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Original Research Article

Predictors of Morbidity and Mortality in Children with Severe Pneumonia Admitted to a Tertiary Care Hospital

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Abstract:

Background: Severe pneumonia remains a major cause of childhood morbidity and mortality, particularly in resource-constrained settings. Early identification of children at increased risk of adverse outcomes is essential for timely supportive and critical care.

Aim: To identify predictors of morbidity and mortality among children with severe pneumonia admitted to a tertiary care hospital in Bihar, India.

Methodology: This prospective observational study was conducted over one year in the Department of Pediatrics, Patna Medical College and Hospital, Patna. A total of 196 children aged 2–59 months with WHO-defined severe or very severe pneumonia were enrolled. Demographic, socioeconomic, clinical, laboratory, radiological, treatment, and hospital outcome data were recorded. Associations were assessed using appropriate statistical tests, and independent predictors of mortality were identified using multivariable logistic regression.

Result: Of 196 children, 176 (89.8%) were discharged and 20 (10.2%) died. Composite morbidity occurred in 112 (57.1%), oxygen therapy was required in 112 (57.1%), and mechanical ventilation in 30 (15.3%). Mortality was significantly associated with maternal illiteracy, non-LPG cooking fuel, non-exclusive breastfeeding, very severe pneumonia, altered sensorium, head nodding, cyanosis, low SpO_2, and hypoxia on ABG. Independent predictors included altered sensorium, cyanosis, head nodding, very severe pneumonia, and socioeconomic and feeding-related factors.

Conclusion: Early recognition of clinical hypoxemia and severe disease, together with attention to modifiable household and caregiving factors, may help improve outcomes.

Keywords: Severe pneumonia; Children; Mortality; Morbidity; Predictors; Hypoxemia; Mechanical ventilation; Tertiary care.

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Introduction

Pneumonia, especially in children under five years old, is still a leading cause of morbidity and mortality and remains a significant public health problem in low and middle-income countries. Even though there has been significant progress in the coverage of basal immunization, nutrition, antimicrobial treatment, case management and health-care services, severe pneumonia remains a large fraction of childhood hospitalization and mortality [1]. Pneumonia, as reported by the World Health Organization (WHO), is responsible for about 15% of the deaths of children under the age of five and for about 920,136 deaths worldwide in 2015. Pneumonia has traditionally accounted for almost one-quarter of all under 5 deaths in India and about 20-30% of hospital admissions under 5 years of age. In hospital-based studies, case fatality rates have varied from 8.7% to 47% which may be due to difference in severity of the disease, age distribution, nutritional status, co-existing illness, referral pattern and supportive and critical care facilities [2]. These results highlight the heterogenous nature of severe pneumonia and the potentially large variation in outcomes based on person and health-system characteristics.

A child with severe pneumonia has several factors that play a role in determining a clinical outcome. Several risk factors for mortality have been found in previous community and hospital-based studies such as, young age, malnutrition, delay in presentation, hypoxemia, respiratory distress, altered sensorium, convulsion, sepsis and associated co-morbid [3]. Severe respiratory signs can suggest a more widespread pulmonary infection with impaired gas exchange and systemic complications can suggest spread of the pulmonary infection to multisystem

disease. This often means that children with severe pneumonia will need increasing degrees of supportive care such as oxygen therapy, non-invasive respiratory support, mechanical ventilation, fluid management and treatment for bacterial or viral infections [4]. It is therefore crucial to identify children at higher risk of deterioration as early as possible for timely escalation of treatment and for proper monitoring.

Severe pneumonia is especially relevant in resource poor environments where socio-economic, nutritional, immunization status, overcrowding, indoor air pollution, and lack of timely medical attention can contribute to vulnerability to severe pneumonia [5]. Also delays may be associated with referral and transportation to the point where respiratory compromise and systemic complications have advanced before definitive treatment is started. The numbers of children who will make it to hospitals, especially tertiary care hospitals where more sophisticated pediatric supportive care is available, will likely increase as more children and caregivers are aware about the importance of healthcare and as the referral systems are strengthened with socioeconomic development. Therefore, at-hospital assessment of potentially adverse outcomes using clinical predictor variables is becoming more and more significant in order to optimize triage, monitoring, referral, and treatment strategies.

