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The effect of prognostic nutritional index and hgb/rdw level on morbidity in children with pneumonia

Ozlem Ozcanli Cay[1*] and Ozlem Kemer Aycan[1*]

Abstract

Background Pneumonia in children remains a significant public health concern as it records high cases of morbidity and mortality especially in developing countries. This research work is the first in the literature which systemically looks at the association of Prognostic Nutritional Index (PNI) as well as Hemoglobin/RDW (Hgb/RDW) ratio with morbidity in childhood pneumonia. No research so far has explored the prognostic value of PNI in children suffering from pneumonia, and hence this study seeks to bridge this critical knowledge gap.

Methods This retrospective case-control study was conducted in Balıkesir Atatürk City Hospital. The study included 150 children diagnosed with community-acquired pneumonia and 150 healthy control subjects of similar age group. PNI was calculated using the formula "(10 x serum albumin [g/dL]) + (0.005 x absolute lymphocyte count [x10^9/L])". Hgb/RDW ratio was obtained by dividing hemoglobin value by RDW. Demographic data, laboratory findings and clinical observations were collected from all participants.

Results PNI values of the pneumonia group were significantly lower than those of the control group (42.4 vs. 48.6, $p < 0.001$). In addition, low PNI (< 40) and high Hgb/RDW ratios were found to be significantly associated with length of hospitalization, need for oxygen support and need for mechanical ventilation. A strong negative correlation was found between PNI and length of hospital stay (r=-0.682, $p < 0.001$) and recovery time (r=-0.724, $p < 0.001$), while Hgb/RDW ratio was significantly associated with these clinical indicators. In the ROC analysis, the AUC value expressing the predictive power of PNI for pneumonia severity was 0.874.

Conclusions In childhood pneumonia, both PNI and Hgb/RDW ratio may be effective markers for predicting disease severity and clinical course. Low PNI and high Hgb/RDW ratios have been associated with prolonged hospitalization and increased risk of complications.

Keywords Pediatric pneumonia, Prognostic nutritional index, Hemoglobin/RDW ratio

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Introduction

Lower respiratory tract infections (LRTIs) are one of the most common causes of hospital admissions in childhood. Among these infections, pneumonia is among the leading causes of morbidity and mortality in childhood, especially in developing countries. Still recognized as the leading cause of death in children under 5 years of age, pneumonia continues to account for approximately one-fifth of child deaths worldwide, despite a reduction from 4 million deaths in 1981 to just over 1 million in 2013 with the implementation of effective and cost-effective interventions [1]. Especially in developing countries, pneumonia accounts for the majority of deaths in children under 5 years of age [2].

Nutritional status plays a critical role in the course of infectious diseases. Malnutrition in childhood weakens immunity against infectious diseases such as pneumonia and increases the risk of complications [3, 4]. At this point, the Prognostic Nutritional Index (PNI) comes to the fore as an important indicator reflecting the nutritional and immune status of patients. PNI was first developed to predict postoperative complications in gastrointestinal surgery patients and has been used in different critical patient groups over time [5]. Due to its efficiency and ease of use, it is widely preferred for preoperative evaluation and surgical risk prediction in gastrointestinal cancer patients. First proposed as a nutritional index and surgical risk marker by Buzby et al. in 1980, it was validated by Onodera et al. in 1984. Many studies in the following years have demonstrated that low PNI is an independent adverse prognostic factor for short-term postoperative complications and long-term outcomes in gastric, colorectal and esophageal cancers [6].

Hematological parameters together with nutritional indices serve as essential prognostic indicators for infectious diseases. The Hgb/RDW ratio represents a new composite indicator which unites hemoglobin measurements for oxygen transport with red blood cell size variability data from RDW. The measurement of red blood cell size variability through RDW increases during inflammatory states and research shows this marker predicts negative results in multiple diseases. Research has proven that children with community-acquired pneumonia show more severe disease symptoms when their RDW values are elevated. The research by Güven et al. revealed that children with community-acquired pneumonia who had elevated RDW values presented with more severe disease symptoms and these values correlated with hospital stay duration [7]. The study by Lee et al. established RDW as an affordable biomarker for pediatric community-acquired pneumonia management because higher RDW values indicate severe disease [8]. The Hgb/RDW ratio unites oxygen-carrying capacity with inflammatory status through hemoglobin and RDW measurements to provide enhanced prognostic information about disease severity beyond what either parameter offers individually.

Studies in children have shown that low PNI values are a strong predictor of mortality, especially in intensive care unit patients [9, 10]. Recent studies have drawn attention to the negative effects of PNI on various infections, especially pneumonia, in children [11, 12]. However, the prognostic value of PNI in childhood pneumonia has not been sufficiently studied [13]. The combined Hgb/RDW ratio has not been specifically evaluated in this patient population despite growing evidence supporting RDW as a prognostic marker in pediatric pneumonia. The potential synergistic prognostic value of using both PNI and Hgb/RDW ratio together in childhood pneumonia remains unexplored.

It is known that inadequate and malnutrition conditions affect the course of pneumonia in children. However, so far there is no publication showing the relationship between PNI value and pneumonia. It is posited in this study that children with pneumonia who have lower PNI values have a higher length of hospital stay and have a higher risk of complications. The Hgb/RDW ratio which combines anemia and inflammatory status will be significantly related to disease severity and clinical outcomes in pediatric pneumonia patients according to our hypothesis. A second hypothesis is posed in this study, that PNI and Hgb/RDW ratio may be effective in predicting clinical outcomes such as mechanical ventilatory support, intensive care requirements and the time taken for recovery.

Methods

Study design and sample

This is a single-center retrospective cross-sectional study conducted in the Pediatrics Clinic of Balıkesir Atatürk City Hospital between January 2023 and December 2023. The sample size was calculated with 95% confidence interval and 80% power level and it was determined that each group should have at least 150 patients. The control group consisted of healthy children who came to the outpatient clinic for routine check-ups or vaccination and had no signs of acute or chronic illness. The target population of the study includes 150 pediatric patients who were clinically diagnosed with community acquired pneumonia on WHO definitions, whereas the comparison group consists of 150 healthy children without any respiratory symptoms or other illnesses.

