Original Article

Clinical Predictors and Respiratory Severity Assessment of Pneumonia in Children with Protein Energy Malnutrition: A Hospital-Based Study

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Abstract

Background: Pneumonia remains a leading cause of morbidity in children with protein-energy malnutrition (PEM), yet atypical presentations frequently complicate bedside diagnosis. This study aimed to evaluate the clinical profile of pneumonia in children with PEM and validate a novel Respiratory Severity Index (RSI) for accurate clinical prediction. **Material and Methods:** A retrospective cross-sectional study was conducted in a tertiary care teaching hospital involving 70 children (aged 6 months to 12 years) diagnosed with PEM according to the Indian Academy of Paediatrics (IAP) classification. Clinical, nutritional, and radiological data were systematically reviewed. A 4-point RSI was developed by assigning one point each for the presence of tachypnoea, chest retractions, crepitations, and feeding difficulty, and was assessed against radiologically confirmed pneumonia. **Results:** The incidence of radiologically confirmed pneumonia in the PEM cohort was 25.7%. Classic respiratory signs—specifically cough, tachypnoea, chest retractions, crepitations—along with feeding difficulties, were universally present (100%) in all pneumonia cases and were significantly more common compared to those without pneumonia ($p < 0.001$). PEM severity (IAP grading) did not significantly correlate with the occurrence of pneumonia ($p = 0.824$). The RSI demonstrated excellent discriminatory ability for identifying pneumonia, yielding an Area Under the Curve (AUC) of 0.962. Furthermore, all children with confirmed pneumonia clustered in the high-risk RSI category (score of 4), exhibiting significantly higher mean scores than those without pneumonia (4.00 vs. 0.44, $p < 0.001$). **Conclusion:** The RSI is a simple, non-invasive, and highly reliable bedside tool that accurately predicts pneumonia in malnourished children. Its routine implementation in resource-limited hospital settings can facilitate early diagnosis, guide prompt management, and ultimately mitigate paediatric morbidity.

Keywords: Protein-Energy Malnutrition; Paediatric Pneumonia; Respiratory Severity Index; Clinical Predictors; Diagnostic Screening; Resource-Limited Settings.

Received: 19 May 2026 **Revised: 03 June 2026** **Accepted: 25 June 2026** **Published: 29 June 2026**

Introduction

Pneumonia is a leading cause of mortality and morbidity among under five children globally and accounts for approximately 18% of all deaths in this age group.[1–3] India is no exception in the amount of the disease burden among developing nations.[4,5] A significant portion of these is linked to undernutrition.[6,7] More than 50% of childhood pneumonia deaths are associated with malnutrition.[8,9] Severe malnutrition profoundly exacerbates prognosis of respiratory infection and may lead to 15 times more fatality rate than compared to well-nourished children.[9]

There is bidirectional relationship between malnutrition and pneumonia, and this creates a vicious cycle of disease and nutritional decline. Protein-energy malnutrition (PEM) leads to deterioration of immune function leading to impairing both cell mediated defences and humoral mediated components.[10] Such conditions predispose malnourished children to severe infection altering disease response. Among malnourish children a clinical presentation of pneumonia are often atypical or protean.[11] Adding to this, sub-optimal inflammatory responses, depletion of intracellular electrolytes and reduced respiratory muscle mass may lead to absence of classical diagnostic signs of tachypnoea and chest indrawing.[12] This occult pneumonia presentation can only be confirmed by radiographically and therefore accurate clinical diagnosis is a major challenge for healthcare professionals.[13]

Given these diagnostic difficulties, complete reliance on clinical criteria can be inadequate for identifying pneumonia in PEM cohorts.[14] To improve diagnostic accuracy and severity grading various respiratory severity scoring systems such as respiratory index severity in children and respiratory severity score have been explored to predict hospitalization duration oxygen requirement and mortality risk.[15–17] There remains a pressing need to identify reliable clinical predictor and develop a tailor

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DOI:
10.21276/amit.2026.v13.i2.788

How to cite this article: Shravanthi J, Reddy RVG, Meghana KS, Shekar BR. Clinical Predictors and Respiratory Severity Assessment of Pneumonia in Children with Protein Energy Malnutrition: A Hospital-Based Study. Acta Med Int. 2026;13(2):894-899.

made simple bedside assessment tool specifically for children with PEM.

