI scores and inflammatory biomarkers in this study show the predominance of mild CAP cases. The negative correlations observed between NLR and both CRP and PCT were unexpected. To assess the influence of extreme values, a sensitivity analysis excluding NLR values above the 99th percentile ( $n = 260$ ) was performed. The inverse correlations between NLR and CRP ( $r = -0.147$ ,  $p = 0.017$ ), as well as CRP and PCT ( $r = -0.174$ ,  $p = 0.005$ ) remained but were weaker, indicating partial distortion by outliers without fully explaining the unexpected inverse trends. This showed the dynamic immune responses in elderly patients, such as immunosenescence [9–12].

NLR shows different expression patterns depending on the underlying infection and clinical context. For example, NLR is significantly higher in post-stroke pneumonia but does not reliably predict other infections such as urinary tract infection, sepsis, or ventriculitis, indicating that the prognostic value is context-specific [13]. Additionally, NLR levels are lower in pulmonary tuberculosis compared with bacterial CAP, suggesting pathogen-related variability in immune responses [14].

Although PCT and CRP showed a moderate positive correlation, the single or combined use of both biomarkers had a strong discriminatory power for predicting mortality based on ROC curve analysis. Among the three biomarkers, CRP had the highest, but still modest, AUC (0.543). The Kaplan-Meier survival analysis showed that only CRP, at a cut-off of 14.5 mg/L, significantly impacted survival. In comparison, NLR and PCT cut-off values did not show statistically significant differences in survival outcomes. Due to the heterogeneity of pneumonia etiology and comorbidities in elderly women, several factors can reduce the predictive performance of NLR and PCT. Therefore, interpretation of these biomarkers, particularly NLR, should consider pathogen type and patients' condition, rather than assuming uniform prognostic utility in all CAP cases.

The results showed that all biomarkers had high sensitivity (91.2%) in identifying non-survivors. However, specificity was limited, with CRP showing 26.8%, NLR 14.9%, and PCT 16.7%, suggesting limited utility as a standalone predictive tool. CRP was significantly associated with survival outcomes, suggesting potential application as an adjunct in risk stratification. Meanwhile, the combined model of CRP, PCT, and NLR did not show a significant improvement in predictive accuracy, with an AUC of 0.538 (95% CI 0.432–0.644). The results show the complexity of predicting mortality using biomarkers alone and the need for a more integrated method. The weak discriminatory performance in this study can be attributed to the mild severity of most cases and the low mortality rate (34 of 262; 13.0%).

This study correlates with existing literature that shows the limitations of using inflammatory biomarkers in isolation for CAP mortality prediction [15–17]. Previous reports have shown similar challenges with biomarkers like CRP and PCT, which are sensitive but often fail to offer sufficient specificity

as reliable stand-alone prognostic tools [18, 19]. This issue is particularly observed in elderly populations, where comorbidities and multiple sources of inflammation can confound biomarker readings [20]. Despite the limitations, CRP, PCT, and NLR remain attractive due to their low cost, availability, and ease of use, particularly in low-resource settings [21, 22].

One of the key strengths of this study is the focus on elderly women. By concentrating on the demographic, the results contribute to a growing body of literature that seeks to understand how biomarkers and clinical management differ across genders in elderly patients. Gender-specific factors, such as immune responses and hormonal influences, can play a significant role in the presentation and response of elderly women to pneumonia [3].

### **Clinical implications**

CRP, PCT, and NLR are readily available in most clinical settings, serving as reliable tools in resource-limited environments. The cost-effectiveness of these biomarkers, combined with ease of use, indicates the essential role in early risk stratification, particularly in low- and middle-income countries [21]. However, several limitations in terms of specificity suggest that CRP, PCT, and NLR should be used as part of a broader clinical assessment, rather than standalone tools for mortality prediction.

### **Limitations**

This study has several limitations, which include the use of a retrospective design, hindering causal inferences, and introducing selection bias. The samples include predominantly mild cases, reducing the ability to detect biomarker differences in severe disease. Furthermore, PCT, CRP, and NLR were available to the treating physicians during hospitalization. This suggests potential influence of treatment intensity, such as antibiotic escalation and intensive care unit (ICU) referral, in reducing mortality risk. Another limitation is that microbiological testing was not routinely performed, hindering stratification of pneumonia etiology (bacterial, viral, or mixed). Finally, this study depends on single-time-point measurements of inflammatory biomarkers, which can be overcome through serial measurements to provide better prognostic insight.