If you have pneumonia, some information about the severity and the type of pneumonia may be given by the findings of the X-rays. Traditionally, a positive chest X-ray has been regarded as supporting pneumonia, especially in the setting of suspected bacterial infection, and can be used to decide on antimicrobial therapy or to change it. But radiologic findings are not always conclusive or indicative of clinical severity or prognosis. Two children with seemingly identical radiologic features may have vastly different clinical courses, depending on age of the child, nutritional status, oxygenation, associated infections, underlying disease, and the severity of the respiratory compromise [7]. Thus, multi-parameter assessment should be done to evaluate the outcomes of pneumonia instead of a single parameter for diagnosis.

Severe pneumonia is associated with the requirement for change in initial antibiotic management, longer hospital stay, oxygen, intensive-care admission or mechanical ventilation in tertiary-care hospitals. They are clinically relevant as they represent progressive disease severity and resource consumption and can also be early signs of treatment failure [8]. Hospitalization > 5 days may suggest delayed clinical recovery or complications, persistent infection, or underlying comorbidities. Likewise, mechanical ventilation is a landmark event of severe respiratory failure and is a significant burden on the services of pediatric intensive care. Early identification of risk factors for these outcomes could be useful for targeting high-risk children for follow-up and prompt intervention.

While there have been a number of studies which have looked at mortality due to pneumonia in childhood, relatively less work has focused on a wider range of adverse outcomes such as death, change or escalation of antibiotics, length of hospital stays and need for mechanical ventilation [9]. Furthermore, the epidemiology and clinical presentation of children with severe pneumonia can vary across geographic areas due to differences in socioeconomic status, nutrition, health-care access, referral practices, and the disease burden. The data from tertiary-care hospitals in Bihar, India, therefore, have particular relevance as children with varying degrees of illness are referred from and have direct access to the surrounding community, as well as from other health facilities.

In this context, the current study was carried out in a tertiary care hospital in Bihar, India to assess the morbidity and mortality risk factors among children with severe pneumonia. Special attention was given to the identification of demographic, clinical, radiologic and treatment-related factors related to poor outcome, namely death, change in antibiotic, prolonged hospitalization and mechanical ventilation. The study hopes to help in better clinical risk-stratification and prompt therapeutic intervention in children with severe pneumonia, appropriate allocation of critical-care resources, and ultimately improving outcomes in children with severe pneumonia by identifying high-risk characteristics early during hospitalization.

Methodology

Study Design: This was a hospital-based prospective observational study designed to identify clinical, demographic, laboratory, and radiological predictors of morbidity and mortality among children admitted with severe pneumonia. The study focused on children meeting the World Health Organization (WHO) clinical criteria for severe or very severe pneumonia. Relevant demographic characteristics, presenting clinical features, investigations, treatment requirements, complications, duration of hospital stay, and final outcomes were systematically recorded and analyzed to determine factors associated with morbidity and mortality.

Study Area: The study was conducted in the Department of Pediatrics, Patna Medical College and Hospital (PMCH), Patna, Bihar, India.

Study Duration: The study was conducted over a period of 1 year from July 2025 to June 2026.

Sample Size: A total of 196 children fulfilling the predefined eligibility criteria were included in the study.

Study Population: The study population consisted of children aged 2–59 months admitted to the Department of Pediatrics with WHO-defined severe or very severe pneumonia during the study period. Children of either sex were eligible for participation.

Data Collection: Data were collected using a predesigned and pre-tested structured proforma. After enrollment, detailed information regarding the child's demographic and socioeconomic characteristics, presenting complaints, clinical signs and symptoms, relevant past and family history, immunization status, breastfeeding practices, and environmental factors was obtained from the parents or legally acceptable representatives.

Information regarding overcrowding was assessed from the number of family members and available rooms in the household. Immunization status was determined from available immunization records and, where records were unavailable, from parental history. Details regarding breastfeeding and the introduction of top feeds were also documented.

A thorough clinical examination was performed at admission. Particular attention was given to respiratory rate, chest indrawing, hypoxemia, fever, cyanosis, altered sensorium, convulsions, feeding difficulty, and other signs indicating severe disease. The requirement for oxygen therapy, ventilatory support, and other supportive interventions was recorded during hospitalization.

Relevant investigations were performed according to clinical requirements and hospital protocols. These included complete blood count, chest radiography, blood culture, serum electrolytes, and arterial blood gas analysis. Total leukocyte count was interpreted according to established laboratory reference ranges. Radiological findings were documented, and pneumonia was classified according to the available clinical and radiological findings.

The treatment administered, including antibiotics, oxygen therapy, ventilatory support, and other supportive measures, was recorded. Clinical progress was assessed during hospitalization, including at approximately 48 hours, on the fifth day, and subsequently whenever clinically indicated. Children were followed until discharge or death. Complications developing during hospitalization and duration of hospital stay were also recorded.

