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Original Article

Prognostic Nutritional Index as a Severity Indicator in Mechanically Ventilated Children

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Abstract

Introduction: Critically ill patients encounter significant health problems, which are reflected in the morbidity and mortality rates in intensive care units (ICUs). The prognostic nutritional index (PNI), which gauges immunological and nutritional health, is increasingly recognized as a significant predictor of outcomes in critical care units. The present study aimed to assess the prognostic nutritional index as a marker of severity in mechanically ventilated children.

Methods: This retrospective cross-sectional study was conducted from January 2023 to October 2024 in the Paediatric Intensive Care Unit (PICU) of M S Ramaiah Medical College Hospital, Bangalore. All critically ill children admitted to the PICU during the study period were included. Purposive sampling was used; 184 consecutive critically ill children (93 were mechanically ventilated and 91 were non-mechanically ventilated) were included. Retrospective case record data collection was performed using a demographic questionnaire, including Paediatric Risk of Mortality III (PRISM-3) scoring and complete blood counts. The data were analysed using SPSS 22 software. Statistical analysis, including Pearson correlation, was used to evaluate the association between the prognostic nutritional index and the severity of illness. *P*-values <0.05 were considered significant.

Results: The mean PNI for ventilated patients was 47.01, which was significantly lower than that for non-ventilated patients (56.84; $P=0.002$**).** PNI also showed a weak positive correlation with length of hospital stay ($r=0.03282$, $P=0.7548$) and PRISM-3 score ($r=0.105$). The mean PNI was lower among non-survivors than among survivors (48.35 vs. 52.73), but the difference was not statistically significant ($P=0.298$).

Conclusion: Our findings highlight that, at admission, PNI is a weak severity indicator among mechanically ventilated children.

Keywords: Prognostic nutritional index, Pediatric risk of mortality III score, Pediatric intensive care unit, Critical illness, Mechanical ventilation, Body mass index

Introduction

Invasive mechanical ventilation (IMV) is necessary for one-third of children hospitalized in a pediatric intensive care unit (PICU). Between 17 and 64 percent of children in PICUs in developed nations are on mechanical ventilation.

A ventilated patient's mortality is determined by their co-morbidities, follow-up issues, and clinical state (1). Immune system dysfunction and malnutrition are particularly common in intensive care unit patients and are major contributors to poor prognosis, delayed recovery, and infection susceptibility. The Prognostic Nutrition Index (PNI) is an objective indicator calculated from serum albumin levels and lymphocyte counts. Laboratory parameters that constitute PNI are routinely evaluated in most clinical settings, making PNI a readily available biomarker. PNI has been used to classify nutritional status, as shown in Table 1 (2).

Originally, PNI was used for risk assessment of post-surgery patients; recently, its use as a risk stratification indicator in critically ill patients has become an area of increasing research. In a longitudinal, retrospective study by Bertagnolli et al., who examined the role of PNI in mortality among children and adolescents who underwent cardiac surgery, concluded that, despite being an easily applicable indicator of nutritional status, PNI showed a poor association with mortality (3). Another retrospective study by Ji et al. examined the association between the prognostic nutritional index and all-cause mortality in critically ill patients with ventilator-associated pneumonia. It concluded that a higher PNI at ICU admission was independently associated with lower short-term and long-term mortality in critically ill VAP patients. Even though studies have yielded varying results, PNI is still being researched, as it is a simple tool that could enable early identification of high-risk patients and guide targeted nutritional and immunological interventions (4).

The importance of lymphocytes in the human immune response is multifold. Its primary functions are to provide innate and adaptive immunity, support antibody

Table 1. Classification of nutritional status based on the Prognostic Nutritional Index.

