

Study on Prevalence of Hypoxia in Children Suffering from Pneumonia and Hypoxemia

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Abstract

Introduction: Childhood pneumonia remains a major cause of morbidity and mortality, particularly among infants in resource-limited settings. Hypoxaemia is a serious complication of severe pneumonia, increasing the risk of respiratory failure, sepsis, prolonged hospitalization, and death. Early detection of hypoxaemia and identification of high-risk clinical features are essential for timely intervention and improved survival.

Aims: To determine the prevalence of hypoxemia and identify predictors of mortality among children aged 2–60 months hospitalized with severe and very severe pneumonia. To assess the association of hypoxemia, measured by SpO₂, PaO₂, or their combination, with clinical outcomes including sepsis, duration of hospital stay, and mortality.

Materials and Methods: The present study was an institution based prospective study. This Study was conducted from November 2022 to May 2024. Department of Paediatric, NRS Medical College and Hospital, Kolkata. Study population 100 consecutive cases.

Result: Among 100 children with pneumonia, 54 were males and 46 females, with no significant association between age and sex ($p=0.38$). Overall, 39 deaths occurred, with higher mortality among children aged ≤ 12 months (22/41), males (26/54), and those with cyanosis (20/37). Mortality was 28.3% among children with anaemia and 48.1% without anaemia. Mortality increased with inadequate immunisation: 20.0% in completely, 48.0% in partially, and 54.3% in non-immunised children. Mean haemoglobin was 8.1 ± 1.0 g/dL with anaemia and 12.2 ± 0.9 g/dL without anaemia.

Conclusion: Early recognition of hypoxaemia and high-risk features is essential in childhood pneumonia. Young age, inadequate immunisation, cyanosis, severe pneumonia, sepsis, radiographic abnormalities, and mechanical ventilation were associated with poor outcomes. Arterial blood gas may provide better prognostic discrimination than pulse oximetry alone.

Keywords: Hypoxia, Pneumonia, Hypoxemia, Healthcare, Paediatrics.

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Introduction

Community-Acquired Pneumonia (CAP) is an acute infection of the pulmonary parenchyma associated with acute infection symptoms with the presence of a new infiltrate on a chest radiograph acquired outside of a hospital setting [1]. Community-acquired pneumonia (CAP) is one of the leading causes of mortality among children under 5 years of age, globally as well as in India. In 2018, CAP accounted for the death of 0.8 million children globally [2], of whom 0.13 million were in India, killing more than 14 children every hour. According to World Health Organization (WHO) data, three to four million people die annually from CAP

worldwide [3]. It can be caused by bacterial, viral, or parasitic infection as well as by noninfectious agents. Most severe cases of pneumonia are caused by bacteria, of which the most important are *Streptococcus pneumoniae* (pneumococcus) and *Haemophilus influenzae*. Mortality in pneumonia is strongly related to the severity of the disease at admission. Pneumonia is detected by WHO guideline. According to the guideline, pneumonia is defined by the presence of fast breathing above age specific cut off. Severity of pneumonia can be diagnosed by clinical signs such as not able to drink, convulsion, head nodding, lethargy,