Patient selection and study procedures

Patients between the ages of 0–18 years of both sexes were included in the study. Inclusion criteria for the pneumonia group were as follows: (1) diagnosis of community-acquired pneumonia according to WHO criteria,

(2) need for hospitalization, (3) no history of chronic disease, (4) no signs of malnutrition. Exclusion criteria for the pneumonia group were defined as (1) age above 18 years, (2) chronic disease, (3) continuous medication use, and (4) malnutrition.

The control group inclusion criteria consisted of: (1) Age range from 0 to 18 years, (2) No acute illness in the past 4 weeks, (3) No history of chronic disease, (4) Normal physical examination findings. The control group exclusion criteria were: (1) Any acute or chronic illness, (2) Any medication use in the past 4 weeks, (3) Hospitalization in the past 6 months, (4) Signs of malnutrition.

Data collection and measurements

Demographic data (age, gender, height, weight, BMI), socioeconomic information (parental education level, monthly income, region of residence) and clinical parameters were recorded using standardized forms. Hemogram, CRP, sedimentation, albumin levels and PNI scores were evaluated as laboratory results. PNI was calculated with the formula "(10 x serum albumin [g/dL]) + (0.005 x absolute lymphocyte count [$x10^9$/L])" [5, 14]. Hemoglobin/Red Cell Distribution Width (Hgb/RDW) ratio was determined by dividing hemoglobin value by RDW. PNI values were categorized into three groups based on ROC analysis and previous literature: low PNI (< 40), moderate PNI (40–45), and high PNI (> 45). Similarly, Hgb/RDW ratio was categorized as low (< 0.85) and high (≥ 0.85) based on ROC analysis results.

Clinical follow-up and endpoints

As the primary endpoint, the relationship between PNI level and Hgb/RDW ratio and duration of hospitalization and clinical course was examined. Secondary endpoints were (1) lung auscultation findings, (2) infection parameters and acute phase reactants, (3) need for mechanical ventilation, and (4) length of ward and intensive care unit stay. Clinical severity was assessed with the Pediatric Respiratory Severity Score (PRESS). The PRESS system is a validated scoring system (0–13 points) that evaluates respiratory rate, oxygen saturation, chest retractions, feeding ability, and mental status.

Statistical analysis

Data were analyzed using the SPSS 22.0 program. Normal distribution was checked by Kolmogorov-Smirnov and Shapiro-Wilk tests. To examine the effect of demographic variables on pneumonia morbidity, Student t-test and ANOVA were used for parametric data, and Mann-Whitney U test was used for non-parametric data. The research used One-way ANOVA to evaluate continuous variables between PNI categories followed by post-hoc Bonferroni correction for multiple comparisons. The Kruskal-Wallis test served as the statistical method for non-parametric analysis between three groups. Chi-square test was applied for categorical variables. Pearson and Spearman tests were used for correlation analysis. Receiver Operating Characteristic (ROC) curve analysis was performed to determine the optimal cut-off values and predictive performance of PNI, CRP, and Hgb/RDW ratio for pneumonia severity. Linear regression analysis was performed to evaluate the relationship between PNI and length of hospital stay. $P < 0.05$ was accepted as the limit of statistical significance.

Ethical considerations

Approval for this study was obtained from the Scientific Research Ethics Committee of Balıkesir Atatürk City Hospital (Decision No: 2024/09/51, Date: 19.09.2024). The study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants included in the study. For participants under the age of 16, informed consent was obtained from their parents or legal guardians, in accordance with national regulations. Confidentiality and security of patient information were ensured in line with hospital data security protocols.

Results

The mean age of the children in the pneumonia group was 4.2 years and 4.5 years in the control group and this age difference was not statistically significant ($p = 0.342$). In terms of gender distribution, the groups were similar to each other, with 52.0% boys and 48.0% girls in the pneumonia group and 49.3% boys and 50.7% girls in the control group ($p = 0.628$). There was no statistically significant difference between the two groups in mean height and weight. While the mean height was 98.4 cm and the mean weight was 15.8 kg in the pneumonia group, the mean height was 99.2 cm and the mean weight was 16.1 kg in the control group ($p = 0.645$ and $p = 0.528$, respectively). BMI values were also similar between the groups ($p = 0.397$) (Table 1).

A significant difference was found between the two groups in terms of maternal education level; the rate of mothers who graduated from primary school was 30.0% in the pneumonia group, while this rate was 23.3% in the control group ($p = 0.042$). There was no significant difference between the two groups in the level of paternal education ($p = 0.136$). The median monthly household income was 12,000 TL (8,000–16,000 TL) in the pneumonia group and 13,000 TL (9,000–17,000 TL) in the control group; this difference was not statistically significant ($p = 0.074$). A significant difference was observed between the groups in terms of place of residence; while the rate of those living in the city was 65.3% in the pneumonia group, it was 76.7% in the control group ($p = 0.028$) (Table 1).

