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Risk factors associated with mortality in children with severe pneumonia

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Abstract
Background: Severe pneumonia remains a leading cause of childhood mortality worldwide, particularly in low- and middle-income countries. Identifying risk factors associated with death is essential to guide early interventions and improve survival.
Aim of the study: To determine clinical, demographic, and laboratory predictors of mortality in children aged 2 months to 5 years admitted with severe pneumonia.
Methods: This retrospective observational study was conducted at the Department of Pediatrics, Kustia General Hospital, Kustia, Bangladesh. Medical records of 140 children admitted with severe pneumonia were reviewed. Data on sociodemographics, clinical parameters, laboratory findings, treatment interventions, and outcomes were extracted using a structured form. Statistical analysis was performed using SPSS v26, employing descriptive statistics, Chi-square/Fisher's exact test, Mann-Whitney U test, and multivariable logistic regression to identify independent predictors of mortality. Model fitness was assessed with the Hosmer-Lemeshow test.
Result: Overall mortality was 21.42%. Independent predictors of death included hypoxia at admission, hypotension, leukocytosis, delayed care beyond 72 hours, and early mechanical ventilation. Protective factors included exclusive breastfeeding, absence of household smoking, and no prior COVID-19 exposure. Socioeconomic status significantly influenced outcomes. Multivariable logistic regression demonstrated that hypoxia (aOR=4.25; 95%CI: 2.10-8.59) and early mechanical ventilation (aOR=5.87; 95%CI: 3.12-11.03) were the strongest independent predictors of mortality.
Conclusion: Mortality in children with severe pneumonia is strongly influenced by both clinical severity and modifiable environmental factors. Early recognition, timely intervention, and addressing preventable risk factors, such as delayed care and household exposures, are essential to reduce deaths. These findings highlight the need for targeted strategies in resource-limited pediatric settings.

Keywords: Severe pneumonia, childhood mortality, risk factors, mechanical ventilation, hypoxia, Bangladesh

Introduction

Pneumonia is an acute infection of the lungs characterized by inflammation of the alveoli, the small air sacs responsible for gas exchange, which leads to fluid or pus accumulation and impaired oxygen absorption [1]. Globally, pneumonia causes approximately 344 million new cases and about 2.7 million deaths annually, affecting all age groups, but with the highest mortality in children under five and adults over 70 years old [2]. In Bangladesh, the incidence of childhood pneumonia ranges from 310 to 511 episodes per 1000 child-years, with a mortality rate of about 4 deaths per 1000 live births [3]. Common comorbidities, such as malnutrition, prematurity, congenital anomalies, and anemia markedly increase pneumonia severity and mortality in children. Severe malnutrition is the strongest predictor, raising pneumonia incidence and inpatient death risk by several folds [4]. Anemia independently raises the risk of fatal outcomes in children hospitalized with pneumonia, even after adjusting for other factors like malnutrition and immunization status [5]. Prematurity and congenital heart disease are also linked to more severe pneumonia and increased mortality, likely due to compromised immune function and underlying organ vulnerabilities [6]. Children with multiple comorbidities, such as HIV exposure combined with malnutrition, face an even greater risk of death from severe pneumonia [7]. These comorbidities weaken immunity and complicate care, making early detection and integrated management vital to reduce deaths [8]. Severe pneumonia in pediatric patients is typically characterized by high fever, respiratory distress signs such as gasping, wheezing, cyanosis, and dyspnea, along with systemic toxic symptoms and hypoxemia. Laboratory markers

often show elevated inflammatory indicators like C-reactive protein (CRP) and procalcitonin (PCT), anemia, and low serum albumin, while chest imaging may reveal complications such as atelectasis or emphysema [9]. If not managed promptly, these clinical features can progress to respiratory failure requiring invasive mechanical ventilation, sepsis, and increased risk of death [10]. Known risk factors for poor outcomes or death include younger age (especially under one year), underlying heart conditions, low albumin levels, hypercapnia, invasive mechanical ventilation, prolonged fever duration, and co-infections with bacteria or other viruses [11]. Early recognition using clinical assessment tools like the Pediatric Assessment Triangle and monitoring of laboratory markers can aid in identifying severe cases, but no single marker reliably predicts severity, highlighting the need for comprehensive clinical evaluation and prompt treatment [9]. Microbiological factors particularly bacterial coinfections and antimicrobial resistance substantially worsen pneumonia outcomes. Coinfections with pathogens like Staphylococcus aureus and multidrug-resistant Klebsiella pneumoniae sharply increase mortality, ICU admissions, and healthcare costs [12]. Hospital-related issues such as late referral, insufficient ICU support, and delayed oxygen therapy raise mortality by allowing disease to progress and preventing timely, effective treatment. [13]. Key gaps persist in identifying context-specific mortality predictors due to varying pathogens, resistance patterns, and resource levels. Studying risk factors in tertiary hospitals where complex and resistant cases concentrate is crucial for developing targeted strategies to improve survival [14]. The study aimed to determine the key predictors of mortality in children with severe pneumonia.

