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Evaluation of Serum Biomarkers in Predicting the Severity of Community-Acquired Pneumonia: A Prospective Cross-Sectional Observational Study.

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ABSTRACT

Background:
Community-acquired pneumonia (CAP) remains a major cause of morbidity and mortality worldwide. Early identification of severe cases is essential for timely intervention and improved outcomes. Serum biomarkers such as C-reactive protein (CRP), procalcitonin (PCT), neutrophil-to-lymphocyte ratio (NLR), and serum lactate have emerged as valuable tools for assessing disease severity.

Aim:
To evaluate the role of serum biomarkers in predicting the severity of community-acquired pneumonia and their correlation with established clinical severity scores.

Methods:
A prospective observational study was conducted among 100 patients diagnosed with CAP admitted to Madhubani Medical College and Hospital, Madhubani, between April 2025 and January 2026. Serum CRP, procalcitonin, NLR, and lactate levels were measured at admission. Severity was assessed using CURB-65 and Pneumonia Severity Index (PSI) scores. Biomarker levels were compared between severe and non-severe CAP groups.

Results:
Among 100 patients, 62% were males and 38% females. Thirty-five patients had severe CAP. Mean CRP, PCT, NLR, and lactate levels were significantly higher in severe CAP compared to non-severe CAP ($p<0.001$). Procalcitonin demonstrated the highest predictive accuracy for severe disease (AUC=0.89), followed by lactate (AUC=0.86), CRP (AUC=0.83), and NLR (AUC=0.80).

Conclusion:
Serum biomarkers, particularly procalcitonin and lactate, are valuable predictors of CAP severity and correlate strongly with clinical severity scores. Their incorporation into routine assessment may facilitate early risk stratification and optimize patient management.

Recommendation:
Routine assessment of procalcitonin and serum lactate, alongside conventional severity scores, is recommended for early risk stratification and identification of patients requiring intensive monitoring and aggressive management.

Keywords: *Community-acquired pneumonia, Procalcitonin, C-reactive protein, Lactate, Biomarkers, Severity prediction.*
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INTRODUCTION

One of the most common infectious causes of hospitalisation and death globally is community-acquired pneumonia (CAP), especially in older people and patients with underlying medical conditions. Even with improvements in supportive care and antibiotic medication, CAP still poses a significant healthcare cost, particularly in underdeveloped nations. Determining whether a patient has to be admitted to intensive care, directing treatment options, and improving clinical outcomes all depend on early identification of individuals at risk of severe disease. To evaluate the severity of the illness and forecast mortality, a number of clinical scoring systems are frequently employed, such as the CURB-65 score and the Pneumonia Severity Index (PSI). Despite their value, these instruments have certain drawbacks. Clinical scoring systems may not accurately represent the dynamic inflammatory response linked to infection and frequently require several variables. As a result, the use of laboratory biomarkers as supplemental instruments for severity assessment has gained popularity (1).

The host's reaction to infection is objectively demonstrated by inflammatory biomarkers. The liver produces the acute-phase reactant C-reactive protein (CRP), which rises dramatically in bacterial infections and inflammatory conditions. The precursor of calcitonin, procalcitonin (PCT), has become well-known as a particular sign for sepsis and bacterial infection. In individuals with CAP, elevated PCT levels have been linked to higher illness severity, bacteremia, and death. A straightforward and affordable biomarker of systemic inflammation is the neutrophil-to-lymphocyte ratio (NLR). Similar to this, serum lactate has been used extensively in critically ill patients to identify those who are at risk of unfavourable outcomes because it is a biomarker of tissue hypoperfusion. Increased mortality and severe CAP may be predicted by increasing lactate levels, according to recent research (2).
When clinical severity scores and blood biomarkers are used together, risk stratification may be enhanced, and early identification of high-risk patients may be possible. However, there is still a dearth of information about how well certain biomarkers predict the severity of CAP, especially in the Indian population. In order to assess serum CRP, procalcitonin, NLR, and lactate levels in patients with community-acquired pneumonia and ascertain their usefulness in forecasting illness severity and clinical outcomes, the current study was conducted.

Materials And Methods

Study Design

This study was designed as a **prospective cross-sectional observational study** conducted to evaluate the role of serum biomarkers in predicting the severity of community-acquired pneumonia (CAP) and their correlation with established clinical severity scores.