Table 1 Demographic and clinical characteristics of pneumonia and control groups

Characteristic	Pneumonia Group (*n* = 150)	Control Group (*n* = 150)	*p*-value
Age (years)*	4.2 ± 2.8	4.5 ± 2.6	0.342[1]
Gender			0.628[3]
- Female	72 (48.0%)	76 (50.7%)	
- Male	78 (52.0%)	74 (49.3%)	
Height (cm)*	98.4 ± 15.6	99.2 ± 14.8	0.645[1]
Weight (kg)*	15.8 ± 4.2	16.1 ± 4.0	0.528[1]
BMI (kg/m^2)*	16.2 ± 2.1	16.4 ± 2.0	0.397[1]
Maternal Education Level			0.042[3]
- Primary school	45 (30.0%)	35 (23.3%)	
- Middle school	48 (32.0%)	42 (28.0%)	
- High school	37 (24.7%)	45 (30.0%)	
- University	20 (13.3%)	28 (18.7%)	
Paternal Education Level			0.136[3]
- Primary school	38 (25.3%)	30 (20.0%)	
- Middle school	45 (30.0%)	40 (26.7%)	
- High school	42 (28.0%)	48 (32.0%)	
- University	25 (16.7%)	32 (21.3%)	
Monthly Household Income (TL)**	12,000 (8000–16000)	13,000 (9000–17000)	0.074[2]
Place of Residence			0.028[3]
- Urban	98 (65.3%)	115 (76.7%)	
- Rural	52 (34.7%)	35 (23.3%)	

Data presented as Mean ± Standard Deviation (*) or Median (Interquartile Range) (**)

Statistical analysis used: Student's t-test ([1]), Mann-Whitney U test ([2]), and Chi-square test ([3])

Table 2 Laboratory parameters of pneumonia and control groups

Parameter	Pneumonia Group (*n* = 150)	Control Group (*n* = 150)	*p*-value
Hemoglobin (g/dL)*	11.8 ± 1.4	12.3 ± 1.2	0.028[1]
RDW (%)*	14.8 ± 1.6	13.2 ± 1.3	0.002[1]
Hgb/RDW ratio*	0.80 ± 0.12	0.93 ± 0.10	< 0.001[1]
White blood cell count (/mm^3)**	15,200 (12400–18600)	8400 (6200–10400)	< 0.001[2]
Neutrophil count (/mm^3)**	9800 (7600–12400)	4200 (3100–5400)	< 0.001[2]
Lymphocyte count (/mm^3)*	3800 ± 1200	3600 ± 1100	0.142[1]
Platelet count (/mm^3)*	342,000 ± 98,000	328,000 ± 86,000	0.186[1]
CRP (mg/L)**	48.5 (24.2–86.4)	3.2 (1.4–5.8)	< 0.001[2]
Sedimentation rate (mm/hr)**	42 (28–65)	12 (8–18)	< 0.001[2]
Albumin (g/dL)*	3.6 ± 0.4	4.2 ± 0.3	< 0.001[1]
PNI score*	42.4 ± 5.2	48.6 ± 4.8	< 0.001[1]

Hgb/RDW ratio was calculated by dividing hemoglobin level (g/dL) by RDW (%)

PNI Prognostic Nutritional Index

Data presented as Mean ± Standard Deviation (*) or Median (Interquartile Range) (**). Statistical analysis used: Student's t-test ([1]) and Mann-Whitney U test ([2]).

The mean hemoglobin level was lower in the pneumonia group 11.8 g/dL compared with 12.3 g/dL in the control group, and this difference was significant ($p = 0.028$). RDW (Red Cell Distribution Width) values were 14.8% and 13.2% in the pneumonia and the control groups, respectively, and this difference was significant ($p = 0.002$). The Hgb/RDW ratio was significantly lower in the pneumonia group (0.80 ± 0.12) compared to the control group (0.93 ± 0.10) ($p < 0.001$). In the pneumonia group leukocyte and neutrophil counts were 15,200/mm^3 and 9,800/mm^3, respectively whereas these were 8,400/mm^3 and 4,200/mm^3 in control group and there was a significant difference in both parameters ($p < 0.001$). No lymphocyte or platelet count differences between the two groups were found to be statistically significant ($p = 0.142$ and $p = 0.186$, respectively). Both CRP and sediments were markedly higher in the pneumonia group with the median CRP value of 48.5 mg/L and sedimentation value of 42 mm/h ($p < 0.001$). BAL albumin level was 3.6 g/dL in pneumonia group whereas, the control group had a level of 4.2 g/dL, with a significant difference between groups ($p < 0.001$). PNI scores were 42.4 in the pneumonia group and the control group had PNI scores of 48.6 and this difference was also statistically significant ($p < 0.001$) (Table 2; Fig. 1).

When the efficacy of CRP and PNI in predicting disease severity was compared by ROC analysis, the AUC value for CRP was calculated as 0.892 (95% CI: 0.854–0.930), which was statistically significantly higher than the AUC value of PNI (0.874) ($p = 0.028$). The optimal cut-off value for CRP was determined as 45 mg/L, with a sensitivity and specificity of 78.6% and 88.4%, respectively. Additionally, ROC analysis for Hgb/RDW ratio revealed an AUC of 0.812 (95% CI: 0.761–0.863), indicating good predictive value for pneumonia severity. The optimal cut-off value for Hgb/RDW ratio was determined as 0.85, with sensitivity of 71.4% and specificity of 76.8%. These findings suggest that CRP is a stronger predictor of pneumonia severity than PNI and Hgb/RDW ratio (Fig. 2).

As a result of ROC analysis, the optimal cut-off value for PNI was determined as 44.0. This cut-off value was determined by maximizing the Youden index (sensitivity + specificity − 1). At a cut-off value of 44.0, sensitivity was 74%, specificity 86.7%, positive predictive value 84.6% and negative predictive value 77.2%. The PNI categories were defined based on previous literature and our ROC analysis results: low PNI (< 40), moderate PNI (40–45), and high PNI (> 45). The cut-off value of 40 for defining low PNI was selected based on studies in critically ill pediatric patients where values below 40 indicated severe malnutrition and immunosuppression. This cut-off value is the first reference value determined in the literature for PNI in childhood pneumonia.