Methodology and Materials

This retrospective observational study was conducted at the Department of Pediatrics, Kustia General Hospital, Kustia, Bangladesh a tertiary care referral center in Bangladesh. The study included children admitted with severe pneumonia between 2021 and 2023.

Inclusion Criteria

- Children aged 2 months to 5 years diagnosed with severe pneumonia according to WHO criteria.
- Admission for clinical management of severe pneumonia.

Exclusion Criteria

- Incomplete clinical or laboratory records.
- Children referred after receiving definitive care elsewhere.

Ethical Considerations

Ethical approval was obtained from the institutional review board. As this study involved retrospective review of medical records, patient identities were anonymized, and confidentiality was strictly maintained. No direct patient contact occurred, and no additional investigations were performed for research purposes.

Data Collection

Data were extracted using a structured, standardized abstraction form. Variables collected included sociodemographic characteristics (age, gender, socioeconomic status, parental education), clinical parameters at admission (vitals, hypoxia status), laboratory findings (leukocyte count, serum calcium), history of risk factors (exclusive breastfeeding, household smoking, contact with COVID-19 patients), treatment interventions (timing of mechanical ventilation), and outcomes (death or discharge). Complications and delays in care were also recorded. Data integrity was ensured by cross-verification by two independent investigators, with discrepancies resolved through chart review.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were presented as medians with interquartile ranges (IQRs), and categorical variables as frequencies and percentages. Comparisons between outcome groups were performed using the Chi-square test or Fisher's exact test for categorical variables and the Mann-Whitney U test for continuous variables. Multivariable logistic regression was used to identify independent predictors of mortality, with candidate variables selected based on clinical relevance and bivariate associations ($p<0.10$). Adjusted odds ratios (aORs) with 95%confidence intervals (CIs) were reported. Model fitness was evaluated using the Hosmer-Lemeshow test.

Results

21.42%of children with severe pneumonia died, while 78.57%were successfully discharged (Figure 1). Mortality was highest in children aged 2-6 months (12.86%), followed by 6-12 months (3.57%), with discharges also most frequent in the 2-6 months group (43.57%). Age was not significantly associated with outcomes (p=0.910) (Table 1). Mortality was slightly higher in males (10.71%) than females (9.29%), and discharges were higher among males (40.71%vs. 21.43%), though the difference was not statistically significant (p=0.126). Socioeconomic status significantly influenced outcomes ($p<0.001$), with most deaths and discharges occurring in the upper-lower class (10.00%and 76.43%, respectively). Table 2 shows that educational status did not significantly affect outcomes (p=0.396), although most deaths occurred among illiterate children (13.57%) and discharges were also highest in this group (44.29%). Exclusive breastfeeding significantly reduced mortality (5.00%vs. 16.43%, $p<0.001$) and increased discharges (41.43%). Other factors associated with higher mortality included exposure to family smoking (13.57%vs. 8.57%, p=0.031), contact with a COVID-positive patient (12.86%, $p<0.001$), delays in seeking medical care beyond 72 hours (6.43%deaths for delays >7 days, $p<0.001$), and transport delays (12.86%vs. 8.57%, $p<0.001$). Among clinical parameters, hypoxia at admission was strongly associated with mortality ($p<0.001$); children with 80-91%oxygen saturation had 19.29%deaths and 57.14%discharges, while severe hypoxia (<80%) had 2.14%deaths and 2.14%discharges (Table 3). Low blood pressure (<90th centile) also significantly increased mortality (20.71%vs. 0.71%, $p<0.001$), with higher discharges in this group (62.86% vs. 15.71%). Admission temperature was not significantly associated with outcome (p=0.312). Leukocytosis strongly predicted mortality (61.54%vs. 38.46%, $p<0.001$), with higher discharges in children without leukocytosis (75.00% vs. 25.00%). Serum calcium levels were not significantly associated with outcomes (p=0.537) (Table 4). Figure 2 shows that the mortality was highest among children who required mechanical ventilation within 6 hours of admission, (89.10%) died, and only discharged (10.90%). Children who received ventilation between 6-12 hours experienced deaths about (80.70%), and discharged (19.30%). For children who received ventilation after 12 hours, died (85.70%) and were discharged (14.30%).