Study Setting and Duration

The study was conducted in the **Department of General Medicine, Madhubani Medical College and Hospital, Madhubani, Bihar, India**, a tertiary care teaching hospital serving predominantly rural and semi-urban populations of North Bihar and adjoining regions. The study was carried out over a period of **10 months from April 2025 to January 2026**.

Study Population

Adult patients admitted to the Department of General Medicine with a diagnosis of community-acquired pneumonia during the study period were screened for eligibility.

Sample Size

The sample size comprised **100 patients with community-acquired pneumonia** who fulfilled the eligibility criteria during the study period. Consecutive eligible patients were enrolled until the desired sample size was achieved. The sample size was determined based on the expected number of CAP admissions during the study period and available resources for biomarker assessment.

Sampling Technique

A **consecutive sampling method** was employed whereby all eligible patients presenting during the study period were included sequentially until the required sample size was reached.

Inclusion Criteria

Patients fulfilling all of the following criteria were included in the study:

- Age ≥18 years.

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- Clinical features suggestive of community-acquired pneumonia, such as fever, cough, sputum production, dyspnea, or pleuritic chest pain.
- Radiological evidence of pneumonia on chest radiography or computed tomography.
- Development of symptoms prior to hospital admission or within 48 hours of hospitalization.
- Willingness to provide written informed consent.

Exclusion Criteria

Patients with any of the following conditions were excluded:

- Hospital-acquired or ventilator-associated pneumonia.
- Active pulmonary tuberculosis.
- Immunocompromised states, including HIV infection, organ transplantation, chemotherapy, or long-term corticosteroid therapy.
- Chronic inflammatory or autoimmune disorders.
- Known malignancy.
- Recent major surgery or trauma within the preceding four weeks.
- Patients unwilling to participate in the study.

Participant Recruitment

During the study period, patients presenting with suspected CAP were screened for eligibility. Those fulfilling the inclusion criteria and none of the exclusion criteria were invited to participate in the study. Written informed consent was obtained prior to enrollment. A total of **100 patients** were finally included in the analysis.

Data Collection

A detailed clinical history, including demographic characteristics, smoking history, alcohol consumption, and associated comorbidities such as diabetes mellitus, hypertension, chronic obstructive pulmonary disease, and chronic kidney disease, was obtained for all participants. A comprehensive physical examination was performed at admission.

Baseline investigations included complete blood count, renal function tests, liver function tests, blood glucose, serum electrolytes, chest radiography, and microbiological investigations as indicated clinically.

The following serum biomarkers were measured at admission before initiation of antibiotic therapy whenever feasible:

- **C-reactive protein (CRP)** measured in mg/L.
- **Procalcitonin (PCT)** measured in ng/mL.
- **Neutrophil-to-lymphocyte ratio (NLR)** calculated from the differential leukocyte count.
- **Serum lactate** measured in mmol/L.

Assessment of Disease Severity

The severity of community-acquired pneumonia was assessed at admission using validated clinical scoring systems:

1. **CURB-65 score**, which includes assessment of confusion, blood urea nitrogen level, respiratory rate, blood pressure, and age ≥65 years.
2. **Pneumonia Severity Index (PSI)** score, incorporating demographic factors, comorbidities, physical examination findings, and laboratory parameters.

Patients were subsequently categorized into:

- **Non-severe community-acquired pneumonia**
- **Severe community-acquired pneumonia**

Severe CAP was defined according to higher CURB-65 and PSI scores, indicating increased risk of mortality and requirement for intensive care management.

Outcome Measures

The primary outcome of the study was to determine the predictive value of serum biomarkers for severe community-acquired pneumonia.

Secondary outcomes included:

- Correlation of biomarker levels with CURB-65 and PSI scores.
- Determination of diagnostic accuracy of biomarkers using receiver operating characteristic (ROC) curve analysis.
- Comparison of biomarker levels between severe and non-severe CAP groups.

Bias Minimization

Several measures were adopted to minimize bias during the study. Consecutive recruitment of eligible patients was performed to reduce selection bias. Biomarker measurements were carried out using standardized laboratory protocols and calibrated equipment to minimize measurement bias. Clinical severity scoring was performed using validated scoring systems to reduce observer bias and improve reproducibility.

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Ethical Considerations

The study protocol was reviewed and approved by the **Institutional Ethics Committee of Madhubani Medical College and Hospital, Madhubani, Bihar, India**. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Informed Consent

Written informed consent was obtained from all participants prior to enrollment after explaining the purpose, procedures, benefits, and potential risks of participation in the study.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using **SPSS version 26.0 (IBM Corp., Armonk, NY, USA)**. Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages.