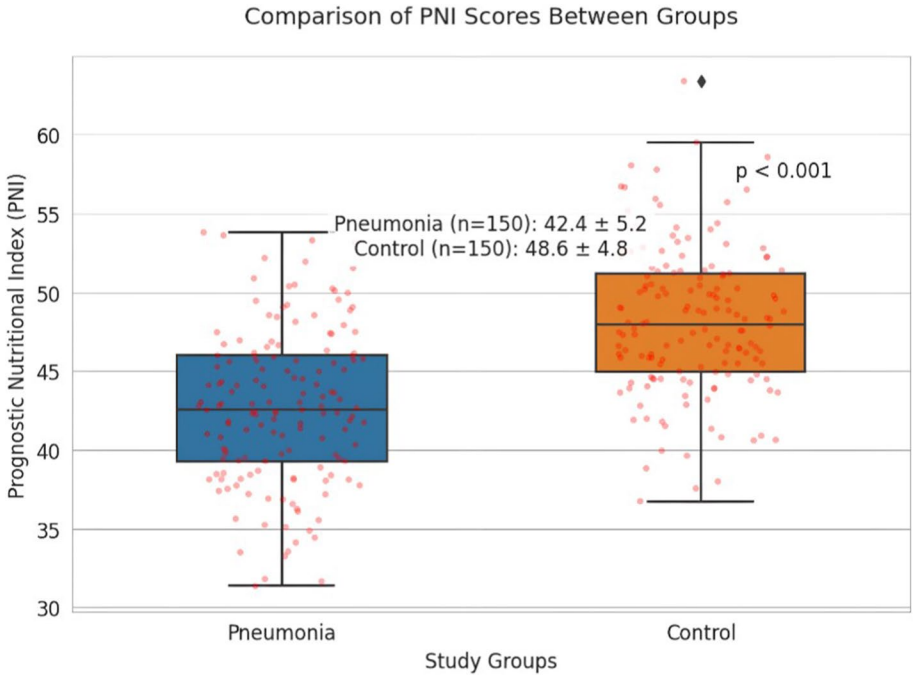

Fig. 1 Comparison of PNI scores between pneumonia and control groups

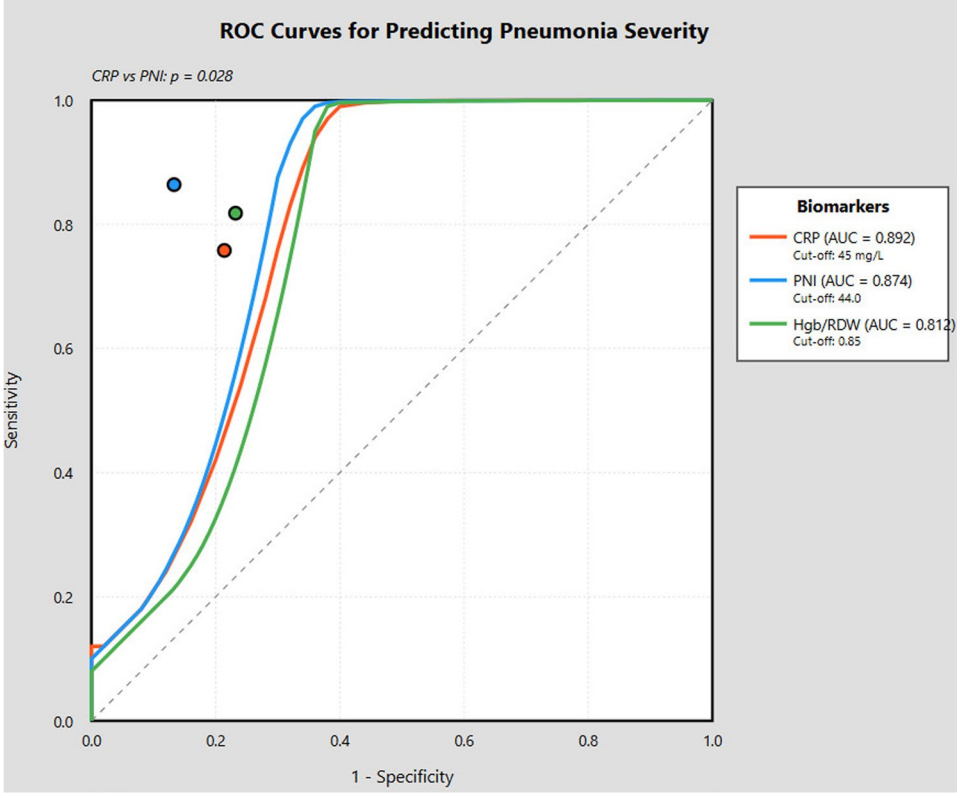

Fig. 2 ROC curves for predicting pneumonia severity: Receiver operating characteristic curves comparing the diagnostic performance of three biomarkers (CRP, PNI, and Hgb/RDW ratio) in predicting pneumonia severity in children. The diagonal dashed line represents the reference line (AUC = 0.5). Circles indicate optimal cut-off points for each biomarker. CRP = C-reactive protein; PNI = Prognostic Nutritional Index; Hgb/RDW = Hemoglobin to Red Cell Distribution Width ratio; AUC = Area under the curve

The mean duration of hospitalization was 8.4 days in the low PNI group, 6.2 days in the medium PNI group and 4.8 days in the high PNI group; the difference between the groups was statistically significant ($p < 0.001$). Oxygen requirement was 84.4% in the low PNI group, 64.6% in the medium PNI group and 45.0% in the high PNI group ($p < 0.001$). The need for mechanical ventilation was highest in the low PNI group (17.8%) and this rate was significantly higher than the other groups ($p = 0.024$). While the need for intensive care was 26.7% in the low PNI group, this rate decreased to 5.0% in the high PNI group ($p = 0.008$). Complication rates also varied according to PNI levels; the complication rate was 64.4% in the low PNI group and the most common complications were pleural effusion (33.3%) and atelectasis (22.2%). The median recovery time was 14 days in the low PNI group and 7 days in the high PNI group ($p < 0.001$). A negative correlation was found between PNI and length of hospitalization, with a correlation coefficient of −0.682 ($p < 0.001$). This result suggests that higher PNI levels are associated with shorter length of hospitalization (Figs. 3 and 4; Table 3).