Therefore, this study was undertaken with objectives of determining the incidence and clinical profile of pneumonia among PEM children, to explore the association between severity of PEM and occurrence of pneumonia. In addition, it was also aimed to develop and assess a Respiratory Severity Index (RSI) based on bedside clinical findings for identifying pneumonia among children with protein energy malnutrition and to evaluate the association between RSI scores and radiologically confirmed pneumonia

Materials and Methods

Study design: A hospital-based retrospective cross-sectional study was conducted in the Department of Paediatrics of a tertiary care teaching hospital. Medical records of children diagnosed with PEM during the study period were reviewed to determine the incidence of pneumonia, evaluate associated clinical characteristics, and identify predictors of pneumonia among malnourished children.

Study duration: The study included eligible children admitted over a two-year period from March 2024 to February 2026.

Study population: The study population comprised children aged 6 months to 12 years diagnosed with protein energy malnutrition and admitted to the paediatric department during the study period.

Definition of Protein Energy Malnutrition: PEM was classified according to the Indian Academy of Paediatrics (IAP) Classification, based on weight-for-age percentage into grade I to IV PEM. For analytical purposes, children were additionally categorized into mild PEM (Grade I) and moderate-to-severe PEM (Grade II–IV).

Definition of pneumonia: Pneumonia was diagnosed based on the documented clinical diagnosis supported by radiological evidence recorded in the medical records. Chest radiograph findings consistent with pneumonia were considered the reference standard for classification.

Sample size: All eligible children with PEM admitted during the study period and having complete clinical, nutritional, and radiological records were included in the study. Consecutive sampling of available medical records was employed.

Inclusion criteria: Children aged 6 months to 12 years, diagnosed with PEM according to IAP criteria, with complete clinical and radiological records available were included in the analysis.

Exclusion criteria: Children with congenital heart disease, chronic lung disease, bronchial asthma, known immunodeficiency disorders, tuberculosis were excluded. Those with incomplete medical records were excluded.

Data collection: Data were extracted retrospectively from inpatient records, nutritional assessment charts, laboratory reports, radiology reports, and discharge summaries using a structured data collection proforma. The following variables were recorded - demographic variables (age and sex), nutritional variables (weight and nutritional grade according to IAP classification). Clinical variables included presence or absence of fever, cough, tachypnoea, chest retractions, feeding difficulty, crepitations on auscultation, oxygen saturation, any other documented respiratory signs. Presence or absence of pneumonia on chest radiograph was noted separately. Outcome variables included recovery, requirement of oxygen therapy, duration of hospitalization and mortality, if any.

Respiratory Severity Index (RSI) was calculated by assigning one point each to tachypnoea, chest retractions, crepitations and feeding difficulty. The total RSI score ranged from 0 to 4, with higher scores indicating greater respiratory severity and were grated into low (0-1), moderate (2-3) and high risk (score 4). A binary variable termed Severe PEM Status was created where Grade I was considered as mild PEM and Grade II–IV was considered as moderate-to-severe PEM. This variable was used to assess the relationship between nutritional severity and occurrence of pneumonia.

Statistical analysis: Data were entered into Microsoft Excel and analyzed using JASP version 0.19.3 (University of Amsterdam, Netherlands). Continuous variables were assessed for normality and summarized as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables were expressed as frequencies and percentages. The incidence of pneumonia among children with PEM was calculated as the proportion of children with radiologically confirmed pneumonia among the total PEM cohort. Comparisons between children with and without pneumonia were performed using Chi-square test or Fisher's exact test for categorical variables and independent Student's t-test or Mann–Whitney U test for continuous variables.

The association between PEM severity and pneumonia was assessed using Chi-square analysis. RSI scores were compared between pneumonia and non-pneumonia groups using the Mann–Whitney U test. The predictive utility of RSI for identifying pneumonia was evaluated using Receiver Operating Characteristic (ROC) curve analysis. Area Under the Curve (AUC), sensitivity, specificity, and optimal cut-off values were calculated using the Youden Index. Odds ratios (OR) with 95% confidence intervals were calculated for significant predictors of pneumonia. A p-value <0.05 was considered statistically significant.