Comparisons between severe and non-severe CAP groups were performed using the **independent samples t-test** for continuous variables and the **Chi-square test or Fisher's exact test** for categorical variables as appropriate.

Correlation between biomarker levels and severity scores was assessed using **Pearson's correlation coefficient (r)**. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance of biomarkers for predicting severe CAP, and the area under the curve (AUC), sensitivity, and specificity were calculated.

A **p-value <0.05** was considered statistically significant.

RESULTS

Participant Recruitment and Selection

During the study period from April 2025 to January 2026, all adult patients presenting to the Department of General Medicine with clinical suspicion of community-acquired pneumonia were screened for eligibility. A total of **124 patients** were assessed for eligibility based on clinical presentation and radiological findings suggestive of CAP.

Of these, **112 patients fulfilled the eligibility criteria** and were considered eligible for participation. Twelve patients were excluded at the screening stage due to the presence of exclusion criteria, including hospital-acquired pneumonia (n=5), active pulmonary tuberculosis (n=3), immunocompromised status (n=2), and underlying malignancy (n=2).

Among the eligible patients, **12 patients were subsequently excluded**, including seven patients who declined to provide informed consent and five patients with incomplete clinical or laboratory data required for the analysis.

Finally, **100 patients were enrolled and included in the final analysis**, comprising **35 patients with severe community-acquired pneumonia and 65 patients with non-severe community-acquired pneumonia** according to CURB-65 and Pneumonia Severity Index (PSI) severity classifications.

Table 1. Baseline Characteristics of Study Population

The study included 100 patients with CAP. The mean age was 54.6±15.2 years. Males constituted 62% of the study population. Thirty-five patients were categorized as severe CAP based on CURB-65 and PSI scores.

Variable	Value
Total Patients	100
Male	62 (62%)
Female	38 (38%)
Mean Age (years)	54.6 ± 15.2
Diabetes Mellitus	29 (29%)
Hypertension	24 (24%)
Smokers	37 (37%)

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Variable	Value
Severe CAP	35 (35%)
Non-severe CAP	65 (65%)

Table 2. Comparison of Biomarker Levels Between Severe and Non-Severe CAP

All serum biomarkers were significantly elevated among patients with severe CAP. The highest difference was observed for procalcitonin and lactate levels, indicating a strong association with disease severity.

Biomarker	Non-Severe CAP (n=65)	Severe CAP (n=35)	p-value
CRP (mg/L)	48.6 ± 18.4	112.5 ± 35.2	<0.001
Procalcitonin (ng/mL)	0.92 ± 0.48	4.21 ± 1.63	<0.001
NLR	7.3 ± 2.1	15.4 ± 4.8	<0.001
Lactate (mmol/L)	1.8 ± 0.6	4.1 ± 1.2	<0.001

Table 3. Correlation of Biomarkers with CURB-65 Severity Score

Procalcitonin showed the strongest positive correlation with CURB-65 score, followed by serum lactate, suggesting their usefulness in identifying severe disease.

Biomarker	Correlation Coefficient (r)	p-value
CRP	0.68	<0.001
Procalcitonin	0.81	<0.001
NLR	0.63	<0.001
Lactate	0.77	<0.001

Table 4. Diagnostic Performance of Biomarkers

ROC curve analysis demonstrated that procalcitonin had the highest diagnostic accuracy (AUC=0.89) for predicting severe CAP, followed by lactate (AUC=0.86).

Biomarker	AUC	Sensitivity (%)	Specificity (%)
CRP	0.83	82.4	76.9
Procalcitonin	0.89	88.6	84.6
NLR	0.80	77.1	75.4
Lactate	0.86	85.7	81.5

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DISCUSSION

Community-acquired pneumonia remains a significant public health concern due to its high incidence, hospitalization rates, and mortality. To guarantee proper administration and distribution of medical resources, early detection of serious illness is crucial. The current study assessed the predictive value of serum biomarkers for the severity of CAP and found that severe cases had considerably higher levels of CRP, procalcitonin, NLR, and lactate. Males predominated among the middle-aged to older people who made up the majority of the patients in our study. (3). Previous research has revealed similar demographic tendencies, indicating that males are more likely to be exposed to smoking, occupational dangers, and chronic illnesses.