Analysis of clinical outcomes based on Hgb/RDW ratio revealed significant differences between patients with low (<0.85) and high (≥0.85) Hgb/RDW ratios. Among the 150 pneumonia patients, 98 (65.3%) had low Hgb/RDW ratios and 52 (34.7%) had high Hgb/RDW ratios. Patients with low Hgb/RDW ratio had significantly longer hospital stays (7.8 ± 2.9 vs. 5.2 ± 2.1 days, $p < 0.001$), higher oxygen requirement (77.6% vs. 61.5%, $p = 0.042$), and longer recovery time (median 12 vs. 8 days, $p < 0.001$). The overall complication rate was significantly higher in the low Hgb/RDW group (59.2% vs. 40.4%, $p = 0.018$), with pleural effusion being the most common complication (28.6% vs. 17.3%). The PRESS score was also significantly higher in the low Hgb/RDW group (median 8 vs. 6, $p = 0.003$), indicating more severe disease (Table 4).

There is a strong negative relationship between PNI and length of hospital stay; the correlation coefficient is exactly −0.682 ($p < 0.001$). So, we can say that the higher the PNI, the shorter the hospital stay. Similarly, recovery time is inversely related to PNI; here the correlation coefficient is −0.724 ($p < 0.001$). Patients with higher PNI tend to recover faster. The Hgb/RDW ratio also showed significant correlations with clinical outcomes, with moderate negative correlations observed with length of hospital stay ($r = -0.524$, $p < 0.001$), recovery time ($r = -0.568$, $p < 0.001$), and PRESS score ($r = -0.486$, $p < 0.001$). There was a moderate positive correlation between Hgb/RDW ratio and PNI score ($r = 0.412$, $p < 0.001$), suggesting that both markers reflect similar aspects of disease severity. There is also a significant

Fig. 3 Relationship between PNI and length of hospital stay

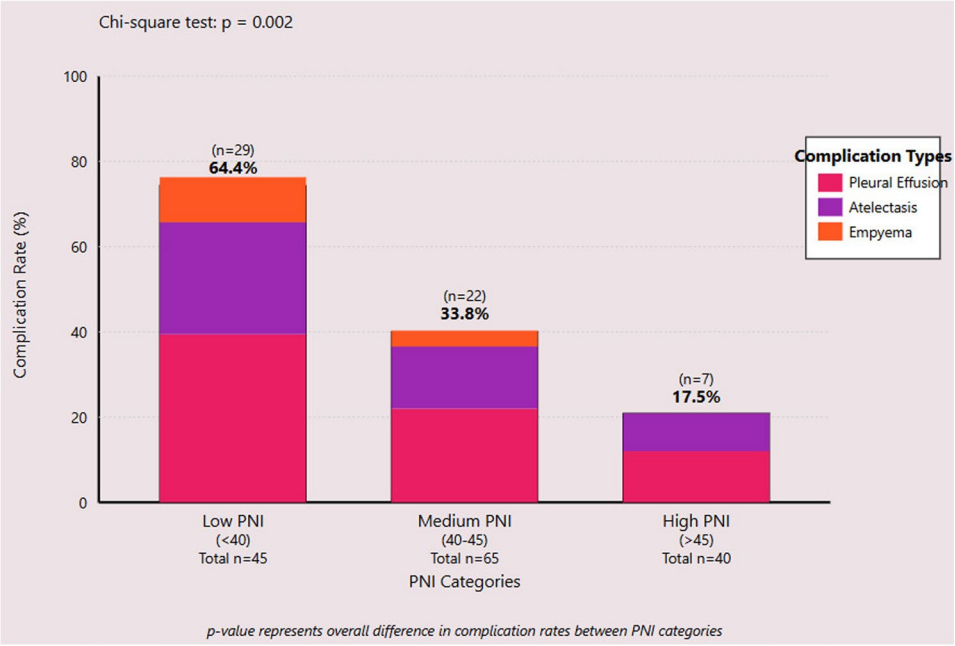

Fig. 4 Complication rates by PNI categories: stacked bar chart showing the distribution of complications (pleural effusion, atelectasis, and empyema) across different PNI categories in children with pneumonia. Pink bars represent pleural effusion, purple bars represent atelectasis, and orange bars represent empyema. PNI = Prognostic Nutritional Index

Table 3 Clinical outcomes of patients according to PNI levels

Clinical Feature	Low PNI (< 40) (*n* = 45)	Moderate PNI (40–45) (*n* = 65)	High PNI (> 45) (*n* = 40)	*p*-value
Length of hospital stay (days)*	8.4 ± 3.2	6.2 ± 2.4	4.8 ± 1.8	< 0.001[1]
Oxygen requirement	38 (84.4%)	42 (64.6%)	18 (45.0%)	< 0.001[2]
Mechanical ventilation need	8 (17.8%)	4 (6.2%)	1 (2.5%)	0.024[2]
ICU requirement	12 (26.7%)	7 (10.8%)	2 (5.0%)	0.008[2]
Complication development				0.002[2]
- Pleural effusion	15 (33.3%)	12 (18.5%)	4 (10.0%)	
- Atelectasis	10 (22.2%)	8 (12.3%)	3 (7.5%)	
- Empyema	4 (8.9%)	2 (3.1%)	0 (0.0%)	
Recovery time (days)**	14 (10–18)	10 (8–13)	7 (5–9)	< 0.001[3]

Data presented as Mean ± Standard Deviation (*) or Median (Interquartile Range) (**). Statistical analysis used: One-way ANOVA ([1]), Chi-square test ([2]), and Kruskal-Wallis test ([3])