unconsciousness, stridor etc. Pneumonia is classified into 4 categories i) no pneumonia, (cough and cold) ii) pneumonia (respiratory rate >60 in <2 month age, >50 in 2-12 month age, >40 in 12-60 month age) iii) severe pneumonia (associated with chest in drawing) iv) very severe pneumonia (cyanosis, severe chest wall in drawing, unable to drink) according to signs and symptoms on presentation [4]. It has been estimated that 9–39% of children hospitalized for CAP in Asian countries have hypoxia [5]. An increased risk of mortality has been reported in cases of hypoxic pneumonia [6, 7]. Currently there is a significant debate on how to improve the identification of cases of “severe ALRI” (Acute Lower Respiratory Infections), and on which are the best prognostic factors that can be used in routine care to identify children with a higher risk of death [8, 9]. Pulse oximetry is a non-invasive, simple and reliable method for measuring the saturation of arterial haemoglobin with oxygen, and it can detect desaturation under a variety of conditions [10, 11]. However, a pulse oximeter may underestimate arterial oxygen saturation if it is incorrectly placed or if the patient has poor peripheral perfusion. Another method of detecting hypoxemia is by arterial blood gas analysis where along with oxygen saturation many other parameters can be detected in one setting. According to a systematic review, hypoxaemia as detected with pulse oximetry has been observed in 13% of children with WHO-defined pneumonia requiring hospitalisation (severe and very severe classifications). This corresponds to at least 1.5 to 2.7 million annual cases of hypoxemic pneumonia presenting to health-care facilities [12]. Studies have explored the possibility of managing children with WHO-defined severe pneumonia and no household danger signs, thereby directing the limited facility-based health-care resources to children most in need of them. For home management to be safe and ethical, it is essential that only children without hypoxaemia are managed outside health-care facilities. Children with hypoxemic pneumonia need to be identified (which is difficult using only clinical signs), admitted, and given supplemental oxygen and close monitoring. Severe pneumonia is associated with low blood oxygen level or hypoxemia. Degree of Hypoxia can be classified as - i) mild hypoxemia ($\text{PaO}_2 < 80$ mm Hg, SpO_2 between 90% -94%) ii) moderate hypoxemia ($\text{PaO}_2 < 60$ mm hg, SpO_2 between 75%-89%) iii) severe hypoxemia ($\text{PaO}_2 < 40$ mm hg, $\text{SpO}_2 < 75\%$). This necessitates a heightened awareness of the prevalence and risk of hypoxaemia among children presenting to health-care facilities, and robust mechanisms to detect it. The aim of this work was to systematically review the evidence on the association between hypoxia and pneumonia and association of mortality with hypoxia in children. A better understanding of this association may inform

both policy makers, health staff directly involved with clinical management of ALRI in children, and researchers.

Materials and Methods

Study design: Institution based prospective study.

Place of study: Paediatrics ward and ICU, Department of Paediatrics, NRS Medical College & Hospital (NRSMCH), Kolkata.

Period of study: 18 months.

Study Population: All patients admitted with pneumonia in paediatric ward and PICU in NRSMCH in the age group of 2-60 months.

Sample size: 100 consecutive cases.

Inclusion Criteria

- Children between age group of 2-60 months admitted with severe and very severe pneumonia in the paediatric ward and PICU in NRSMCH
- Children whose guardian will give proper consent for the study.

Exclusion criteria

- Children less than 2 months age
- Children more than 60 months age
- Children admitted with non-pneumonia lower respiratory tract infection
- Children with congenital heart disease
- Immunocompromised children & children with chronic organ failure

Study Variable

- **Demographic variables:** Age, sex, weight.
- **Clinical variables:** Duration of illness, respiratory rate, heart rate, temperature, respiratory distress, chest indrawing and pneumonia severity.
- **Hypoxemia-related variables:** SpO_2 , PaO_2 , presence and severity of hypoxemia, and oxygen requirement.
- **Complications and treatment variables:** Sepsis, respiratory failure, PICU admission, non-invasive/mechanical ventilation and inotropic support.
- **Outcome variables:** Duration of hospital stay, clinical outcome, need for ventilatory support and mortality.

Statistical Analysis: For statistical analysis, data were initially entered into a Microsoft Excel spreadsheet and then analyzed using SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism (version 5). Numerical variables were summarized using means and standard deviations, while Data were entered into Excel and analyzed using SPSS and GraphPad Prism. Numerical variables were summarized using means and

standard deviations, while categorical variables were described with counts and percentages. Two-sample t-tests were used to compare independent groups, while paired t-tests accounted for correlations in paired data. Chi-square tests (including Fisher's exact test for small sample sizes)

were used for categorical data comparisons. P-values ≤ 0.05 were considered statistically significant.