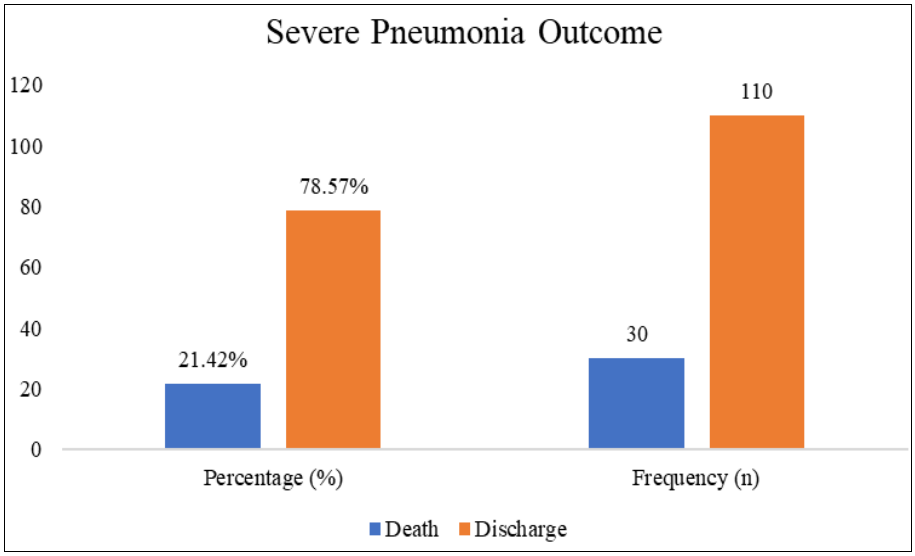

Fig 1: Outcome of Children with Severe Pneumonia (n=140)

Table 1: Association of Sociodemographic Parameters with Outcome (n=140)

Sociodemographic Parameters	Outcome, n	%	Outcome, n	%	Total	P value
	Death		Discharge			
Age (Months) (n=140)						
2-6	18	12.86	61	43.57	79	0.910
6-12	5	3.57	23	16.43	28	
12-24	3	2.14	10	7.14	13	
24-60	3	2.14	14	10.00	17	
Gender (n=140)						
Female	13	9.29	30	21.43	43	0.126
Male	15	10.71	57	40.71	72	
SES (n=140)						
Upper	0	0.00	0	0.00	0	<0.001
Upper middle	1	0.71	2	1.43	3	
Lower middle	7	5.00	10	7.14	17	
Upper lower	14	10.00	107	76.43	121	
Lower	5	3.57	2	1.43	7	

Table 2: Association of Various Risk Factors with Outcome (n = 140)

Risk Factors	Frequency	%	Frequency	%	Total	P value
	Death		Discharge			
Education (n=140)						
Illiterate	19	13.57	62	44.29	81	0.396
Primary school	6	4.29	31	22.14	37	
Middle school	3	2.14	7	5.00	10	
High school	2	1.43	5	3.57	7	
Post high school	0	0.00	5	3.57	5	
Exclusive breast feeding (n=140)						
No	23	16.43	51	36.43	74	<0.001
Yes	7	5.00	58	41.43	65	
Smoking in family (n=140)						
No	12	8.57	61	43.57	73	0.031
Yes	19	13.57	49	35.00	68	
H/o contact with COVID patient (n=140)						
No	12	8.57	92	65.71	104	<0.001
Yes	18	12.86	18	12.86	36	
Delay in seeking medical care (n=140)						
<72 hours	15	10.71	93	66.43	108	
72 hours-7 days	6	4.29	12	8.57	18	<0.001
>7 days	9	6.43	5	3.57	14	
Delay in transport (n=140)						
No	12	8.57	77	55.00	89	<0.001
Yes	18		33		51	

Table 3: Association of Vitals on Admission with Outcome (n = 140)