Ethical considerations: Institutional Ethics Committee approval was obtained prior to commencement of the study. As the study involved retrospective review of existing hospital records, waiver of informed consent was obtained from the Ethics Committee. All patient identifiers were removed before data extraction and analysis. Confidentiality of patient information was maintained throughout the study, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the Indian Council of Medical Research guidelines for biomedical research involving human participants.

Results

Baseline characteristics: A total of 70 children with protein energy malnutrition were included. The mean age was 28.47 ± 16.20 months. Males constituted 41 cases (58.6%) and females 29 cases (41.4%). According to IAP grading, 52 children (74.3%) had Grade I PEM, 15 (21.4%) had Grade II PEM, and 3 (4.3%) had Grade III PEM.

Incidence of pneumonia among children with PEM: Radiologically confirmed pneumonia was present in 18 of 70 children, giving an incidence/proportion of 25.7% among children with PEM [Figure 1].

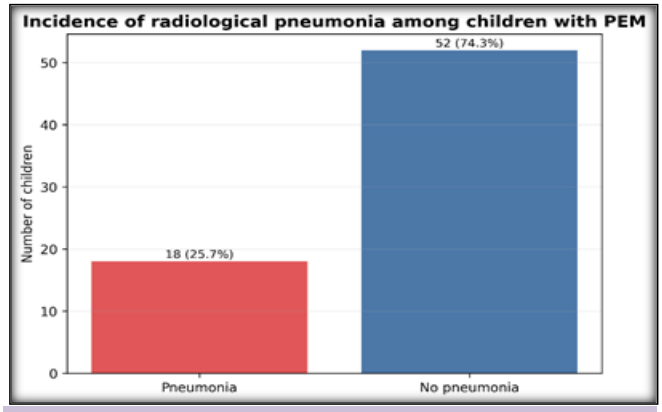

Figure 1: Incidence of radiologically confirmed pneumonia among children with protein energy malnutrition.

Association between PEM severity and pneumonia: Pneumonia was seen in 14/52 children (26.9%) with Grade I PEM, 3/15 (20.0%) with Grade II PEM, and 1/3 (33.3%) with Grade III PEM. The association between IAP grade of PEM and pneumonia was not statistically significant ($\chi^2 = 0.39$, $p = 0.824$).

Clinical profile of children with pneumonia

Among children with radiological pneumonia, cough, feeding difficulty, tachypnea, chest retraction, and crepitations were present in all 18 cases (100%). Fever was present in 13 children (72.2%). Hepatomegaly was observed in 6 children (33.3%). No child with pneumonia had altered sensorium [Figure 1]. When compared with children without pneumonia, cough, feeding difficulty, tachypnea, chest retraction, and crepitations were significantly more common among children with pneumonia [Table 1].

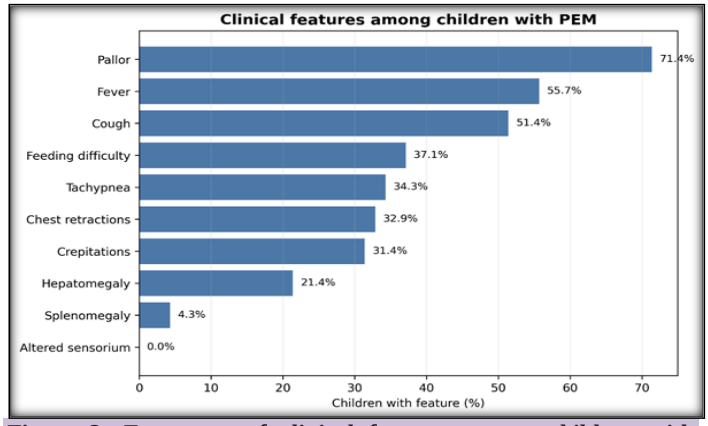

Figure 2: Frequency of clinical features among children with protein energy malnutrition

Table 1: comparison of clinical profile of PEM children with and without pneumonia.