Result

Table 1: Degrees of Hypoxia

	SpO2 level	PaO2 level
Mild	90-94 %	<80 mm hg
Moderate	75-89%	<60 mm hg
Severe	<75%	<40 mm hg

Table 2: Gender with Age distribution

Age Category	Male	Female	Total
Less than equal to 1 Year	20	21	41
More than 1 Year	34	25	59
Total	54	46	100
P-Value	0.38		

Table 3: Cross tabulation for age and mortality

Age category	Death	Discharged	Total
Less than equal to 12 month	22	19	41
More than 12 month	17	42	59
Total	39	61	100

Table 4: Cross tabulation regarding gender and outcome

Gender	Death	Discharged	Total
Male	26	28	54
Female	13	33	46
Total	39	61	100

Table 5: Cross tabulation for Anaemia v/s outcome

	Death	Discharged	Total
With anaemia	13	33	46
Without anaemia	26	28	54
Total	39	61	100

Table 6: Distribution of Central Cyanosis v/s Outcome

	Death	Discharged	Total
With cyanosis	20	17	37
Without cyanosis	19	44	63
Total	39	61	100

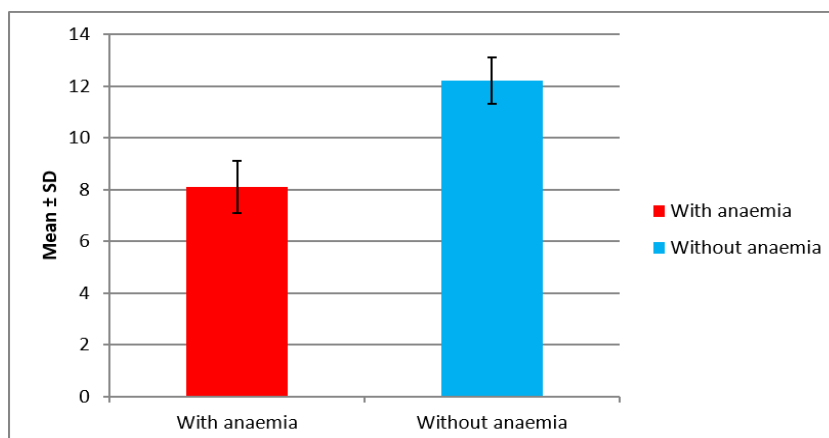


Figure 1: Cross tabulation regarding Haemoglobin distribution

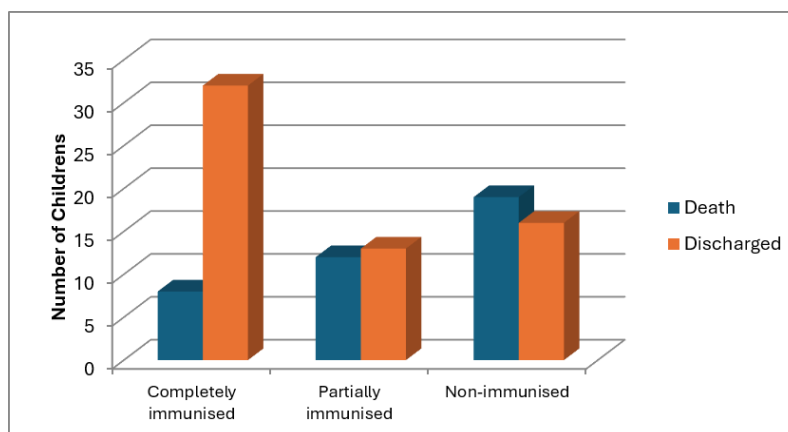


Figure 2: Distribution of immunity vs outcome

Among children with pneumonia, hypoxemia was categorized according to the severity of oxygen desaturation. Mild hypoxemia was defined as SpO₂ of 90–94% with PaO₂ <80 mmHg, moderate hypoxemia as SpO₂ 75–89% with PaO₂ <60 mmHg, and severe hypoxemia as SpO₂ <75% with PaO₂ <40 mmHg. Thus, increasing severity of hypoxemia was associated with progressively lower SpO₂ and PaO₂ levels (Table 1).