PNI value	Nutritional status
≥50	Normal
<50	Mild malnutrition
<45	Moderate to severe malnutrition
<40	Serious malnutrition

PNI, Prognostic Nutritional Index

production, and destroy cancerous cells. Hence, it is not surprising that it has been used in multiple indices to assess its prognostic significance. Lymphocyte count ratios, such as the neutrophil-to-lymphocyte ratio and the platelet-to-lymphocyte ratio, are well-documented markers of severity (5). In low- and middle-income countries, such as India, undernutrition is significant. PNI is a baseline screening tool that is easily applied to assess nutrition and immune status. Our literature search showed a paucity of research material on the use of PNI in critically ill mechanically ventilated children, especially from our subcontinent; hence, this study was designed to assess PNI as a severity indicator in mechanically ventilated children by evaluating its association with all-cause in-hospital mortality, length of hospital stay, and PRISM-3 scores, and by comparing PNI between mechanically ventilated and non-mechanically ventilated children.

Methods

This is a cross-sectional, retrospective study conducted from January 2023 to October 2024 at an intramural level-3 PICU of a tertiary care hospital in India to evaluate the association of PNI with mechanically ventilated children. This study was approved by the institute ethics committee (Number- EC/NEW/INST/2023/KA/0244).

We included critically ill children between the ages of 2 months and 18 years who were mechanically ventilated and non-mechanically ventilated. Children with incomplete data, such as no albumin or CBC data, and those who died within 6 hours of admission were excluded.

Retrospective case file analysis was performed; patient demographic details, including age, gender, height, weight, body mass index, diagnosis, PRISM-3 scores at admission, whole blood counts, absolute lymphocyte count, serum albumin, and serum creatinine, were recorded in a detailed form. Outcome measures, such as in-hospital mortality and length of ICU stay, were recorded. For all enrolled subjects, the Prognostic Nutritional Index was calculated as: PNI = 10 × serum albumin (g/dL) + 0.005 × total lymphocyte count (cells/mm^3). Patients were assessed for both primary and secondary outcomes. Primary outcome measures included the length of hospital stay, all-cause in-hospital mortality, and PRISM-3 scores among mechanically ventilated children. The secondary outcome was to compare PNI between ventilated and non-ventilated children.-

The sample size was calculated using the formula below

$$\frac{N = Z^2 \times p(1-p)}{d^2}$$

where:

- N = required sample size
- Z = Z-value (1.96 for 95% confidence)
- p = expected sensitivity or specificity (whichever is lower or more conservative)
- d = precision (margin of error), here 0.10 (10%)

A retrospective study on the relationship between the Prognostic Nutrition Index (PNI) and all-cause mortality in critically ill patients found that PNI sensitivity for predicting poor outcome was 73.5% and specificity was 73.3% (4). The Prognostic Nutrition Index (PNI) among children in the present study was expected to yield results similar to those in mechanically ventilated children with 95% confidence and 10% absolute precision, and the calculated minimum sample size was 75. The sample collected comprised 93 mechanically ventilated patients and 91 non-mechanically ventilated critically ill children for comparative analysis.

Data were entered into a Microsoft Excel sheet, and analysis was performed using SPSS version 22 (IBM SPSS Statistics, Somers, NY, USA). Categorical data were represented as frequencies and proportions. The chi-square test or Fisher's exact test (for 2 × 2 tables only) was used to test significance for qualitative data. Continuous data were reported as mean ± standard deviation. An independent *t*-test was used to test the significance of the difference between two quantitative variables. Correlations were performed with the Pearson correlation coefficient.

Results

We screened the records of over 800 cases who were admitted to a tertiary-level PICU at Ramaiah Medical College Hospital from January 2023 to October 2024. Of these, 110 patients were mechanically ventilated; 17 were excluded due to repeated admissions and missing albumin level data. For the final analysis, 93 critically ill ventilated children were included in the study group. We also included 91 critically ill children who did not require ventilatory support as a comparative group.