Clinical feature	Pneumonia present (n=18)	Pneumonia absent (n=52)	p-value
Fever	13 (72.2%)	26 (50.0%)	0.168
Cough	18 (100%)	18 (34.6%)	<0.001
Feeding difficulty	18 (100%)	8 (15.4%)	<0.001
Tachypnea	18 (100%)	6 (11.5%)	<0.001
Chest retraction	18 (100%)	5 (9.6%)	<0.001
Crepitations	18 (100%)	4 (7.7%)	<0.001
Hepatomegaly	6 (33.3%)	9 (17.3%)	0.188

Respiratory Severity Index analysis

The Respiratory Severity Index ranged from 0 to 4. All children with radiological pneumonia had an RSI score of 4, whereas most children without pneumonia had an RSI score of 0.

The mean RSI was significantly higher among children with pneumonia compared with those without pneumonia (4.00 ± 0.00 vs 0.44 ± 1.16; $p < 0.001$). Pneumonia cases clustered predominantly in the high-risk RSI category, while most children without pneumonia were in the low-risk category [Table 2].

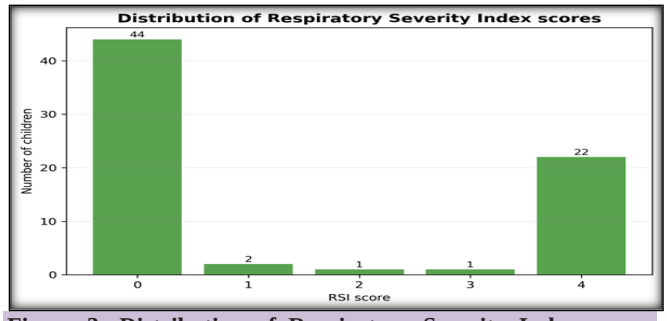

Figure 3: Distribution of Respiratory Severity Index scores among children with protein energy malnutrition. Higher RSI scores indicate a greater burden of bedside respiratory severity markers, including tachypnea, chest retractions, crepitations, and feeding difficulty.

Table 2: Association between Respiratory Severity Index (RSI) category and radiologically confirmed pneumonia status.

RSI category	Pneumonia present	Pneumonia absent
Low risk (0–1)	0	46
Moderate risk (2–3)	0	2
High risk (4)	18	4

ROC analysis showed excellent discriminatory ability of RSI for identifying radiological pneumonia, with an AUC of 0.962 [Figure 4].

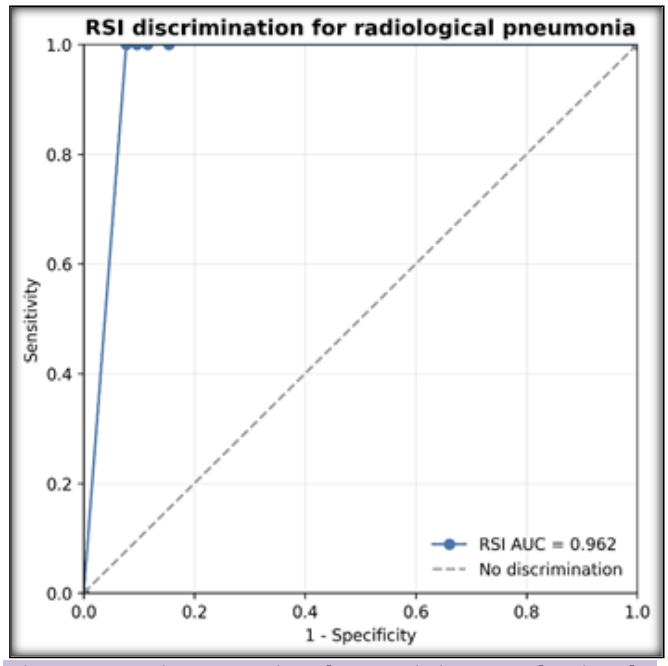

Figure 4: Receiver operating characteristic curve showing the discriminatory performance of the Respiratory Severity Index for identifying radiologically confirmed pneumonia among children with protein energy malnutrition. The RSI demonstrated excellent discrimination, with an area under the curve of 0.962.