Among the 100 children included in the study, 54 were males and 46 were females. Among children aged ≤1 year, 41 were included, comprising 20 males and 21 females. Among those aged >1 year, 59 children were included, with 34 males and 25 females. There was no statistically significant association between age category and sex ($p = 0.38$) (Table 2).

Among the 100 children included in the study, 39 died and 51 were discharged. In children aged ≤12 months, 22 died and 19 were discharged. Among children aged >12 months, 17 died and 42 were discharged. Thus, mortality was higher among children aged ≤12 months compared with those aged >12 months (Table 3).

Among the 100 children studied, 39 died and 61 were discharged. Of the 54 male children, 26 died and 28 were discharged, whereas of the 36 female children, 13 died and 33 were discharged. Mortality was higher in males than in females (Table 4).

Of the 46 children with anaemia, 13 died and 33 were discharged. Of the 54 children without anaemia, 26 died and 28 were discharged. Mortality was higher among children without anaemia compared with those with anaemia (Table 5).

Among 37 children with cyanosis, 20 died and 17 were discharged. Among 63 children without cyanosis, 19 died and 44 were discharged. Mortality was higher in children with cyanosis compared with those without cyanosis (Table 6).

The mean haemoglobin level was 8.1 ± 1.0 g/dL among children with anaemia, with a median of 8.1

g/dL and a range of 6.4–10.6 g/dL. Among children without anaemia, the mean haemoglobin level was 12.2 ± 0.9 g/dL, with a median of 12.1 g/dL and a range of 10.2–14.6 g/dL. Thus, the haemoglobin level was substantially lower in children with anaemia (Figure 1).

Among 40 completely immunised children, 8 died and 32 were discharged. Among 25 partially immunised children, 12 died and 13 were discharged. Among 35 non-immunised children, 19 died and 16 were discharged. Mortality was highest among non-immunised children, followed by partially immunised and completely immunised children (Figure 2).

Discussion

The present study evaluated hypoxaemia among children with severe and very severe pneumonia and examined its relationship with important clinical outcomes, including mortality. Hypoxaemia was categorized according to SpO₂ and PaO₂ levels into mild, moderate, and severe categories, with progressively lower oxygen saturation and arterial oxygen tension indicating increasing severity. Hypoxaemia is a major determinant of poor outcome in childhood pneumonia, particularly in hospitalized children with severe disease. Rahman et al. reported a high prevalence of hypoxaemia among children with pneumonia in low- and middle-income countries and emphasized its association with disease severity and mortality [13]. Similarly, Lazzerini et al. demonstrated that hypoxaemia is an important risk factor for mortality among children with acute lower respiratory infections [4]. The World Health Organization therefore recommends pulse oximetry for early recognition of hypoxaemia and appropriate oxygen therapy in children with severe pneumonia [14].

In the present study, 100 children were included, of whom 54 were males and 46 were females. Among children aged ≤1 year, 20 were males and 21 were females, giving a total of 41 children. Among those aged >1 year, 34 were males and 25 were females,

giving a total of 59 children. There was no statistically significant association between age category and sex ($p=0.38$). The relatively higher representation of children aged >1 year may reflect the pattern of hospital admission in the study population. Similar demographic variation has been reported in hospital-based studies of severe childhood pneumonia, although age and sex distributions vary between populations Bokade et al. [15].