Table 2 shows the demographic details of the study cohort for both mechanically and non-mechanically ventilated children. In the ventilated group, 46.2% were male, and 53.8% were female. In the non-ventilated group, 51.6% were male, and 48.4% were female. The mean age in the ventilated group was 7.84 years with a standard deviation (SD) of 5.70, vs. 8.77 years with an SD of 5.59 in the non-ventilated group. The mean BMI for the ventilated group was 16.04 kg/m^2 with an SD of 3.31 vs. 16.56 kg/m^2 with an SD of 3.07 in the non-ventilated group. The mean WBC count for the ventilated group was 14608 with an SD of 10062, vs. 13487 with an SD of 8468. The mean ALC for the ventilated group was 3766.84 with an SD of 3818.03, vs. 3621.02 with an SD of 3871.038 in the non-ventilated group. There was no statistically significant difference between the two groups for age,

Table 2. Demographic details of the study cohort

	Ventilated n=93	Non-ventilated n=91	*P* value
Age (years) Mean (SD)	7.84 (5.70)	8.77(5.59)	0.262
Gender Male, *n* (%) Female, *n* (%)	43 (46.2) 50 (53.8)	47(51.6) 44 (48.4)	0.555
Body mass index (BMI) (kg/m^2) Mean (SD)	16.04 (3.31)	16.56 (3.0749)	0.268
White blood cell count (WBC) (/mm^3) Mean (SD)	14608 (10062)	13487 (8468)	0.418
Absolute lymphocyte count (ALC) Mean (SD)	3766.84 (3818.03)	3621.02 (3871.038)	0.798
Platelets(10^9/mm^3) Mean (SD)	1.14 (0.47)	2 (1.45)	<0.01
S. Albumin Mean (SD)	2.8 (0.6)	3.9 (0.9)	<0.01
S. Creatinine Mean (SD)	1.64 (0.76)	0.50 (0.30)	<0.01
Length of hospital stay (days) Mean (SD)	11 (7)	4 (2)	<0.01
Systems (%) Central nervous system Cardiovascular system Respiratory system Gastrointestinal system Renal system Infectious diseases Poisonings Surgical Others	26.9 14 16 9.7 4.3 9.7 3.2 5.4 10.8	17.6 2.2 12.1 19.8 5.5 19.8 12 3.3 7.7	
PNI , Mean (SD)	47.01 (19.9)	56.84 (23.12)	0.002
PRISM-3, Mean (SD)	23.30 (5.974)	13.21 (5.691)	<0.001
Death	34	0	

gender, BMI, ALC, or WBC (*P*-values > 0.05). In contrast, ventilated patients showed significantly deranged biochemical and nutritional parameters: platelet counts were markedly lower (1.14 ± 0.47 vs. 2.00 ± 1.45, $P < 0.01$), serum albumin levels were reduced (2.8 ± 0.6 vs. 3.9 ± 0.9, $P < 0.01$), and the serum creatinine was higher (1.64 ± 0.76 vs. 0.50 ± 0.30, $P < 0.01$). The length of hospital stay was significantly longer in the ventilated group (11 ± 7 vs. 4 ± 2 days, $P < 0.01$). Among mechanically ventilated and non-mechanically ventilated children, the central nervous system (CNS) was the most frequently affected system requiring admission. This was followed by infectious, respiratory, and gastrointestinal (GIT) conditions. The mean PNI for ventilated patients (47.01) was significantly lower than that for non-ventilated patients (56.84), with a *P*-value of 0.002, indicating statistical significance. Mean PRISM-3 score for ventilated patients (23.30) was significantly higher than that for non-ventilated patients (13.21), with a *P*-value < 0.001.

Table 3 shows the comparison of PNI and PRISM-3 scores between survivors and non-survivors in the mechanically ventilated group. The mean PNI was 48.35 in non-survivors and 52.73 in survivors, with a *P*-value of 0.298, indicating no statistical significance. However, survivors had a higher mean PNI compared to non-survivors. The mean PRISM-III score for non-survivors was 30, significantly higher than the 15.61 seen in survivors, which was statistically significant ($P < 0.001$), indicating a strong association between elevated PRISM-III scores and mortality risk among mechanically ventilated patients.