Vitals on Admission	Frequency Death	%	Frequency Discharge	%	Total	P value
Hypoxia (n=140)						
80-91%	27	19.29	80	57.14	107	<0.001
<80%	3	2.14	3	2.14	6	
No	0	0.00	27	19.29	27	
Blood pressure (n=140)						
<90th centile	29	20.71	88	62.86	117	<0.001
>90th centile	1	0.71	22	15.71	23	
Temperature (°F) (n=140)						
>100°F	12	8.57	64	45.71	76	0.312
<100°F	19	13.57	45	32.14	64	

Table 4: Association of Leukocytosis & Calcium Level with Outcome (n = 140)

Laboratory Parameter	Death n	Death%	Discharge n	Discharge%	Total n	Total%	p-value
Leucocytosis							
No	20	38.46	141	75.00	161	67.08	<0.001
Yes	32	61.54	47	25.00	79	32.92	
Serum Calcium (mg/dL)							
< 8	32	61.54	102	54.55	134	56.07	0.537
8-11	20	38.46	83	44.44	103	43.12	
> 11	0	0.00	2	1.01	2	0.81	

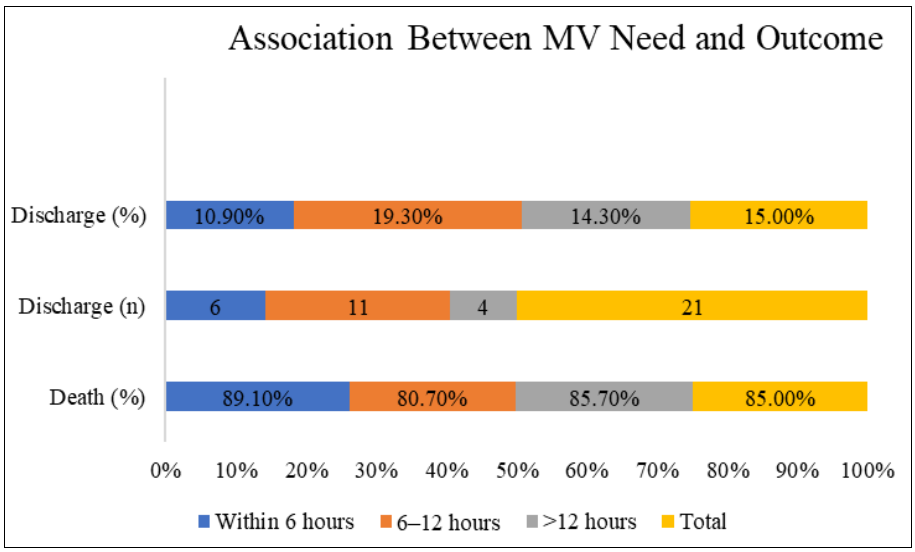

Fig 2: Association of Need for Mechanical Ventilation with Outcome (n=140)

Discussion

This study identifies key determinants that shape mortality outcomes among children diagnosed with severe pneumonia [15]. In our study, 21.42%of children with severe pneumonia died (Figure 1). Rahman *et al*. reported a mortality of 8.7%among children hospitalized with severe pneumonia [16]. Mortality was highest at 2-6 months (12.86%), slightly higher in males (10.71%), and strongly influenced by socioeconomic status (p<0.001), with the upper-lower class showing the greatest proportion of deaths (10.00%) and discharges (76.43%). Bokade *et al*. reported that the most affected age group among children with severe pneumonia was 2-12 months, indicating heightened vulnerability during early infancy. In contrast, global epidemiological data show that the overall prevalence of pneumonia is highest among children aged 1-4 years, with a case fatality rate of 8.62%, compared with an all-cause mortality of 3.9%in the same age group [17]. Shah *et al*. found a case fatality rate of 6.3%(9 cases), more than half of which (55.5%) occurred within the first 24 hours of hospitalization; they also noted that nearly 60%of pneumonia cases were male, yielding a male-to-female ratio of 1.45 [18]. Similarly, Nasrin *et al*. described a male predominance (63%) in children presenting with severe pneumonia [19]. Socioeconomic disparities also contribute to outcome variability: Nirmolia *et al*. documented the highest mortality burden in the "upper-lower" socioeconomic class (42.3%), underscoring the interplay between social determinants and disease severity [20]. In addition, Sutriana *et al*. evaluated maternal educational level and observed no significant association with pneumonia incidence in children, suggesting that other contextual or environmental variables may exert stronger influence in certain settings [21]. Mortality was highest among children of illiterate parents (13.57%) but reduced by exclusive breastfeeding (5.00%vs. 16.43%, p<0.001) and increased with family smoking, COVID contact, care delays >7 days, and transport delays. Hastuti *et al*. demonstrated that children who were exclusively breastfed experienced significantly fewer episodes of illness compared to those who were not breastfed [22]. Consistent with this, Lamberti *et*

