Scholars Journal of Applied Medical Sciences
Abbreviated Key Title: Sch J App Med Sci
ISSN 2347-954X (Print) | ISSN 2320-6691 (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Pediatrics

Assessment of Inflammatory Markers (CBC and CRP) and their Impact on Severity and Recurrence of Pneumonia in Under-Five Children

Dr. Shahina Pervin[1*], Dr. Rozina Akhter[2], Dr. Nawsin Farzana[3], Dr. Tasnim Khanom[4]

[1]Associate Professor, Department of Pediatrics, Dr. Sirajul Islam Medical College Hospital, Dhaka, Bangladesh
[2]Associate Professor, Department of Pediatrics, Dr. Sirajul Islam Medical College Hospital, Dhaka, Bangladesh
[3]Assistant Professor, Department of Pediatrics, Dr. Sirajul Islam Medical College Hospital, Dhaka, Bangladesh
[4]Associate Professor, Department of Ophthalmology, Dr. Sirajul Islam Medical College Hospital, Dhaka, Bangladesh

DOI: https://doi.org/10.36347/sjams.2024.v12i10.021 | **Received:** 16.09.2024 | **Accepted:** 24.10.2024 | **Published:** 28.10.2024

***Corresponding author:** Dr. Shahina Pervin
Associate Professor, Department of Pediatrics, Dr. Sirajul Islam Medical College Hospital, Dhaka, Bangladesh

Abstract **Original Research Article**

Background: Pneumonia remains a leading cause of morbidity and mortality in children under five. This study evaluates the association between inflammatory markers complete blood count (CBC) parameters and C-reactive protein (CRP) levels and pneumonia severity and recurrence. ***Methods:*** A prospective study was conducted with 110 children diagnosed with pneumonia at Dr. Sirajul Islam Medical College & Hospital and Islami Bank Hospital, Motijheel, Dhaka, from January to December 2023. Clinical assessments included demographic data, pneumonia severity classification, and inflammatory marker measurements. ***Results:*** The study population comprised 62 males (56.4%) and 48 females (43.6%), with a mean age of 24.6 months. Inflammatory marker analysis revealed significant differences in WBC count, neutrophil percentage, lymphocyte percentage, and CRP levels across mild, moderate, and severe pneumonia groups ($p < 0.001$). Higher levels of WBC count (14,500 ± 3,500), neutrophils (72.2 ± 8.6%), and CRP (38.5 ± 11.2) were observed in patients with pneumonia recurrence compared to those without recurrence. Multivariate regression analysis identified WBC count, neutrophil count, and CRP levels as significant predictors of pneumonia recurrence. ***Conclusion:*** Elevated inflammatory markers, particularly CBC parameters and CRP levels, correlate with increased severity and recurrence of pneumonia in young children. Monitoring these markers can aid in early identification and management of at-risk pediatric patients, potentially improving clinical outcomes. Further research is needed to explore additional biomarkers and their implications in pediatric pneumonia management.

Keywords: Pneumonia, Inflammatory markers, Complete Blood Count (CBC), C-reactive protein (CRP), Pediatric.

INTRODUCTION

Pneumonia remains a leading cause of morbidity and mortality in children under five years of age, especially in developing countries [1]. According to the World Health Organization (WHO), pneumonia accounts for approximately 15% of all deaths among children in this age group globally, with an estimated 800,000 child fatalities every year [2]. In regions like Bangladesh, where access to healthcare may be limited, and malnutrition, preterm low birth weight and other risk factors are prevalent, the burden of pneumonia is disproportionately high [3]. Despite advances in healthcare and the availability of vaccines, the management and prevention of pneumonia in young children continue to present significant challenges [4].

Pneumonia in children is primarily caused by viral or bacterial infections, with common pathogens including Streptococcus pneumoniae, Haemophilusinfluenzae, Respiratory Syncytial Virus (RSV), and influenza viruses [5]. In developing countries malnutrition, lack of immunization, overcrowded living conditions, and limited access to healthcare further exacerbate the risks [6]. Identifying the severity of pneumonia and predicting recurrence is crucial for improving patient outcomes, guiding treatment decisions, and allocating healthcare resources effectively [7].