Table 3. Comparison of PNI and PRISM 3 between survivors and non-survivors in the mechanically ventilated group

	Outcome	Mean	SD	*P*-value
PNI value	Non survivors	48.350000	24.1118762	0.298
	Survivors	52.738935	21.6675177	
PRISM-3	Non survivors	30.00	3.191	<0.001
	Survivors	15.61	5.691	

Figure 1 shows a scatter plot illustrating the correlation between the Prognostic Nutritional Index (PNI) and the length of hospital stay in mechanically ventilated children admitted to the intensive care unit. The analysis revealed a weak positive correlation between PNI scores and hospital stay duration ($r = 0.03282$). However, this correlation was not statistically significant (*P*-value = 0.7548).

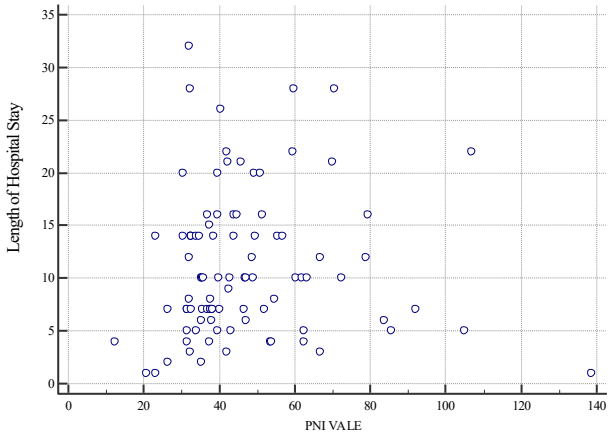
Figure 2 shows a scatter plot representing the correlation between the Prognostic Nutritional Index (PNI) and the PRISM-3 score among the mechanically ventilated group. PRISM-3 was used as a marker of disease severity in mechanically ventilated pediatric patients. When PNI was correlated with PRISM-3 scores, the analysis showed a weak positive correlation ($r = 0.1058$).

Discussion

The present study investigated the relationship between PNI and the severity of indicators in critically ill, ventilated patients. Based on the baseline characteristics of the subjects enrolled in this study, there are no significant differences in age, BMI, gender, or systemic involvement between the ventilated and non-ventilated groups. However, significant differences were observed in mean PNI values, severity scores, and laboratory parameters between the two groups. Regarding the association between PNI and mortality, our study did not show a significant difference, although the mean PNI values (48.3 vs. 52.73) were lower among non-survivors. Further, PNI showed only a weak positive correlation between length of hospital stay and PRISM-3 scores.

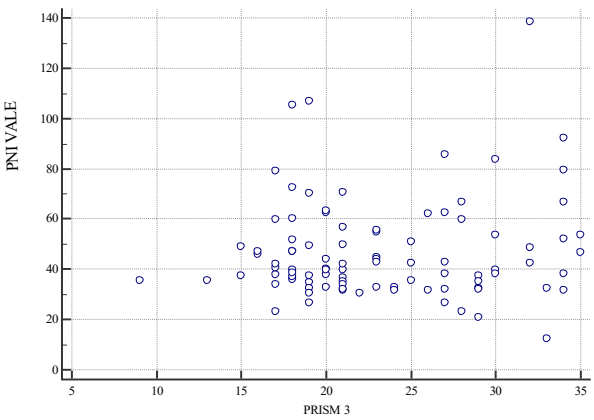
To the best of our knowledge, this is the first study to examine the association between the Prognostic Nutritional Index and non-COVID-19 ventilated paediatric patients.