### **Conclusion**

In conclusion, CRP shows modest prognostic value in elderly women with CAP, but the limited specificity underscores the need for more comprehensive risk models. Consequently, further studies should explore the interplay of age, gender, and immune response to improve outcomes in elderly women.

### **Abbreviations**

AUC: area under the curve

CAP: community-acquired pneumonia

CRP: C-reactive protein

HCU: high care unit

ICU: intensive care unit

IHM: in-hospital mortality

NLR: neutrophil-to-lymphocyte ratio

PCT: procalcitonin

PSI: pneumonia severity index

ROC: receiver operating characteristic

VIF: variance inflation factor

WBC: white blood cell

## Declarations

### Author contributions

ID and IN: Conceptualization, Writing—review & editing, Investigation, Visualization, Funding acquisition. DRN: Data curation, Formal analysis, Writing—review & editing. RR: Formal analysis, Writing—original draft, Writing—review & editing, Visualization. DLT: Supervision, Writing—review & editing. All authors read and approved the submitted version.

### Conflicts of interest

The authors declare that there are no conflicts of interest.

### Ethical approval

This study was approved by the Health Research Ethics Commission, Faculty of Medicine, Hasanuddin University (No. 670/UN4.6.4.5.31/PP36/2023). This study complies with the 2013 Declaration of Helsinki.

### Consent to participate

Informed consent to participate in the study was obtained from all participants.

### Consent to publication

Not applicable.

### Availability of data and materials

Data supporting the results of this study are included in the manuscript. Additional information is available from the corresponding author upon reasonable request.

### Funding

This study was supported by the BLU (Public Service Agency) fund of RSUP Dr. Wahidin Sudirohusodo (No. HK.02.03/DXIX/23369/2024). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

### Copyright

© The Author(s) 2026.

## Publisher's note

Open Exploration maintains a neutral stance on jurisdictional claims in published institutional affiliations and maps. All opinions expressed in this article are the personal views of the author(s) and do not represent the stance of the editorial team or the publisher.

## References

1. The top 10 causes of death [Internet]. WHO; c2026 [cited 2025 May 15]. Available from: <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>
2. Yang T, Wan C, Wang H, Qin J, Chen L, Shen Y, et al. The prognostic and risk-stratified value of neutrophil-lymphocyte count ratio in Chinese patients with community-acquired pneumonia. *Eur J Inflamm.* 2017;15:22–7. [DOI]
3. Corica B, Tartaglia F, D'Amico T, Romiti GF, Cangemi R. Sex and gender differences in community-acquired pneumonia. *Intern Emerg Med.* 2022;17:1575–88. [DOI] [PubMed] [PMC]
4. de Miguel-Díez J, Jiménez-García R, Hernández-Barrera V, Jiménez-Trujillo I, de Miguel-Yanes JM, Méndez-Bailón M, et al. Trends in hospitalizations for community-acquired pneumonia in Spain: 2004 to 2013. *Eur J Intern Med.* 2017;40:64–71. [DOI] [PubMed]