One of the key components in managing pediatric pneumonia is the assessment of inflammatory markers, such as the complete blood count (CBC) and C-reactive protein (CRP) [8]. The CBC, specifically white blood cell (WBC) count and differential (neutrophil and

lymphocyte counts), provides valuable insights into the body's immune response to infection. Elevated WBC and neutrophil levels are typically associated with bacterial infections, while viral infections may present with lower WBC counts and higher lymphocyte percentages [9]. CRP, an acute-phase protein produced by the liver in response to inflammation, is another well-established marker for detecting infection and assessing disease severity [10]. Elevated CRP levels are commonly observed in bacterial pneumonia and may correlate with more severe forms of the disease [11].

Inflammatory markers such as CBC and CRP are widely used not only for diagnosing pneumonia but also for assessing the severity and prognosis of the disease.[5]Several studies have demonstrated the association between higher WBC counts, elevated CRP levels, and more severe pneumonia in children. However, limited data exist on how these markers might predict the likelihood of pneumonia recurrence, especially in resource-limited settings like Bangladesh, where the recurrence of pneumonia due to environmental and socio-economic factors is common [12]. Understanding the relationship between inflammatory markers and disease recurrence is critical, as recurrent pneumonia significantly increases the risk of long-term complications such as chronic lung disease and impaired lung function [13].

The recurrence of pneumonia in children can be influenced by various factors, including the presence of comorbidities, malnutrition, incomplete recovery from previous infections, and environmental factors such as exposure to smoke or pollution [14]. Children who suffer from recurrent pneumonia are also at a higher risk of developing antibiotic resistance, making treatment more challenging [15]. Therefore, identifying children at risk of recurrence can help tailor follow-up care and preventive interventions, such as timely vaccinations and improved environmental conditions, to reduce the overall disease burden [16,17].

In this context, the current study seeks to assess the role of CBC and CRP as markers of severity and recurrence of pneumonia in children under five years of age. While many studies have focused on the use of these markers in acute diagnosis and severity assessment, fewer have explored their predictive value for recurrence. Given the high rates of childhood pneumonia in Bangladesh and other developing countries, a deeper understanding of these relationships could enhance clinical decision-making and improve the long-term management of pediatric patients.

METHODOLOGY & MATERIALS

This prospective observational study was conducted from January 2023 to December 2023 at Dr. Sirajul Islam Medical College & Hospital and Islami Bank Hospital, Motijheel, Dhaka. A total of 110 children under five years of age, diagnosed with pneumonia based on history like fever, respiratory difficulty, cough & cold, clinical examination and radiological findings, were included. Purposive sampling was employed to select patients.

Inclusion criteria included children under five years presenting with community-acquired pneumonia, confirmed through physical examination and chest X-ray. Exclusion criteria included children of bronchiolitis, chronic respiratory diseases (e.g., asthma), immunocompromised states, or other significant chronic illnesses.

Data were collected using a pre-designed data collection sheet. Variables recorded included age, gender, weight, nutritional status, and the severity of pneumonia. Pneumonia severity was classified into mild, moderate, and severe according to WHO guidelines. Blood samples were collected at admission and also from outpatient department to assess complete blood count (CBC), including white blood cell (WBC) count, neutrophil and lymphocyte percentages, and C-reactive protein (CRP) levels. The inflammatory markers were correlated with the severity of pneumonia.

Each child was followed up for 6 months to track recurrence of pneumonia, defined as a new episode occurring after clinical resolution of the initial illness. The association between CBC, CRP, and pneumonia recurrence was also assessed.

Statistical analysis was performed using SPSS version 26.0. Descriptive statistics (mean, median, standard deviation) were used for baseline characteristics. Independent sample t-tests and ANOVA were used to compare CBC and CRP levels between different severity groups. Pearson or Spearman correlation was applied to examine the relationship between inflammatory markers and pneumonia severity. Logistic regression analysis was used to identify predictors of recurrence. Statistical significance was set at $p < 0.05$. The study was conducted in accordance with ethical principles.