Discussion

This study evaluated the incidence clinical profile and predictors of pneumonia among children with the PEM. Further a 4-point bedside RSI based on clinical features was developed. The RSI demonstrated excellent discriminatory ability (AUC = 0.962), with all pneumonia cases clustering in the high-risk category (RSI score of 4). Interestingly, our study did not find a statistically significant association between the severity grade of PEM and the occurrence of pneumonia (p = 0.824).

The incidence of pneumonia in our PEM cohort is somewhat lower (25.7%) compared to several other Indian studies. Dillip Das et al. reported a pneumonia prevalence of 46.2% among children with severe acute malnutrition admitted to a tertiary centre in Cuttack, Odisha.[18] Similarly, Arpitha et al. from Khammam, Andhra Pradesh, reported a 46% prevalence.[19] The lower incidence in our study could be attributed to the demographic makeup of our cohort, wherein the majority of patients (74.3%) had mild (Grade I) PEM, whereas the aforementioned studies focused predominantly on severe forms of acute malnutrition.

Recognizing pneumonia in malnourished children relies heavily on bedside clinical signs, though these can sometimes be atypical due to blunted immune responses. In our study, classic respiratory signs including cough, tachypnoea, chest retractions, and crepitations, along with feeding difficulties, were present in 100% of the pneumonia cases. This strong clinical presentation aligns with extensive Indian literature. Shukla et al., in a study from Baroda, Gujarat, found cough in 98% and fast breathing in 95% of severe acute malnutrition children with pneumonia.[20] Das et al. similarly noted tachypnoea in 97.5% and chest retractions in 96.7%.[18] Fever was present in 72.2% of our pneumonia cases, which is strikingly consistent with the 72% reported by Arpitha et al.[19] and the 72.1% reported by Das et al.[18]

Unlike several previous studies,[21-24] our analysis did not find a statistically significant correlation between the IAP grade of PEM and the incidence of pneumonia. In contrast, Arpitha et al. demonstrated a clear dose-response relationship, noting that the incidence of pneumonia increased significantly from 35.5% in Grade I PEM to 72% in Grade IV PEM, alongside an increase in disease severity.[19] The lack of a significant association in our findings may be influenced by the uneven distribution of nutritional grades in our sample, with only a very small fraction (4.3%) belonging to Grade III and no Grade IV cases, limiting the statistical power to detect such a trend.

A hallmark finding of this study is the validation of the RSI. Due to the altered physiology in malnourished children, classic diagnostic signs can sometimes be absent, leading to "occult pneumonia" (radiological pneumonia without standard clinical signs), which Raza & Beig observed in 12.8% of their severe acute malnutrition cohort in Aligarh.[25] This makes structured clinical scoring systems essential. Our RSI successfully discriminated pneumonia cases with an AUC of 0.962. The reliance on simple bedside scoring is supported by another Indian researcher, Verma et al. in Assam validated the Respiratory Index of Severity in Children (RISC) score, confirming its utility as a reliable tool for predicting mortality and severity in paediatric pneumonia in resource-limited, hospital-based settings.[26] Developing and utilizing such indices enables prompt, aggressive management before severe hypoxic or septic complications arise.

Limitations of the study: As a retrospective cross-sectional study, it inherently relies on the accuracy and completeness of existing medical and radiological records, which may introduce information bias or missing data. Underrepresentation of severe PEM grades likely reduced the statistical power to accurately assess the relationship between malnutrition severity and pneumonia occurrence. Single tertiary care teaching hospital may not be entirely generalizable to community settings. Study did not account for concurrent micronutrient deficiencies (such as Vitamin D deficiency).

Conclusion

Based on the findings of this hospital-based study, pneumonia was noted among 25.7% children with PEM. The severity of malnutrition according to the IAP grading system did not show a statistically significant association with the occurrence of pneumonia. This study successfully developed and evaluated a 4-point bedside Respiratory Severity Index (RSI). The RSI demonstrated excellent discriminatory ability for identifying radiologically confirmed pneumonia, achieving an Area Under the Curve (AUC) of 0.962. Its routine implementation in resource-limited and hospital-based settings can facilitate the

early bedside diagnosis of pneumonia.

Acknowledgements: Authors acknowledge the faculty of medical record section for providing data required to undertake this study. Authors also thank Dean and management of college for facilitating the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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