5. Naheed A, Breiman RF, Islam MS, Saha SK, Tabassum Naved R. Disparities by sex in care-seeking behaviors and treatment outcomes for pneumonia among children admitted to hospitals in Bangladesh. *PLoS One*. 2019;14:e0213238. [DOI] [PubMed] [PMC]
6. López-de-Andrés A, Albaladejo-Vicente R, de Miguel-Diez J, Hernández-Barrera V, Ji Z, Zamorano-León JJ, et al. Gender differences in incidence and in-hospital outcomes of community-acquired, ventilator-associated and nonventilator hospital-acquired pneumonia in Spain. *Int J Clin Pract*. 2021;75:e13762. [DOI] [PubMed]
7. Reade MC, Yende S, D'Angelo G, Kong L, Kellum JA, Barnato AE, et al.; Genetic and Inflammatory Markers of Sepsis Investigators. Differences in immune response may explain lower survival among older men with pneumonia. *Crit Care Med*. 2009;37:1655–62. [DOI] [PubMed] [PMC]
8. Kuikel S, Pathak N, Poudel S, Thapa S, Bhattarai SL, Chaudhary G, et al. Neutrophil-lymphocyte ratio as a predictor of adverse outcome in patients with community-acquired pneumonia: A systematic review. *Health Sci Rep*. 2022;5:e630. [DOI] [PubMed] [PMC]
9. Chebib N, Cuvelier C, Malézieux-Picard A, Parent T, Roux X, Fassier T, et al. Pneumonia prevention in the elderly patients: the other sides. *Aging Clin Exp Res*. 2021;33:1091–100. [DOI] [PubMed]
10. Singh B, Goyal A, Patel BC. C-Reactive Protein: Clinical Relevance and Interpretation. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; 2026.
11. Ponnappan S, Ponnappan U. Aging and immune function: molecular mechanisms to interventions. *Antioxid Redox Signal*. 2011;14:1551–85. [DOI] [PubMed] [PMC]
12. Goronzy JJ, Weyand CM. Understanding immunosenescence to improve responses to vaccines. *Nat Immunol*. 2013;14:428–36. [DOI] [PubMed] [PMC]
13. Khanzadeh S, Lucke-Wold B, Eshghyar F, Rezaei K, Clark A. The Neutrophil to Lymphocyte Ratio in Poststroke Infection: A Systematic Review and Meta-Analysis. *Dis Markers*. 2022;2022:1983455. [DOI] [PubMed] [PMC]
14. Shojaan H, Kalami N, Ghasempour Alamdari M, Emami Alorizy SM, Ghaedi A, Bazrgar A, et al. Diagnostic value of the neutrophil lymphocyte ratio in discrimination between tuberculosis and bacterial community acquired pneumonia: A meta-analysis. *J Clin Tuberc Other Mycobact Dis*. 2023; 33:100395. [DOI] [PubMed] [PMC]
15. Malézieux-Picard A, Nascè A, Azurmendi L, Pagano S, Vuilleumier N, Sanchez JC, et al. Kinetics of inflammatory biomarkers to predict one-year mortality in older patients hospitalized for pneumonia: a multivariable analysis. *Int J Infect Dis*. 2022;122:63–9. [DOI] [PubMed]
16. Tekin A, Wireko FW, Gajic O, Odeyemi YE. The Neutrophil/Lymphocyte Ratio and Outcomes in Hospitalized Patients with Community-Acquired Pneumonia: A Retrospective Cohort Study. *Biomedicine*. 2024;12:260. [DOI] [PubMed] [PMC]
17. Liu D, Su LX, Guan W, Xiao K, Xie LX. Prognostic value of procalcitonin in pneumonia: A systematic review and meta-analysis. *Respirology*. 2016;21:280–8. [DOI] [PubMed] [PMC]
18. Akagi T, Nagata N, Miyazaki H, Harada T, Takeda S, Yoshida Y, et al. Procalcitonin is not an independent predictor of 30-day mortality, albeit predicts pneumonia severity in patients with pneumonia acquired outside the hospital. *BMC Geriatr*. 2019;19:3. [DOI] [PubMed] [PMC]
19. Sharma Y, Thompson C, Zinellu A, Shahi R, Horwood C, Mangoni AA. The role of the neutrophil-to-lymphocyte ratio in predicting outcomes among patients with community-acquired pneumonia. *Clin Med (Lond)*. 2025;25:100278. [DOI] [PubMed] [PMC]
20. Franceschi C, Campisi J. Chronic inflammation (inflammaging) and its potential contribution to age-associated diseases. *J Gerontol A Biol Sci Med Sci*. 2014;69 Suppl 1:S4–9. [DOI] [PubMed]

21. Curbelo J, Luquero Bueno S, Galván-Román JM, Ortega-Gómez M, Rajas O, Fernández-Jiménez G, et al. Inflammation biomarkers in blood as mortality predictors in community-acquired pneumonia admitted patients: Importance of comparison with neutrophil count percentage or neutrophil-lymphocyte ratio. *PLoS One*. 2017;12:e0173947. [DOI] [PubMed] [PMC]
22. Harrison M, Collins CD. Is procalcitonin-guided antimicrobial use cost-effective in adult patients with suspected bacterial infection and sepsis? *Infect Control Hosp Epidemiol*. 2015;36:265–72. [DOI] [PubMed]