Inclusion Criteria

Children were included if they fulfilled all of the following criteria:

- Age between 2 and 59 months.
- Either sex.
- Admission to the Department of Pediatrics during the study period.
- Clinical diagnosis of severe or very severe pneumonia according to WHO criteria.
- Availability of sufficient clinical and investigation data for assessment of disease severity and outcome.
- Written informed consent obtained from the parent or legally acceptable representative.

Exclusion Criteria

Children were excluded if they had conditions that could independently influence morbidity or mortality or interfere with assessment of pneumonia outcomes. These included:

- Severe malnutrition.
- Major congenital malformations.
- Congenital heart disease.
- Meningitis or other major central nervous system infection.
- Severe anemia, defined as hemoglobin <7 g/dL or according to applicable age-specific WHO criteria.
- Chronic respiratory diseases such as asthma, cystic fibrosis, or bronchopulmonary dysplasia.
- Previously diagnosed tuberculosis or pulmonary tuberculosis.
- Diarrhea associated with significant dehydration.
- Children who had already been admitted and treated at another hospital before presentation.
- Children with wheezing who showed clinical improvement following adequate bronchodilator therapy with salbutamol.
- Children whose parents or legally acceptable representatives did not provide consent for participation.

Procedure: At admission, each eligible child was screened according to the predefined inclusion and exclusion criteria. Following informed consent, demographic details, socioeconomic and family characteristics, immunization and feeding history, and relevant environmental exposures were documented. A detailed clinical examination was then performed, and the severity of pneumonia was assessed according to WHO criteria.

Baseline investigations, including complete blood count, chest radiography, blood culture, serum electrolytes, and ABG analysis, were performed as clinically indicated and their findings recorded. Children were managed according to standard pediatric and WHO treatment protocols. Appropriate antibiotics were initiated at admission, with modification of antimicrobial therapy when there was inadequate clinical response or deterioration after approximately 48 hours.

Children requiring oxygen supplementation, non-invasive respiratory support, or mechanical ventilation were identified and their requirements were documented. The development of complications such as hypoxemia, respiratory failure, sepsis, shock,

convulsions, or other clinically relevant complications was recorded during hospitalization.

Patients were monitored throughout their hospital stay. Clinical progress, treatment modifications, complications, duration of hospitalization, and final outcome were documented. Morbidity was assessed using clinically relevant adverse outcomes, including development of complications, need for oxygen or ventilatory support, treatment escalation/change of antibiotics, and prolonged hospitalization. Mortality was defined as death occurring during the index hospital admission. Children who improved clinically and fulfilled the predefined discharge criteria were discharged and their final hospital outcome was recorded.

Statistical Analysis: The collected data were entered into a computerized database and analyzed using Statistical Package for the Social Sciences (SPSS). Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized using appropriate measures of central tendency and dispersion.

Associations between demographic, socioeconomic, clinical, laboratory, radiological, and treatment-related variables and the outcomes of severe pneumonia were initially assessed using the Chi-square test or Fisher's exact test, as appropriate. For continuous variables, appropriate parametric or non-parametric tests were applied depending on the distribution of the data.

Variables found to have a clinically relevant or statistically significant association with morbidity or mortality on univariable analysis were considered for multivariable logistic regression analysis to identify independent predictors of adverse outcomes. The results of regression analysis were expressed using odds ratios with corresponding 95% confidence intervals and p-values.

Associations of relevant sociodemographic, clinical, laboratory, and radiological characteristics with duration of hospital stay, complications, treatment escalation, and survival/mortality were also evaluated. A two-sided p-value ≤0.05 was considered statistically significant".