Regarding mortality, 39 (39.0%) children died and 51 were discharged. Among children aged ≤ 12 months, 22 died and 19 were discharged, whereas among children aged >12 months, 17 died and 42 were discharged. Thus, mortality was considerably higher in children aged ≤ 12 months. This finding is consistent with previous studies identifying younger age, particularly infancy, as an important risk factor for mortality in severe childhood pneumonia. Bokade et al. reported that younger children with severe and very severe pneumonia had an increased risk of death [15]. Similarly, Awasthi et al. identified younger age as an important predictor of mortality among children hospitalized with community-acquired pneumonia [16]. The increased vulnerability of younger children may be explained by immature immune function, smaller airway calibre and limited physiological reserve.

With respect to sex, 26 of 54 male children died and 28 were discharged, whereas 13 of 36 female children died and 33 were discharged. Therefore, the proportion of mortality was higher among males than females in the present study. However, this observation should be interpreted cautiously, particularly in the absence of a reported statistical significance test for this comparison.

Previous studies have shown inconsistent associations between sex and pneumonia mortality. Awasthi et al. reported female sex as a potential risk factor for mortality in their large hospital-based cohort, demonstrating that the direction of sex-related risk may differ between populations [16]. Differences in healthcare-seeking behaviour, referral patterns, disease severity and sample characteristics may contribute to these variations.

Cyanosis demonstrated a clinically important association with mortality. Among 37 children with cyanosis, 20 died and 17 were discharged, whereas among 63 children without cyanosis, 19 died and 44 were discharged. Thus, mortality was substantially higher among children presenting with cyanosis. Cyanosis is an important clinical manifestation of significant oxygen desaturation and may indicate advanced respiratory compromise. This finding is consistent with previous evidence showing that cyanosis and hypoxaemia are important markers of severe disease and increased mortality risk in childhood pneumonia Wilkes et al. [17].

Anaemia showed an unexpected pattern in relation to mortality in the present study. Among 46 children with anaemia, 13 died and 33 were discharged, whereas among 54 children without anaemia, 26 died and 28 were discharged. Therefore, mortality was higher among children without anaemia. The mean haemoglobin concentration among children with anaemia was 8.1 ± 1.0 g/dL, with a median of 8.1 g/dL and a range of 6.4–10.6 g/dL. Among children without anaemia, the mean haemoglobin was 12.2 ± 0.9 g/dL, with a median of 12.1 g/dL and a range of 10.2–14.6 g/dL. Although the observed difference in mortality was contrary to the commonly reported association between anaemia and poor outcomes, this finding may be influenced by sample size, underlying disease characteristics and other confounding clinical factors. Previous systematic evidence has generally identified anaemia as a potential risk factor for mortality among children with pneumonia Wilkes et al. [17].

Immunisation status showed a clear gradient in mortality. Among 40 completely immunised children, 8 died and 32 were discharged. Among 25 partially immunised children, 12 died and 13 were discharged, whereas among 35 non-immunised children, 19 died and 16 were discharged. Thus, mortality increased progressively from completely immunised children to partially immunised and non-immunised children. The mortality rate was more than twice as high among partially immunised children and almost three times as high among non-immunised children compared with completely immunised children. This observation is consistent with previous studies identifying incomplete or absent immunisation as an important risk factor for severe pneumonia and mortality Wilkes et al. [17]. Inadequate immunisation may increase susceptibility to vaccine-preventable infections and may also reflect broader barriers to preventive healthcare and timely medical care.

Conclusion

The present study demonstrates that hypoxaemia is an important clinical concern among children hospitalized with severe and very severe pneumonia and is associated with adverse outcomes. Mortality was higher among children aged ≤ 12 months, males, and those presenting with cyanosis. A clear gradient in mortality was observed according to immunisation status, with the highest mortality among non-immunised children and the lowest among completely immunised children.

Although mortality was unexpectedly higher among children without anaemia, this finding should be interpreted cautiously and requires further evaluation with multivariable analysis. Overall, early identification of hypoxaemia using SpO_2 and PaO_2 , particularly in children with cyanosis and severe pneumonia, is essential for timely oxygen

therapy and appropriate management. Routine pulse oximetry and early recognition of high-risk children may help reduce morbidity and mortality associated with childhood pneumonia.

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