Numerous previous studies have assessed the utility of PNI in the paediatric age group; a study in infants (< 18 months) undergoing congenital cardiac surgery found that a PNI cutoff of ≤ 66.5 predicted longer ICU stays, hospital stays, and mechanical ventilation duration (6). Another large study, conducted in 1196 neonates, assessed PNI as a predictor of neonatal sepsis and its severity and found that PNI was independently and inversely associated with sepsis risk and severity. Lower PNI correlated with higher procalcitonin and CRP levels and longer hospital stays (7). In a study on 54 children



Sample size	93
Correlation coefficient (*r*)	0.03282
Significance level	*p* = 0.7548
95% Confidence interval for *r*	−0.1720 to 0.2350

Figure 1. Scatter plot showing correlation between PNI value and length of hospital stay



Variable Y	PNI_VALE PNI VALE
Variable X	PRISM_3 PRISM 3
Sample size	93
Correlation coefficient (*r*)	0.1058
Significance level	*p* = 0.3129
95% Confidence interval for *r*	−0.1001 to 0.3030

Figure 2. Scatter plot showing correlation between PNI and PRISM-3 score

with chronic kidney disease (CKD), the PNI was < 35 in 29 children (53.7%) and ≥ 38 in 13 (24.1%). The study further added that children in the low PNI group had stage 4 CKD and also a low glomerular filtration rate (8). All studies have consistently shown a strong correlation between PNI and mortality (9). In a 2014 review, 16 nutrition-related biomarkers and indices, including PNI, were assessed in critically ill children aged 1 day to 18 years. No single biomarker or index, including PNI, consistently predicted outcomes across all trials. However, several biomarkers, including PNI, showed positive associations with clinical outcomes in individual studies (e.g., ICU stay, ventilation duration, and mortality) (10).

Poor nutritional status has been linked to impaired immune function, increased susceptibility to infections, and prolonged recovery, all of which are critical concerns in pediatric intensive care.–A retrospective study done in 2020 on ventilated children in a trauma unit found that normal-weight patients had a mean ventilator duration of 4.6 days, while both underweight and morbidly obese patients required a longer duration of mechanical ventilation (11). Malnutrition at admission is a prognostic factor in pediatric critical care; its dynamic nature often worsens during the course of critical illness due to cumulative deficits in energy and protein driven by ongoing catabolism (12). Albumin has a long half-life; a single assessment may not reflect acute changes in nutritional status during severe illness (13). Our study results show that at admission, PNI had a very weak association with illness severity but did not predict mortality. There is a disparity between our study results and those of other studies. Firstly, only 18 of our ventilated patients had signs of undernutrition, suggesting that our cohort did not have abnormal nutritional status, unlike subjects in other studies, especially those involving adults or patients with more chronic conditions. Secondly, albumin levels can fluctuate due to factors beyond nutritional intake, such as acute-phase responses, liver function, hydration status, and the effects of medications or interventions. Finally, in children with chronic illness, admission nutritional status is often compromised, which can affect baseline PNI scores. As our subjects did not present with pre-existing chronic illness, it makes sense that their PNI scores at admission may not have reflected the same severity of illness or risk as the subjects in other studies. Hence, a single PNI measurement can serve as a severity marker in critically ill pediatric patients, particularly during ventilation.

The key strengths of our study include a large total sample size ($N = 183$), a substantial subset of mechanically ventilated children ($n = 93$), and a heterogeneous cohort encompassing multiple disease categories. This study also has limitations. It was a single-center study; therefore, the findings may not be generalizable to the broader population of critically ill pediatric patients, particularly those in other healthcare environments, regions, or countries.

Conclusion

PNI is an easily applicable, objective, and fast tool.

Children who are mechanically ventilated with a low PNI may have poorer outcomes and longer ICU stays. Low PNI (<45) can be used as a triage score for length of hospital stay and severity, but PNI is not a predictor of mortality.

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Authors' Contribution
Conceptualization: Hari Chandana and Shruti Patil
Data curation: Hari Chandana, Isha Kittur, and Karthik Yadavalli
Formal analysis: Hari Chandana and Shruti Patil
Investigation: Hari Chandana
Methodology: Hari Chandana and Shruti Patil
Project administration: Hari Chandana and Shruti Patil
Supervision: Shruti Patil
Validation: Hari Chandana and Shruti Patil
Writing original draft: Hari Chandana
Writing review & editing: Hari Chandana and Shruti Patil

Competing Interests
None.

Ethical Approval
This study was approved by the institute ethics committee (Number-EC/NEW/INST/2023/KA/0244).

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