al. reported that suboptimal or non-exclusive breastfeeding was associated with an increased risk of morbidity and mortality secondary to pneumonia across all pediatric age groups [23]. Environmental factors also contribute to risk: Greenberg *et al*. found that children under five years of age exposed to secondhand smoke had a significantly higher likelihood of developing pneumonia compared to non-exposed children (p = 0.016) [24]. Health-seeking behaviors further influence outcomes; Kirolos *et al*. reported a mean delay of 3.6 days (median 3.0, interquartile range [IQR] 2-4, range 0-20) before caregivers sought medical attention for children with pneumonia [25]. Nutritional status remains a critical determinant of disease severity, with Caulfield *et al*. indicating that malnutrition accounts for 52.3%of child deaths attributable to pneumonia, highlighting its substantial contribution to the global burden of disease [26]. Rady *et al*. emphasized that children under five are particularly vulnerable to severe illnesses, with pneumonia representing the leading cause of pediatric intensive care unit (PICU) admissions globally and an associated mortality rate of 29.9%[27]. Hypoxia at admission strongly predicted mortality (p<0.001), with 19.29%deaths at 80-91%saturation and 2.14%at <80%; low blood pressure (<90th centile) also increased deaths (20.71%vs. 0.71%, p<0.001), while admission temperature showed no significant effect (p = 0.312). Tiewsoh *et al*. investigated clinical factors associated with hypoxemia, identifying specific predictors that may aid in early recognition and management of severe pneumonia [28]. In addition, Kasundriya *et al*. assessed host biomarkers, such as total leukocyte count (TLC), and reported that its diagnostic utility was limited to cases exhibiting moderate leukocytosis [29]. Leukocytosis was associated with higher mortality (61.5%vs. 38.5%, p<0.001) and lower discharge (25%vs. 75%), whereas serum calcium was not significant (p=0.537). Zhao *et al*. reported that higher serum calcium at admission was linked to lower mortality, with each 1 mmol/dL increase reducing risk by 24%(adjusted HR 0.76, 95%CI 0.67-0.87) [30]. Tekam *et al*. reported that in children with severe pneumonia, leukocytosis was significantly associated with mortality, with elevated WBC counts linked to a higher risk of death [15]. Mortality was highest in children ventilated within 6 hours (89.1%), compared to 6-12 hours (80.7%) and after 12 hours (85.7%). Zhang *et al*. demonstrated that prolonged mechanical ventilation is associated with an increased risk of complications and higher mortality in critically ill patients [10]. Wong *et al*. reported that 51.8%of patients received invasive mechanical ventilation and 59.1%received noninvasive respiratory support, with an overall mortality of 7.7%[31].

Limitations of the Study: This study has several limitations. Its retrospective design relied on medical records, which may have incomplete or inconsistent data, potentially affecting accuracy. The single-center setting limits generalizability to other hospitals or regions. Small sample size may reduce statistical power to detect associations for less common risk factors. Some potential confounders, such as nutritional status, immunization completeness, and coexisting infections, could not be fully controlled. Additionally, long-term outcomes post-discharge were not assessed, restricting understanding of extended morbidity and mortality.

Conclusion

Severe pneumonia in children was associated with a high mortality rate of 21.42%, with key risk factors identified as hypoxia, hypotension, leukocytosis, delayed initiation of medical care, and early requirement of mechanical ventilation. Protective factors included exclusive breastfeeding and absence of household smoking or COVID-19 exposure. Socioeconomic status also significantly influenced outcomes, highlighting disparities in access to timely care. These findings emphasize that early recognition of clinical deterioration, prompt intervention, and addressing modifiable risk factors can substantially reduce mortality. Targeted strategies, including caregiver education, early referral, and optimization of supportive care, are critical to improving survival in children with severe pneumonia in resource-limited settings.

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Conflict of Interest

None declared

Ethical approval

The study was approved by the Institutional Ethics Committee.

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