Post-hoc analysis results: Length of hospital stay was significantly different among all groups (Bonferroni correction, $p < 0.05$); Recovery time was significantly different among all groups (Mann-Whitney U test, Bonferroni correction, $p < 0.05$)

relationship between hemoglobin level and PNI; this time a positive relationship was observed ($r = 0.458$, $p < 0.001$). There is an inverse, moderate correlation between RDW and PNI ($r = -0.392$, $p < 0.001$). The Hgb/RDW ratio, combining both parameters, showed a moderate positive correlation with PNI ($r = 0.412$, $p < 0.001$). Leukocyte and neutrophil counts show a weaker negative correlation with PNI ($r = -0.286$, $p = 0.008$ and $r = -0.312$, $p = 0.004$, respectively). Lymphocyte count was different; here a strong positive correlation with PNI was found ($r = 0.624$, $p < 0.001$). Platelet count was not significantly associated with PNI ($r = -0.184$, $p = 0.092$). Among the inflammatory markers, CRP and sedimentation values also showed a negative correlation with PNI. CRP also showed a moderate negative correlation with Hgb/RDW ratio ($r = -0.398$, $p < 0.001$). On the other hand, the positive correlation between albumin level and PNI is quite strong ($r = 0.845$, $p < 0.001$) and this seems to support the accuracy of PNI as an indicator of nutritional status. When we look at markers of clinical severity, there is a moderate positive correlation between oxygen saturation and PNI ($r = 0.548$, $p < 0.001$). Oxygen saturation also showed a moderate positive correlation with Hgb/RDW ratio ($r = 0.442$, $p < 0.001$). In contrast, there are negative correlations between respiratory rate ($r = -0.462$, $p < 0.001$), fever ($r = -0.386$, $p < 0.001$) and PRESS score and PNI; the relationship with PRESS score is particularly strong ($r = -0.628$, $p < 0.001$). The PRESS score also showed a moderate negative correlation with Hgb/RDW ratio ($r = -0.486$, $p < 0.001$) (Table 5).

Discussion

This study aims to investigate the effects of Prognostic Nutritional Index (PNI) and Hemoglobin/Red Cell Distribution Width (Hgb/RDW) ratio on the prognosis of pneumonia cases, which are common in childhood and

Table 4 Hgb/RDW ratio analysis and clinical outcomes

Parameter/Clinical Feature	Pneumonia Group ($n=150$)	Control Group ($n=150$)	Low Hgb/RDW (< 0.85) < br>($n=98$, Pneumonia)	High Hgb/RDW (≥ 0.85) < br>($n=52$, Pneumonia)	*p*-value
Hgb/RDW ratio*	0.80 ± 0.12	0.93 ± 0.10	–	–	< 0.001[1]
Hgb/RDW Categories	98 (65.3%)	42 (28.0%)	–	–	< 0.001[3]
	52 (34.7%)	108 (72.0%)	–	–	
Clinical Outcomes					
Length of hospital stay (days)*	–	–	7.8 ± 2.9	5.2 ± 2.1	< 0.001[1]
Oxygen requirement	–	–	76 (77.6%)	32 (61.5%)	0.042[3]
Mechanical ventilation need	–	–	15 (15.3%)	3 (5.8%)	0.089[3]
ICU requirement	–	–	22 (22.4%)	6 (11.5%)	0.106[3]
Complication development					0.018[3]
- Any complication	–	–	58 (59.2%)	21 (40.4%)	
- Pleural effusion	–	–	28 (28.6%)	9 (17.3%)	
- Atelectasis	–	–	19 (19.4%)	6 (11.5%)	
- Empyema	–	–	6 (6.1%)	1 (1.9%)	
- Other complications	–	–	5 (5.1%)	5 (9.6%)	
Recovery time (days)**	–	–	12 (9–16)	8 (6–11)	< 0.001[2]
PRESS score**	–	–	8 (6–10)	6 (4–8)	0.003[2]
Correlation Analysis					
Length of hospital stay	$r = -0.524$	–	–	–	< 0.001 (Pearson)
Recovery time	$r = -0.568$	–	–	–	< 0.001 (Spearman)
PRESS score	$r = -0.486$	–	–	–	< 0.001 (Spearman)
PNI score	$r = 0.412$	–	–	–	< 0.001 (Pearson)
CRP	$r = -0.398$	–	–	–	< 0.001 (Spearman)
Oxygen saturation	$r = 0.442$	–	–	–	< 0.001 (Pearson)

PRESS Pediatric Respiratory Severity Score

Data are expressed as mean ± standard deviation (*), median (interquartile range) (**), or n (%). The Hgb/RDW ratio was calculated by dividing hemoglobin level (g/dL) by RDW (%).

Statistical tests used: Student's t-test ([1]), Mann–Whitney U test ([2]), and Chi-square test ([3]).

The cut-off value of 0.85 was determined via ROC analysis (AUC: 0.812, 95% CI: 0.761–0.863; sensitivity: 71.4%, specificity: 76.8%).

carry a high morbidity risk. The role of nutritional status on the course of serious infections such as pneumonia in pediatric patients has been limited in the literature. However, PNI, as an important biomarker reflecting nutritional and immune status, is closely associated with clinical outcomes such as complication development and recovery time in childhood diseases.

The evidence presented above suggests that among the children with pneumonia, those with the lowest PNI scores had the highest length of hospital stay, required the maximum amount of oxygen, and needed mechanical ventilation as well. This makes it possible that PNI and Hgb/RDW ratio can be applied for assessing pneumonia severity as well. Our study firstly demonstrates that patients with significantly low PNI values and subsequent risk of poor clinical outcomes are more likely to have several complications.

Our research confirmed that the Hgb/RDW ratio functions as a strong prognostic indicator. The patients who had low Hgb/RDW ratios (< 0.85) required longer hospital stays (7.8 vs. 5.2 days) and needed more oxygen therapy (77.6% vs. 61.5%) and developed more complications (59.2% vs. 40.4%) than patients with high ratios. The combination of low hemoglobin levels (which indicate anemia and decreased oxygen delivery) with high RDW values (which show red blood cell heterogeneity and inflammation) gives a complete view of disease severity. Research has confirmed that elevated RDW values in pediatric pneumonia patients indicate poor outcomes because they indicate the inflammatory processes and oxidative stress that occur during severe infections.