RESULTS

Table I: Baseline Characteristics of the Study Population (N = 110)

Characteristics	n	%
Gender		
Male	62	56.4
Female	48	43.6
Age (months)	24.6 ± 10.2	
Weight (kg)	10.4 ± 1.8	
Nutritional Status		
Normal	75	68.2
Underweight	35	31.8
Severity of Pneumonia		
Mild	40	36.4
Moderate	45	40.9
Severe	25	22.7

Table I summarizes the baseline characteristics of 110 children with pneumonia. The group was slightly male-dominated, with 62 boys (56.4%) and 48 girls (43.6%). The average age was 24.6 months (±10.2), and the average weight was 10.4 kg (±1.8). Nutritional status showed that 68.2% had normal nutrition, while 31.8% were underweight. Pneumonia severity varied, with 36.4% having mild, 40.9% moderate, and 22.7% severe cases, reflecting a range of clinical presentations.

Table II: CBC and CRP Levels in Relation to Pneumonia Severity

Parameter	Mild Pneumonia (n=40)	Moderate Pneumonia (n=45)	Severe Pneumonia (n=25)	p-value
WBC count (cells/mm³)	10,000 ± 2,500	13,500 ± 3,200	16,000 ± 3,800	0.001
Neutrophil count (%)	60.2 ± 8.3	68.5 ± 7.5	74.2 ± 9.1	0.002
Lymphocyte count (%)	28.6 ± 5.1	24.4 ± 4.8	20.1 ± 3.9	0.008
CRP (mg/L)	10.8 ± 4.5	25.2 ± 6.7	45.6 ± 10.3	<0.001

Table II shows the relationship between pneumonia severity and key inflammatory markers. As severity increased, WBC and neutrophil counts also rose from 10,000 cells/mm³ and 60.2% in mild cases to 16,000 cells/mm³ and 74.2% in severe cases (p-values: 0.001 and 0.002). Lymphocyte counts decreased with severity, from 28.6% in mild to 20.1% in severe cases ($p = 0.008$). CRP levels significantly increased, from 10.8 mg/L in mild to 45.6 mg/L in severe cases ($p < 0.001$), indicating a clear link between higher inflammation and pneumonia severity.

Table III: Percentage of Outpatients Admitted to the Hospital

Outpatients (n=30)	Number Admitted to Hospital	Percentage Admitted
30	12	40%

Table III presents the percentage of outpatients who were subsequently admitted to the hospital. Out of 30 evaluated outpatients, 12 required hospitalization, representing 40% of the total outpatient group.

Table IV: Association between Inflammatory Markers and Recurrence of Pneumonia within 6 Months

Parameter	No Recurrence (n=80)	Recurrence (n=30)	p-value
WBC count (cells/mm³)	12,000 ± 2,800	14,500 ± 3,500	0.015
Neutrophil count (%)	63.5 ± 7.0	72.2 ± 8.6	0.005
Lymphocyte count (%)	26.5 ± 5.2	21.4 ± 4.3	0.007
CRP (mg/L)	15.2 ± 6.3	38.5 ± 11.2	<0.001

Table IV highlights the association between inflammatory markers and pneumonia recurrence within 6 months. Children with pneumonia recurrence had higher average WBC counts (14,500 vs. 12,000 cells/mm³, $p = 0.015$) and neutrophil percentages (72.2% vs. 63.5%, $p = 0.005$) compared to those without recurrence. Lymphocyte counts were lower in the recurrence group (21.4% vs. 26.5%, $p = 0.007$). CRP levels were significantly elevated in children with recurrence (38.5 mg/L vs. 15.2 mg/L, $p < 0.001$),

indicating a strong link between elevated inflammatory markers and the likelihood of pneumonia recurrence.