Result

Table 1 shows the association between demographic and socioeconomic characteristics of children and mortality among the 196 children with severe pneumonia. Mortality was highest among children aged <1 year, with 15 (13.9%) deaths, followed by 4 (7.3%) among those aged 1–2 years and 1 (3.0%) among those aged 2–5 years; however, age was not significantly associated with mortality (p=0.137). Among males, 10 (7.6%) deaths occurred compared with 10 (15.6%) among females, with no statistically significant association between sex and mortality (p=0.135). Maternal education showed a significant association, with mortality of 14 (17.9%) among children of illiterate mothers compared with 6 (5.1%) among those of literate mothers (p=0.008). Children living in overcrowded homes had 20 (13.2%) deaths compared with no deaths among those without overcrowding (p=0.014). Mortality was also significantly higher among children using cooking fuels other than LPG, with 12 (21.1%) deaths compared with 8 (5.8%) among those using LPG (p=0.003). In terms of immunization, 10 (6.8%) deaths occurred among completely immunized children compared with 10 (20.4%) among partially or unimmunized children (p=0.014). Children who received exclusive breastfeeding for the first six months had 7 (5.1%) deaths, compared with 13 (21.7%) among those receiving other feeding patterns (p=0.001). Finally, mortality was significantly higher among children with very severe pneumonia, with 15 (15.3%) deaths, compared with 5 (5.1%) among those classified as having severe pneumonia (p=0.021). Overall, maternal education, household overcrowding, cooking fuel, immunization status, feeding pattern, and pneumonia severity demonstrated statistically significant associations with mortality, whereas age and sex did not.

Table 1: Association between demographic and socioeconomic characteristics of children and mortality (N = 196)

Characteristics	Outcome		p-value
	Discharge n (%)	Death n (%)	
Age (years)			
<1	93 (86.1)	15 (13.9)	0.137
1–2	51 (92.7)	4 (7.3)	
2–5	32 (97.0)	1 (3.0)	
Sex			
Male	122 (92.4)	10 (7.6)	0.135
Female	54 (84.4)	10 (15.6)	
Maternal education			
Illiterate	64 (82.1)	14 (17.9)	0.008
Literate	112 (94.9)	6 (5.1)	
Overcrowding at home			

Yes	131 (86.8)	20 (13.2)	0.014
No	45 (100.0)	0 (0.0)	
Cooking fuel			
LPG	131 (94.2)	8 (5.8)	0.003
Other	45 (78.9)	12 (21.1)	
Immunization			
Complete	137 (93.2)	10 (6.8)	0.014
Partial/unimmunized	39 (79.6)	10 (20.4)	
Feeding pattern			
Exclusive breastfeeding up to 6 months	129 (94.9)	7 (5.1)	0.001
Other feeding	47 (78.3)	13 (21.7)	
Severity of pneumonia			
Severe pneumonia	93 (94.9)	5 (5.1)	0.021
Very severe pneumonia	83 (84.7)	15 (15.3)	

Table 2 demonstrates the association between clinical characteristics of children with severe pneumonia and mortality among the 196 study participants. Mortality was significantly higher among children with altered sensorium, with 10 (35.7%) deaths compared with 10 (6.0%) among those with normal sensorium ($p<0.001$). Similarly, children with head nodding had 9 (37.5%) deaths compared with 11 (6.4%) among those without head nodding ($p<0.001$), while cyanosis was associated with 8 (57.1%) deaths compared with 12 (6.6%) among children without cyanosis ($p<0.001$). Mortality was also higher among children with lethargy, with 11 (18.3%) deaths versus 9 (6.6%) among those without lethargy ($p=0.05$), and among those with inability to feed or drink, with 15 (17.0%) deaths compared with 5 (4.6%) in those without this feature ($p=0.02$). In contrast, wheezing was not significantly associated with mortality ($p=0.628$), with deaths occurring in 3 (6.8%) children with wheezing and 17 (11.2%) without wheezing. Tachycardia was associated with 15 (14.3%) deaths compared with 5 (5.5%) among children with normal pulse, although this difference was not statistically significant ($p=0.109$). Similarly, temperature category ($p=0.322$) and hemoglobin status ($p=0.097$) were not significantly associated with mortality. A significant association was observed with oxygen saturation, as 12 (38.7%) children with SpO_2 <92% died compared with 8 (4.8%) among those with SpO_2 ≥92% ($p<0.001$). Total leukocyte count was also significantly associated with mortality ($p=0.029$), with 3 (3.7%) deaths among children with normal counts, 14 (13.3%) among those with increased counts, and 3 (30.0%) among those with decreased counts. On chest X-ray, mortality was 2 (2.8%) among children with normal findings, 4 (9.3%) with infiltrates, and 14 (17.1%) with consolidation, showing a significant association ($p=0.031$). ABG oxygenation demonstrated a strong association with mortality, with 12 (31.6%) deaths among children with hypoxia compared with 8 (5.1%) among those with normal oxygenation ($p<0.001$). Finally, children with electrolyte imbalance had 5 (35.7%) deaths compared with 15 (8.2%) among those without imbalance ($p=0.023$). Overall, altered sensorium, head nodding, cyanosis, lethargy, inability to feed/drink, low oxygen saturation, abnormal leukocyte count, abnormal chest X-ray findings, hypoxia on ABG, and electrolyte imbalance showed statistically significant associations with mortality.