These findings support existing evidence that PNI can be used as a prognostic marker in various diseases. For example, Hong et al. reported that low PNI was associated with worse survival in small cell lung cancer patients, emphasizing that PNI may play a decisive role in disease prognosis by reflecting immunological and nutritional status [15]. Similarly, Migita et al. found that lower values of PNI were associated with worse long-term survival rates in gastric cancer patients [16]. Şahin et al.

Table 5 Correlation analysis of PNI and hgb/rdw ratio with clinical, laboratory, and severity indicators

Parameter	*r*-value	*p*-value	Correlation Type
Clinical Parameters			
Length of hospital stay (PNI)	−0.682	< 0.001	Pearson
Recovery time (PNI)	−0.724	< 0.001	Spearman
Length of hospital stay (Hgb/RDW ratio)	−0.524	< 0.001	Pearson
Recovery time (Hgb/RDW ratio)	−0.568	< 0.001	Spearman
Laboratory Parameters			
Hemoglobin (PNI)	0.458	< 0.001	Pearson
RDW (PNI)	−0.392	< 0.001	Pearson
Hgb/RDW ratio (PNI)	0.412	< 0.001	Pearson
White blood cell count (PNI)	−0.286	0.008	Spearman
Neutrophil count (PNI)	−0.312	0.004	Spearman
Lymphocyte count (PNI)	0.624	< 0.001	Pearson
Platelet count (PNI)	−0.184	0.092	Pearson
CRP (PNI)	−0.542	< 0.001	Spearman
CRP (Hgb/RDW ratio)	−0.398	< 0.001	Spearman
Sedimentation rate (PNI)	−0.486	< 0.001	Spearman
Nutritional Status & Inflammation			
Albumin (PNI)	0.845	< 0.001	Pearson
PNI score (Hgb/RDW ratio)	0.412	< 0.001	Pearson
Clinical Severity Indicators			
Oxygen saturation (PNI)	0.548	< 0.001	Pearson
Oxygen saturation (Hgb/RDW ratio)	0.442	< 0.001	Pearson
Respiratory rate (PNI)	−0.462	< 0.001	Pearson
Temperature (PNI)	−0.386	< 0.001	Pearson
PRESS score* (PNI)	−0.628	< 0.001	Spearman
PRESS score* (Hgb/RDW ratio)	−0.486	< 0.001	Spearman

Hgb/RDW ratio shows moderate negative correlations with disease severity indicators and moderate positive correlation with PNI score

Interpretation of correlation coefficient (r): 0.0-0.2

Very weak correlation; 0.2–0.4: Weak correlation; 0.4–0.6: Moderate correlation; 0.6–0.8: Strong correlation; 0.8-1.0: Very strong correlation

PRESS Pediatric Respiratory Severity Score

reported that PNI had a significant effect on intensive care requirement and mortality in cases of COVID-19 pneumonia. Our study makes a valuable contribution to the literature by demonstrating that low PNI in pediatric pneumonia cases may be an important indicator on prognosis by increasing the risk of complications [17].

In our study, we found that low hemoglobin and high RDW (Red Cell Distribution Width) values were associated with poor prognosis in pediatric patients with pneumonia. RDW is known to be an elevated marker in cases of increased inflammatory processes and therefore may play a prognostic role in the course of infection. The study by Güven et al. also points to similar findings; it was shown that high RDW values were associated with a more severe disease picture in children with community-acquired pneumonia (CAP). In particular, high RDW levels were found to reflect the severity of infection and were associated with important clinical outcomes such as length of hospitalization [7]. Similarly, the study by Lee et al. demonstrated the association of high RDW values with severe cases of pneumonia in children and emphasized that RDW can be used in the management of CAP as a low-cost, easily accessible biomarker. These findings support the hypothesis of our study that RDW may be an effective marker for predicting pneumonia prognosis [8].

The clinical practice should include PNI and Hgb/RDW ratio assessments for all children with pneumonia at the time of admission. Children who have PNI values below 40 and/or Hgb/RDW ratios below 0.85 should be classified as high-risk and may need: (1) close intensive monitoring and aggressive supportive care, (2) nutritional support interventions to improve albumin levels, (3) close monitoring of inflammatory markers and oxygen requirements, and (4) early consideration for ICU admission. These markers can be easily integrated into existing risk assessment protocols as they require only routine laboratory tests (complete blood count and albumin), making them cost-effective and widely accessible tools for risk stratification.

Our analysis of PNI components revealed important insights. The pneumonia group showed significantly lower albumin levels at 3.6 g/dL compared to 4.2 g/dL ($p < 0.001$) but lymphocyte counts remained similar between groups ($p = 0.142$). The albumin component of PNI appears to be the main prognostic factor in pediatric pneumonia according to this finding. The strong correlation between PNI and albumin ($r = 0.845$, $p < 0.001$) further supports this observation. Research has shown that albumin functions as a multifunctional protein in pediatric infections. Ari HF and colleagues found that critically ill children with hypoalbuminemia had higher mortality rates (OR: 0.322, 95% CI: 0.263–0.395) and established 3.785 g/dL as the optimal albumin level for mortality prediction [18]. Albumin functions as both a nutritional indicator and an essential regulator of inflammatory reactions and oxidative stress which play vital roles in severe pneumonia development.