Table V: Multivariate Regression Analysis for Predictors of Pneumonia Recurrence

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
WBC count	1.12	1.01 – 1.24	0.032
Neutrophil count	1.18	1.05 – 1.34	0.004
Lymphocyte count	0.85	0.78 – 0.93	0.009
CRP level	1.25	1.15 – 1.35	<0.001
Severity of Pneumonia	1.45	1.11 – 1.89	0.013

Table V displays the multivariate regression analysis results identifying key predictors of pneumonia recurrence. Elevated WBC count was associated with a higher risk of recurrence, with an odds ratio (OR) of 1.12 (95% CI: 1.01 – 1.24, p = 0.032). Increased neutrophil percentage also showed a significant risk, with an OR of 1.18 (95% CI: 1.05 – 1.34, p = 0.004). Conversely, higher lymphocyte counts were protective, with an OR of 0.85 (95% CI: 0.78 – 0.93, p = 0.009).

CRP levels were a strong predictor of recurrence, with an OR of 1.25 (95% CI: 1.15 – 1.35, p < 0.001), indicating that elevated CRP significantly increases the risk. Severity of pneumonia was also a notable predictor, with an OR of 1.45 (95% CI: 1.11 – 1.89, p = 0.013), reinforcing the link between severe initial episodes and future recurrence.

Table VI: Comparison of Length of Hospital Stay Based on Inflammatory Markers

Parameter	Length of Stay (days) Mean ± SD	p-value
WBC count (cells/mm³)	10.2 ± 3.1	0.043
Neutrophil count (%)	12.1 ± 4.0	0.008
Lymphocyte count (%)	8.5 ± 2.6	0.112
CRP (mg/L)	14.3 ± 5.3	<0.001

Table VI compares the length of hospital stay with levels of key inflammatory markers. A higher WBC count was associated with a longer stay, averaging 10.2 days (p = 0.043). Neutrophil count was significantly linked to extended hospitalization, with an average stay of 12.1 days (p = 0.008). In contrast, lymphocyte count did not significantly impact the duration of stay, averaging 8.5 days (p = 0.112). CRP levels showed the strongest association with prolonged hospital stay, with a mean of 14.3 days (p < 0.001), highlighting the influence of higher inflammation on recovery time.

DISCUSSION

This study was focused on the importance of inflammatory markers, specifically Complete Blood Count (CBC) parameters and C-reactive Protein (CRP), in assessing the severity, recurrence, and outcomes of pneumonia in children under five. Our results clearly demonstrated significant correlations between elevated inflammatory markers and increased pneumonia severity, higher recurrence rates, and prolonged hospital stays.

In our study, elevated White Blood Cell (WBC) and neutrophil counts were strongly associated with pneumonia severity. As seen in our data, WBC and neutrophil counts increased progressively from mild to severe pneumonia cases, with averages for mild cases at 10,000 ± 2,500 cells/mm³, moderate cases at 13,500 ± 3,200 cells/mm³, and severe cases at 16,000 ± 3,800 cells/mm³. These findings are in agreement with previous research, such as Das *et al.*, who emphasized that elevated WBC levels are reliable indicators of bacterial infections in pediatric pneumonia cases [18]. Additionally, our findings showed that neutrophil counts rose from 60.2% in mild cases to 74.2% in severe cases, reflecting an increased inflammatory response typical of bacterial infections.

Regarding recurrence, children who experienced recurrent pneumonia had significantly higher initial WBC (14,500 ± 3,500 cells/mm³) and neutrophil counts (72.2 ± 8.6%) compared to those without recurrence. This aligns with studies by El Wakeel *et al.*, which reported that elevated WBC and neutrophil counts during the initial infection can predispose children to recurrent pneumonia episodes [19]. Our findings also noted lower lymphocyte counts (21.4 ± 4.3%) in the recurrence group, suggesting a potentially weaker immune response in these children, a trend noted in the work by Isezuo *et al.*, [20].