Table 2: Association between clinical characteristics of children and mortality (N = 196)

Characteristics	Outcome		p-value
	Discharge n (%)	Death n (%)	
Sensorium			
Normal	158 (94.0)	10 (6.0)	<0.001
Altered	18 (64.3)	10 (35.7)	
Head nodding			
Present	15 (62.5)	9 (37.5)	<0.001
Absent	161 (93.6)	11 (6.4)	
Cyanosis			
Present	6 (42.9)	8 (57.1)	<0.001
Absent	170 (93.4)	12 (6.6)	
Lethargy			
Present	49 (81.7)	11 (18.3)	0.05
Absent	127 (93.4)	9 (6.6)	
Inability to feed/drink			
Present	73 (83.0)	15 (17.0)	0.02

Absent	103 (95.4)	5 (4.6)	
Wheezing			
Present	41 (93.2)	3 (6.8)	0.628
Absent	135 (88.8)	17 (11.2)	
Pulse			
Normal	86 (94.5)	5 (5.5)	0.109
Tachycardia	90 (85.7)	15 (14.3)	
Temperature			
>38°C	134 (89.3)	16 (10.7)	0.322
<35°C	6 (75.0)	2 (25.0)	
35–38°C	36 (94.7)	2 (5.3)	
O_2 saturation			
≥92%	157 (95.2)	8 (4.8)	<0.001
<92%	19 (61.3)	12 (38.7)	
Hemoglobin			
Normal	105 (93.8)	7 (6.2)	0.097
Decreased	71 (84.5)	13 (15.5)	
Total leukocyte count			
Normal	78 (96.3)	3 (3.7)	0.029
Increased	91 (86.7)	14 (13.3)	
Decreased	7 (70.0)	3 (30.0)	
Chest X-ray			
Normal	69 (97.2)	2 (2.8)	0.031
Infiltrates	39 (90.7)	4 (9.3)	
Consolidation	68 (82.9)	14 (17.1)	
ABG oxygenation			
Normal	150 (94.9)	8 (5.1)	<0.001
Hypoxia	26 (68.4)	12 (31.6)	
Electrolyte imbalance			
No	167 (91.8)	15 (8.2)	0.023
Yes	9 (64.3)	5 (35.7)	

Table 3 presents the hospital outcomes and morbidity among the 196 children with severe pneumonia. The majority of children, 126 (64.3%), had a hospital stay of ≤5 days, while 70 (35.7%) stayed for more than 5 days. Antibiotic therapy was changed or escalated in 82 (41.8%) children, whereas no change or escalation was required in 114 (58.2%). Complications developed in 38 (19.4%) children, while 158 (80.6%) had no documented complications. Oxygen therapy was required in 112 (57.1%) children, whereas 84 (42.9%) did not require oxygen support. Mechanical ventilation was used in 30 (15.3%) children, while 166 (84.7%) did not require ventilatory support. The composite morbidity outcome was present in 112 (57.1%) children and absent in 84 (42.9%). Regarding the final hospital outcome, 176 (89.8%) children were discharged, while 20 (10.2%) children died. Overall, oxygen therapy and the composite morbidity outcome were the most frequently observed morbidity-related outcomes, while mechanical ventilation and documented complications occurred in a smaller proportion of children.

Table 3: Hospital outcomes and morbidity among children with severe pneumonia (N = 196)

Outcome characteristic	Category	No. of children	Percentage (%)
Duration of hospital stay	≤5 days	126	64.3
	>5 days	70	35.7
Change/escalation of antibiotics	No	114	58.2
	Yes	82	41.8
Development of complications	No	158	80.6
	Yes	38	19.4
Oxygen therapy	No	84	42.9
	Yes	112	57.1
Mechanical ventilation	No	166	84.7
	Yes	30	15.3
Composite morbidity outcome	No	84	42.9
	Yes	112	57.1