The study revealed that kids suffering from pneumonia often have nutrition leading to impacts, on both the diseases progression and the chances of developing complications. Malnutrition is one of the main factors that increase susceptibility to infections by suppressing the immune system in children. The comprehensive review by Rytter et al. noted that malnutrition weakens immune responses in children, increasing the risk of death. It was pointed out that this immunosuppression creates great difficulties in the fight against infections [19]. Similarly, Krawinkel's study emphasizes that malnutrition

increases susceptibility to infections by impairing cellular and molecular immune functions. It was stated that correction of nutritional status has an important role in infection management and the importance of nutritional support was emphasized [20]. Furthermore, the study by Koçak et al. revealed that malnutrition increases the severity of infectious diseases such as pneumonia in children and the link between malnutrition and inflammation has a negative impact on prognosis [21]. These findings reveal the determinant role of nutritional status on infectious diseases and support the importance of nutritional interventions to improve the prognosis of pneumonia in children.

Research indicates that albumin combined with other inflammatory markers enhances the accuracy of patient prognosis. The lactate/albumin ratio measured at 24 h proved to be the most effective predictor of mortality for children suffering from nosocomial infections according to Arı et al. [22]. The procalcitonin/albumin ratio proved to be a strong predictor of mortality in sepsis according to Keskin and Aci who established a cut-off value of 0.185 with 79.2% sensitivity and 81.8% specificity [23]. The combination of albumin with other markers creates composite indicators which merge nutritional and immune status with inflammatory burden to provide better prognostic information than single markers.

This study brings a first and novel perspective to the literature by focusing on the use of the Prognostic Nutritional Index (PNI) in childhood pneumonia. The adults population has been shown the effectiveness of PNI in predicting prognosis during surgical and infectious diseases. For example, Araki et al. reported that in patients undergoing cardiovascular surgery, low PNI had adverse effects on postoperative complications and long-term survival [24]. Similarly, Hayashi et al. revealed that low PNI increased the risk of infection after cardiac surgery and was associated with prolonged intensive care unit stay [25]. In contrast to these studies, a study by Park et al. on patients undergoing lung cancer surgery showed that PNI is an important marker affecting both complication rates and long-term survival [26]. Our study extends these findings to childhood pneumonia cases, demonstrating that low PNI levels are associated with increased risk of complications and poor prognosis. These results suggest that PNI can be used as a valuable prognostic indicator in childhood pneumonia and emphasize the importance of nutritional status in the management of pediatric patients.

This study has some important limitations. As a first point, owing to the retrospective nature, the data quality, and the completeness of the data could not be ascertained. This might cause some data-related gaps or limitations which will bring about the loss of reliability of the findings. The retrospective design introduces selection bias by excluding patients with incomplete laboratory data and information bias from inconsistent data recording. Moreover, since it was a single center's study, the internal structure of the findings is limited to that particular center. The study's findings have limited generalizability because patient demographics and treatment protocols and outcomes may differ between healthcare settings with different resource levels and expertise. The recruitment of relatively less number of study participants might have reduced the statistical power and may have placed some doubts on the strength of the outcomes. Additionally, the retrospective design limited our ability to assess the impact of nutritional interventions on outcomes. The study had limitations because it could not control important confounding factors such as preexisting nutritional status, timing of measurements, and socioeconomic variables which prevented the establishment of causality. The generalizability of our findings may be limited to similar healthcare settings with comparable patient populations and treatment protocols.

In future studies, it would be good to focus on larger patient population, and to adopt multicenter, prospective designs. Moreover, the assessment of the predictive utility of PNI scores in variably aged subgroups as well as in different types of pneumonia, may also be able to offer worthwhile information. Stronger confidence in clinical practice may be obtained comparing PNI and other biomarkers. Long term outcome data will be a great addition to the aforementioned literature by demonstrating how prognostic PNI scores are in the long run. Future research should also investigate the optimal timing and type of nutritional interventions in children with low PNI or Hgb/RDW ratios, and whether early intervention can improve clinical outcomes.

Conclusion

This study reveals that both the Prognostic Nutritional Index (PNI) and Hemoglobin/Red Cell Distribution Width (Hgb/RDW) ratio are important prognostic markers in childhood pneumonia. Lower PNI values (<40) were associated with longer hospitalization and increased risk of complications. The study found that patients with low Hgb/RDW ratios below 0.85 experienced longer hospital stays (7.8 vs. 5.2 days) and required more oxygen (77.6% vs. 61.5%) and developed more complications (59.2% vs. 40.4%). The two markers provide different types of information because PNI shows nutritional and immune system status and Hgb/RDW ratio shows both oxygen delivery capacity and inflammatory load.

The easy availability of parameters such as serum albumin concentration and peripheral blood lymphocyte count used in the calculation of PNI, along with hemoglobin and RDW values routinely obtained from complete blood counts, makes both indices suitable for risk

assessment in pediatric pneumonia patients in clinical practice. The results indicate that children with PNI < 40 and/or Hgb/RDW ratio < 0.85 should be considered high-risk and may benefit from early intensive monitoring, aggressive supportive care, and nutritional interventions.

Furthermore, the evaluation of PNI in combination with Hgb/RDW ratio has demonstrated the potential to more accurately predict the prognosis of patients. The markers show strong correlations with clinical outcomes such as hospital stay duration and recovery time and mechanical ventilation requirements which makes them useful as practical prognostic tools. With the consistent utilization of these markers, it is possible to identify those patients who are members of the high-risk cohort such that treatment strategies can be customized for them. Such an approach will assist in offering better and more focused care in the health care management of childhood pneumonia.

Abbreviations

PNI	Prognostic Nutritional Index - A measure of nutritional and immune status calculated using serum albumin and lymphocyte count
Hgb/RDW	Hemoglobin to Red Cell Distribution Width Ratio - A ratio used to assess inflammation and anemia
CRP	C-reactive Protein - A biomarker of inflammation

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
O.C and O.A. designed the study.O.C. and O.A. wrote the main manuscript text.O.C. prepared tables and figures.All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Ethical approval for the study was obtained from the Scientific Research Ethics Committee of Balıkesir Atatürk City Hospital (Decision No: 2024/09/51, Date: 19.09.2024). Written informed consent was obtained from all participants, and for participants under the age of 16, consent was obtained from their parents or legal guardians.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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