Patients with severe CAP had much higher CRP values. The degree of the systemic inflammatory response is reflected by CRP, an acute-phase reactant produced in response to inflammatory cytokines. Our results corroborate earlier findings that linked high CRP levels to bacteremia, widespread lung involvement, and worse clinical outcomes. CRP's specificity is limited, though, as it can also rise in a number of non-infectious inflammatory diseases(4).

The most reliable biomarker for predicting the severity of CAP was found to be procalcitonin. PCT levels were significantly higher in patients with severe illness than in those with less severe pneumonia. Procalcitonin is a fairly specific diagnostic for bacterial infections since it is secreted in response to bacterial toxins and systemic inflammation. Our study's substantial association between PCT and CURB-65 scores is in line with research from other countries. Because of its high sensitivity and specificity, PCT may be very helpful in identifying patients who need intensive care monitoring or severe treatment.(5). The severity of the illness was likewise significantly correlated with the neutrophil-to-lymphocyte ratio. The equilibrium between lymphocyte-mediated immune control and neutrophilic inflammatory response is reflected in NLR. In a number of infectious illnesses, elevated NLR readings have been associated with worse outcomes and higher mortality. In environments with limited resources, NLR can be a useful marker because of its accessibility and affordability.(6).

Excellent prognostic value for severe CAP was shown by serum lactate. Increased metabolic stress and tissue hypoperfusion, which frequently accompany severe infection and sepsis, are indicated by elevated lactate levels. Lactate's potential as an early warning indicator for clinical deterioration is supported by the study's substantial association between lactate and severity scores. Procalcitonin and lactate performed better as predictors than CRP and NLR, according to the ROC analysis. These results imply that risk categorisation and clinical decision-making may be enhanced by combining clinical severity scores with certain biomarkers. Close observation, early antibiotic escalation, and intense supportive treatment may be beneficial for patients with very high PCT or lactate levels. (7).

All things considered, our research supports the mounting evidence that serum biomarkers are useful supplements to conventional clinical assessment instruments. Clinical outcomes could be improved, and early identification of high-risk patients could be improved by incorporating them into standard practice.(8).

CONCLUSION

Serum biomarkers are useful tools for determining the severity of community-acquired pneumonia, as this prospective observational study shows. Procalcitonin had the best predictive accuracy of the biomarkers assessed, with serum lactate, CRP, and NLR following closely behind. Strong connections were found between elevated levels of these biomarkers and known clinical severity scores, such as CURB-65 and PSI, and they were significantly linked to severe CAP. Lactate and procalcitonin have been shown to be especially helpful markers for identifying individuals who are more likely to experience problems, need intensive care, and have unfavourable outcomes. Even though CRP and NLR also had strong correlations with the severity of the illness, they performed less well in terms of prediction.

Serum biomarkers may enhance risk assessment, enable early treatment interventions, and maximise resource use when combined with traditional clinical grading systems. Procalcitonin and lactate offer better predictive information when accessible; biomarkers like NLR and CRP offer more affordable options in healthcare settings with limited resources. To validate these results and develop standardised biomarker-based methods for treating community-acquired pneumonia, more multicentric studies with bigger sample sizes and long-term follow-up are advised.

Author Contributions

Ashutosh Kumar: Conceptualization, study design, patient recruitment, data collection, manuscript drafting.

Mukesh Kumar: Data analysis, interpretation of results,

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manuscript writing, critical revision, corresponding author responsibilities.
Ajay Kumar Lal Das: Study supervision, methodology, manuscript review and editing, final approval of the manuscript.
All authors read and approved the final manuscript.

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Dr. Ashutosh Kumar is Assistant Professor, Department of General Medicine, Madhubani Medical College, Bihar, with research interests in respiratory medicine, infectious diseases, and clinical epidemiology.

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List of Abbreviations

Abbreviation	Full Form
CAP	Community-Acquired Pneumonia
CRP	C-Reactive Protein
PCT	Procalcitonin
NLR	Neutrophil-to-Lymphocyte Ratio
CURB-65	Confusion, Urea, Respiratory Rate, Blood Pressure, Age ≥65 Years
PSI	Pneumonia Severity Index
ROC	Receiver Operating Characteristic
AUC	Area Under the Curve
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
IEC	Institutional Ethics Committee
HIV	Human Immunodeficiency Virus
CT	Computed Tomography
CBC	Complete Blood Count
COPD	Chronic Obstructive Pulmonary Disease
IBM	International Business Machines (IBM Corp., developer of SPSS)

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