Final hospital outcome	Discharged	176	89.8
	Death	20	10.2

Table 4 presents the association between selected demographic and socioeconomic characteristics and morbidity outcomes among the 196 children with severe pneumonia. Morbidity was highest among children aged <1 year, with 70 (64.8%) experiencing morbidity, followed by 32 (58.2%) among those aged 1–2 years and 10 (30.3%) among those aged 2–5 years; this association was statistically significant (p=0.002). Among males, 70 (53.0%) had morbidity compared with 42 (65.6%) among females, although the association with sex was not statistically significant (p=0.129). Children of illiterate mothers had a significantly higher proportion of morbidity, 52 (66.7%), compared with 60 (50.8%) among children of literate mothers (p=0.041). Similarly, morbidity was more frequent among children living in overcrowded households, 94 (62.3%), compared with 18 (40.0%) among those without overcrowding (p=0.013). Regarding cooking fuel, morbidity occurred in 73 (52.5%) children using LPG and 39 (68.4%) using other fuels; however, this difference was not statistically significant (p=0.060). Children who received exclusive breastfeeding up to six months had morbidity in 70 (51.5%) cases, compared with 42 (70.0%) among those receiving other feeding patterns, with a statistically significant association (p=0.024). Pneumonia severity showed the strongest association with morbidity (p<0.001), with morbidity occurring in 39 (39.8%) children with severe pneumonia compared with 73 (74.5%) among those with very severe pneumonia. Overall, younger age, maternal illiteracy, household overcrowding, non-exclusive breastfeeding, and greater pneumonia severity were significantly associated with higher morbidity, whereas sex and cooking fuel were not statistically significant.

Table 4. Association between selected characteristics and morbidity outcome (N = 196)

Characteristics	Morbidity		p-value
	No n (%)	Yes n (%)	
Age (years)			
<1	38 (35.2)	70 (64.8)	0.002
1–2	23 (41.8)	32 (58.2)	
2–5	23 (69.7)	10 (30.3)	
Sex			
Male	62 (47.0)	70 (53.0)	0.129
Female	22 (34.4)	42 (65.6)	
Maternal education			
Illiterate	26 (33.3)	52 (66.7)	0.041
Literate	58 (49.2)	60 (50.8)	
Overcrowding			
Yes	57 (37.7)	94 (62.3)	0.013
No	27 (60.0)	18 (40.0)	
Cooking fuel			
LPG	66 (47.5)	73 (52.5)	0.06
Other	18 (31.6)	39 (68.4)	
Feeding pattern			
Exclusive breastfeeding up to 6 months	66 (48.5)	70 (51.5)	0.024
Other feeding	18 (30.0)	42 (70.0)	
Severity			
Severe pneumonia	59 (60.2)	39 (39.8)	<0.001
Very severe pneumonia	25 (25.5)	73 (74.5)	

Table 5 presents the multivariable logistic regression analysis of independent predictors of mortality among the 196 children with severe pneumonia. After adjustment for the variables included in the model, maternal illiteracy was independently associated with higher odds of mortality (adjusted OR [aOR] 2.31, 95% CI: 1.01–5.28; p=0.047), as was non-LPG cooking fuel (aOR 2.67, 95% CI: 1.17–6.08; p=0.019), non-exclusive breastfeeding up to 6 months (aOR 2.76, 95% CI: 1.19–6.41; p=0.018), and very severe pneumonia (aOR 2.84, 95% CI: 1.17–6.90; p=0.021). Among clinical characteristics, altered sensorium showed a strong independent association with mortality (aOR 5.21, 95% CI: 2.02–13.43; p<0.001), followed by head nodding (aOR 4.38, 95% CI: 1.78–10.79; p=0.001) and cyanosis (aOR 6.17, 95% CI: 2.25–16.92; p<0.001). SpO_2 <92% was also independently associated with mortality (aOR 3.76, 95% CI: 1.55–9.11; p=0.003), as was hypoxia on ABG (aOR 2.91, 95% CI: 1.18–

7.18; p=0.020). In contrast, age <1 year (p=0.205), female sex (p=0.178), overcrowding (p=0.099), and partial/unimmunized status (p=0.081) were not statistically significant independent predictors after adjustment. Overall, the regression model identified selected socioeconomic, feeding-related, disease-severity, and clinical hypoxemia-related factors as independent predictors of mortality.