CRP levels in our study were markedly higher in severe cases, averaging 45.6 ± 10.3 mg/L compared to 10.8 ± 4.5 mg/L in mild cases. This aligns with findings by Ismail *et al.*, who identified CRP as a crucial marker for distinguishing bacterial from viral pneumonia, with higher CRP levels linked to severe bacterial infections [21]. Our data also showed that elevated CRP levels were a significant predictor of recurrence within six months. Children with recurrent pneumonia had an initial average

CRP of 38.5 ± 11.2 mg/L, much higher than the 15.2 ± 6.3 mg/L observed in non-recurrent cases. This supports studies that highlight CRP's value in assessing infection prognosis and guiding management.

Elevated CRP levels also corresponded with longer hospital stays. In our cohort, children with higher CRP levels had longer hospitalizations, indicating a more severe and prolonged illness course. Previous studies, such as those by Mohammed *et al.*, similarly noted the association between high CRP and prolonged hospital stays, underlining its clinical importance in predicting recovery time [22].

Our findings demonstrated that higher WBC and CRP levels were significantly associated with longer hospital stays, with WBC count having an average of 10.2 ± 3.1 days and CRP averaging 14.3 ± 5.3 days. These markers indicated ongoing inflammation requiring extended treatment. However, our data showed that lymphocyte counts did not significantly impact the length of stay, aligning with findings by Al-Banaa *et al.*, who also found limited predictive value of lymphocytes for hospitalization duration [23].

Our multivariate regression analysis revealed that elevated WBC, neutrophil counts, and CRP were significant predictors of pneumonia recurrence. The odds ratios for WBC, neutrophil count, and CRP indicated that these markers play a crucial role in predicting recurrence risk. Additionally, the severity of pneumonia also emerged as a predictor, emphasizing the importance of initial assessment in guiding follow-up care. These findings align with studies by Taha *et al.*, who underscored the predictive power of inflammatory markers for pneumonia outcomes [24].

The study suggests that incorporating CBC and CRP measurements into routine clinical practice can enhance pneumonia management. By identifying high-risk children early, healthcare professionals can implement targeted interventions to reduce the chances of severe outcomes and recurrent episodes.

The strong association between inflammatory markers and clinical outcomes demonstrated in our study underscores the need for routine use of CBC and CRP in pediatric pneumonia management. Early identification of elevated markers can guide treatment decisions, particularly in resource-limited settings where advanced diagnostics may be unavailable. Our findings support the use of CRP as a standard measure for monitoring disease progression and predicting complications.

Limitations of the study

This study has some limitations. The study was conducted at two hospitals, which may limit the applicability of the results to other settings, particularly rural or low-resource areas. The sample size, though adequate for initial analysis, may not fully capture pneumonia variations across demographics. The focus was mainly on CBC and CRP, potentially missing other key biomarkers. Additionally, as an observational study, it cannot establish definitive causal relationships between inflammatory markers and clinical outcomes.

RECOMMENDATIONS

Regular monitoring of CBC and CRP in children with pneumonia could improve early detection of severe cases and guide timely treatment. Future studies should involve larger, diverse populations across multiple centers to confirm these results. Expanding research to include markers like procalcitonin and interleukins could offer deeper insights. Long-term studies are needed to examine the impact of elevated markers on recurrent pneumonia and children's respiratory health. Additionally, exploring the effects of nutrition and immunity on pneumonia outcomes may reveal new preventive strategies.

CONCLUSION

In conclusion, this study highlights the significant association between inflammatory markers specifically CBC parameters and CRP levels and the severity, recurrence, and outcomes of pneumonia in children under five years of age. Elevated WBC and neutrophil counts, along with increased CRP levels, were strongly linked to higher severity of illness, increased recurrence rates, and longer hospital stays. These findings underscore the importance of incorporating inflammatory marker assessments into routine clinical practice for pediatric pneumonia management. By identifying at-risk patients early, healthcare providers can implement targeted interventions to improve outcomes and reduce the burden of pneumonia in children.

Acknowledgment

I would like to express my sincere gratitude for the invaluable support and cooperation provided by the staff, participants, and my co-authors/colleagues who contributed to this study.

Financial support and sponsorship: No funding sources.

Conflicts of interest: There are no conflicts of interest.

Ethical approval: The study was approved by the Institutional Ethics Committee.

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