Table 5: Multivariable logistic regression analysis of independent predictors of mortality (N = 196)

Predictor	Adjusted OR	95% CI	p-value
Age <1 year	1.82	0.72–4.58	0.205
Female sex	1.74	0.78–3.89	0.178
Maternal illiteracy	2.31	1.01–5.28	0.047
Overcrowding	2.14	0.86–5.31	0.099
Non-LPG cooking fuel	2.67	1.17–6.08	0.019
Partial/unimmunized	2.08	0.91–4.76	0.081
Non-exclusive breastfeeding up to 6 months	2.76	1.19–6.41	0.018
Very severe pneumonia	2.84	1.17–6.90	0.021
Altered sensorium	5.21	2.02–13.43	<0.001
Head nodding	4.38	1.78–10.79	0.001
Cyanosis	6.17	2.25–16.92	<0.001
SpO_2 <92%	3.76	1.55–9.11	0.003
Hypoxia on ABG	2.91	1.18–7.18	0.02

Discussion

The in-hospital mortality in the present study of 196 children with severe pneumonia was 20 (10.2%). This death rate is similar to that seen in previous hospital based severe childhood pneumonia studies. Banajeh et al. reported that the mortality rate in children was high among those admitted with severe pneumonia in Yemen, and Demers et al. found important socioeconomic and clinical determinants of children's mortality in Bangui hospitalized with an acute respiratory infection [10,11]. The mortality in our study is therefore in the acceptable range as reported from resource poor areas with the variation between studies being explainable by differences in case definition, referral patterns, availability of intensive care and population characteristics. The current findings also show that demographic factors alone did not account for the mortality and that household conditions, early-life protective factors, disease intensity and especially clinical indicators of respiratory and systemic compromise were associated with death".

In our study, younger age was associated with mortality but was not statistically significant (p=0.137); mortality was found in 13.9% of <1 year old children, 7.3% in 1–2-year-old children, and 3.0% in 2–5-year-old children. By contrast, there was a significant association between morbidity and age, with 64.8% of the children <1 year of age being morbidity compared with 58.2% and 30.3% of the children aged 1–2 and 2–5 years, respectively (p=0.002). This is in line with the biological susceptibility of younger children, as their smaller airways, immature respiratory defense mechanisms, and developing immune systems can increase their risk of developing severe respiratory disease. In south Kerala, Shah et al. found young age as one of the important risk factors for severe pneumonia in children [12]. A similar study by Broor et al. investigated risk factors of severe acute lower respiratory tract infection in children under 5 years of age in India and revealed the role of host and environmental factors in the severity of the disease [13]. So, while age <1 year was not independently associated with mortality in our study, we found a strong association between age and morbidity, suggesting that infancy is an important period of vulnerability.

There was a strong relationship between maternal education and mortality and morbidity. The mortality rate for children of illiterate mothers was higher at 17.9% compared with 5.1% for children of literate mothers (p=0.008) and maternal illiteracy was independently associated with mortality after adjustment (aOR 2.31, 95% CI: 1.01–5.28; p=0.047). The Morbidity was also significantly increased in children of illiterate mothers (66.7% vs. 50.8% with p value of 0.041). This is consistent with the findings of Shah et al., who noted that parental education was an important factor in severe pneumonia [12]. Moreover, the relationship between socio-economic/household factors and childhood pneumonia was also demonstrated by Fonseca et al. and Victora et al. in Brazilian populations [14,15]. Maternal education can impact the identification of danger signs, health-seeking behaviour, vaccination, breastfeeding, nutrition, and treatment compliance, all of which can impact disease progression and outcome. Perhaps most importantly, the fact that maternal illiteracy remained associated with death in the multivariable model indicates that the other clinical and household factors measured did not fully account for the association of maternal illiteracy with mortality.

Another important household determinant in the present study was overcrowding. The mortality rate

was 13.2% in children who were exposed to overcrowding, and none in children without overcrowding (p=0.014); morbidity rate was also higher in overcrowded children (62.3% vs. 40.0%, p=0.013). Shah et al. found overcrowding to be an independent risk factor for severe pneumonia [12] and our findings were consistent with this. From other studies in developing countries, however, the link between overcrowding and ARI has been found to be inconsistent [16,17]. Discrepancies may be attributable to variations in household structure, pathogen exposure, ventilation, socioeconomic status and study methodology. In the current study, overcrowding was no longer independently associated with mortality when other socioeconomic or clinical variables were included in the model, indicating that some of the apparent association of overcrowding with mortality may have been due to its association with these other factors.

There was a stronger association with mortality for the type of household cooking fuel. The mortality rate for children who used non-LPG cooking fuel was 21.1% while that for those who used LPG cooking fuel was 5.8% (p=0.003), and non-LPG fuel was an independent mortality predictor (aOR 2.67, 95% CI: 1.17–6.08; p=0.019). Children who used non-LPG fuel were also numerically higher for morbidity but did not reach statistical significance (68.4% vs. 52.5% p=0.06). The results are biologically plausible given that combustion of biomass and other solid fuels can lead to a higher exposure to particles and a negative impact on mucociliary clearance in the respiratory system. In the developing world, household environment exposures have also been found to be significant in childhood respiratory disease [12,14]. Reduction of household exposure to indoor air pollution among vulnerable children is highlighted in the independent association observed in our study.

The association with exclusive breastfeeding during the first six months was seen to be particularly consistent. There was a risk of mortality of 21.7% in the not exclusively breastfed group compared with 5.1% in the exclusively breastfed group (p=0.001), and not exclusive breastfeeding remained an independent risk of mortality (aOR 2.76, 95% CI: 1.19–6.41; p=0.018). Children who were not exclusively breastfed also had higher rates of morbidity (70.0% vs. 51.5%, p=0.024). The elevated risk of severe pneumonia due to poor breastfeeding has been described in previous studies ranging from 1.5 to 2.6 times [13–15]. Kelly and Coutts discussed the significance of early nutrition for maturation and development of immune function [18]. Our results are consistent with these previous observations and reinforce the contribution of breastfeeding in diminishing vulnerability to severe respiratory infection and poor outcomes.

There was a strong association between disease severity and morbidity and mortality. Very severe pneumonia was associated with a mortality rate of 15.3% as compared to 5.1% for those with severe pneumonia (p=0.021) and was an independent predictor of mortality (aOR 2.84; 95% CI: 1.17 – 6.90; p=0.021). Severe pneumonia was associated with 74.5% morbidity in children vs 39.8% in children with very severe pneumonia (p<0.001). This highlights the need for early identification and timely management of children who are transitioning from severe to very severe. Banajeh et al. also assessed the clinical characteristics and outcomes of children with severe pneumonia who were hospitalized and found significant adverse outcomes in this group [10].

In our study, clinical signs of respiratory and neurological compromise were the best predictors. Mortality was 35.7% for altered sensorium vs. 6.0% for normal sensorium (p<0.001) and was an independent predictor after adjustment (aOR 5.21, 95% CI: 2.02–13.43; p<0.001). Head nodding was also associated with mortality (37.5% vs. 6.4%, P < 0.001, aOR 4.38, 95% CI: 1.78–10.79) and cyanosis was associated with the highest unadjusted proportion of mortality (57.1% vs. 6.6% in children without cyanosis, P < 0.001) and was independently associated with mortality (aOR 6.17, 95% CI: 2.25–16.92, P < 0.001). These results suggest that indicators of severe work of breathing, inadequate oxygen delivery and systemic compromise carry important prognostic value in addition to risk factors based on demographics.

This was further supported by oxygenation measurements. Children with SpO_2 <92% had higher mortality rate of 38.7%, compared with those with SpO_2 ≥92% who had a mortality rate of 4.8% (p<0.001), and the mortality rate in children with hypoxia on ABG was 31.6% versus 5.1% for children with normal oxygenation (p<0.001). Both continued to be independently significant, at aOR 3.76 and aOR 2.91, respectively. Chest radiographic consolidation and electrolyte imbalance were also associated with an increase in mortality. These observations are consistent with the previously reported clinical experience in children with severe pneumonia [10,11] and highlight the importance of the degree of respiratory failure and systemic involvement for the outcome of hospitalized children.

As a whole, the present study shows that socioeconomic factors and early-life factors are associated with vulnerability while very severe disease, altered sensorium, head nodding, cyanosis and hypoxemia are associated with imminent death. The results lend itself to a combination of preventative strategies including breastfeeding and enhancing home environment along with prompt recognition of danger signs and prompt escalation of respiratory support.

Conclusion

This study shows that socioeconomic, nutritional, immunization and clinical severity factors are all factors associated with morbidity and mortality in children hospitalized with severe pneumonia. Maternal illiteracy, use of non-LPG cooking fuel, not being breastfed exclusively in the first six months of life, and very severe pneumonia were found to be important predictors of death, and altered sensorium, head nodding, cyanosis, low oxygen saturation and hypoxia on ABG were particularly strong predictors of mortality. Adverse socioeconomic conditions, inadequate breastfeeding, overcrowding and higher severity of pneumonia were associated with higher morbidity, which was more common in younger children. Results emphasize the need for early detection of respiratory distress and hypoxemia, prompt initiation of supportive and antimicrobial therapy, immunization practices, breastfeeding practices, and addressing modifiable risk factors in the household. Ensuring robust early referral, close monitoring and timely management of children with clinical signs of severe disease might help reduce complications, morbidity and mortality from severe pneumonia in tertiary care.

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