NIGERIAN JOURNAL OF PAEDIATRICS

https://www.njpaediatrics.com

PRINT: ISSN 0302-4660

ONLINE: ISSN 2814-2985

OFFICIAL JOURNAL
OF THE PAEDIATRIC
ASSOCIATION OF
NIGERIA

VOLUME 52
NUMBER 1
JANUARY – MARCH 2025

ORIGINAL RESEARCH

Nigerian Journal of Paediatrics 2025; Volume 52(1): 73-81.
https://dx.doi.org/10.63270/njp.2025.v52.i1.2000008

Prevalence and Clinical Predictors of Hypoxaemia in Hospitalized Children with Pneumonia in Northern Nigeria

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Abstract

Background: Early detection of hypoxaemia and commencement of oxygen therapy improves the management outcome of children with pneumonia.

Objective: To find the prevalence of hypoxaemia and its clinical predictors amongst children presenting with pneumonia at a hospital in northeastern Nigeria.

Methods: Two hundred and ninety (290) children aged 2-59 months who presented to the Emergency Paediatric Unit of the hospital were studied from February 2016 to January 2017. They were selected based on the WHO-defined cases of pneumonia. General and systemic examination was carried out with particular emphasis on the respiratory system. Thereafter, arterial oxygen saturation was measured using a Nellcore Oximax® pulse oximeter.

Results: Hypoxaemia occurred in 169 (58.3%) children. The clinical features of pneumonia which were found to be significantly associated with hypoxaemia were cyanosis ($p<0.001$), inability to feed ($p<0.001$), head nodding ($p<0.001$) and impaired consciousness ($p<0.001$). The clinical features found most likely to independently predict hypoxaemia were head nodding ($p = 0.009$, OR = 6.834) and inability to feed ($p = 0.000$, OR = 16.33).

Conclusion: The prevalence of hypoxaemia in childhood pneumonia was high. The presence of a combination of cyanosis, head nodding, and inability to feed may be used to identify hypoxaemia and serve as a criterion for oxygen administration in children with pneumonia.

Keywords: Cyanosis, Hypoxia, Hypoxaemia, Pneumonia, Pulse oximetry, Clinical predictors.

Introduction

Hypoxaemia is one of the most serious manifestations of severe respiratory illness in children and a strong risk factor for mortality.[1] Prevalence rates of hypoxaemia ranging between 31% and 72% in children with pneumonia have been reported by various investigators using different definitions for hypoxaemia.[2-10] Pulse oximetry provides a reliable way of monitoring patients with little or no distress and is an acceptable standard method for detecting hypoxaemia.[11] The machines used to take these measurements are expensive, need constant maintenance and are not readily available in health facilities of countries with low resource settings.[12]

Several clinical signs and symptoms alone or in combination have been evaluated for their ability to predict hypoxaemia in children 2-59 months old with pneumonia in different regions of the world. [2-9,13] In many developing countries where the pulse oximeter may not be readily available, using clinical features that best predict

hypoxaemia in pneumonia from previous studies may be beneficial.[2-8,12] It will, therefore, be of benefit to identify these children with pneumonia at risk of having moderate to severe hypoxaemia in our environment using clinical features so as to detect early those who will require our limited supply of supplemental oxygen and close monitoring. This study will also add to the literature on the prevalence of hypoxaemia among children with pneumonia from this part of the country.

Methods

The study was conducted at the Federal University of Health Sciences Teaching Hospital, Azare, in Northeastern Nigeria from 1st February 2016 to 31st January 2017 (over 12 months). Ethical approval was obtained from the hospital's Health Research Ethics Committee before the study's commencement.

This was a cross-sectional, descriptive, hospital-based study. All children aged 2-59 months old who presented to the Emergency Paediatric Unit (EPU) with complaints of fever, cough and chest in-drawing or fast breathing (pneumonia cases) with or without danger signs such as grunting, cyanosis, impaired consciousness, inability to feed or drink (severe pneumonia cases) were eligible for inclusion. The symptoms would have been present for less than 14 days duration and tallied with the revised WHO diagnosis and classification of pneumonia.[14]

The minimum sample size for this study was estimated using a prevalence rate of 50% for hypoxaemia in children aged 2-59 months with pneumonia.[15] This was because, at the time of the research, no similar study had been carried out in that area. The final calculated sample size was 286; however, during the study period, 290 patients were recruited. Quota sampling method was used to predetermine the proportion of children studied in different age groups (2-11 months, 12-36 months and 37-59 months). This was based on percentages of these different age groups of children who had presented to the EPU with pneumonia for the year 2013-2014. Therefore, 170 children aged 2-11 months, 88 children aged 12-36 months and 32 patients aged 37-59 months were recruited.

Children who met the inclusion criteria for this study were recruited. They were assessed on presentation to the EPU by measuring arterial oxygen saturation and emergency management, such as fluid and oxygen administration, if necessary. Biodata and socio-demographic features of the child and parents/caregiver were obtained. Age (in months) was determined by the chronological age from the month and year of birth obtained from the caregiver and verified from birth certificates, if available. Parental/caregiver information on occupation and parents' educational level was obtained, a socioeconomic index score was calculated, and a parental social class using the Oyedeji socioeconomic classification was assigned to each child.[16]

A general physical examination was carried out on all children as follows: axillary temperature was taken with a digital thermometer and documented. Pallor was examined by looking at the conjunctivae and oral mucosa. The signs of dehydration, such as dry patchy mucosa, sunken eyes, tenting of pinched skin over the sternum and delayed capillary refill, were searched for. The Paediatric Glasgow Coma Scale was used to assess the level of consciousness, and a score of less than 13 was documented as impaired consciousness. Features like head nodding (forward and backward movement of the head with each respiration due to the use of accessory muscles of respiration: sternocleidomastoid and scalene muscles), grunting and wheezing, and other evidence of respiratory difficulty such as cyanosis, subcostal and intercostal recession were looked for and documented.

A detailed respiratory system examination was also conducted following the standard procedures. The presence of abnormal examination findings of the respiratory system was used to classify pneumonia as bronchopneumonia or lobar pneumonia and identify complications such as pleural effusion and pneumothorax as determined on examination or by chest radiograph. At presentation, oxygen saturation (SpO_2) was determined using a portable pulse oximeter (Nellcore TM Oximax N-65, 2014 USA). Classification of hypoxaemia based on arterial oxygen saturation was done: children who had arterial oxygen saturation 92-100% were classified as having normal oxygen saturation, while children with hypoxaemia were classified as having either mild hypoxaemia (90-91%), moderate hypoxaemia (75-89%) or severe hypoxaemia (<75 %).[17]

Data analysis

The data was analysed using the Statistical Package for Social Sciences (SPSS) software version 20. Discrete clinical signs and symptoms between hypoxaemic and non-hypoxaemic children were compared using the Chi-square test. Diagnostic accuracy (sensitivity and specificity) and predictive values were calculated for each clinical finding alone and in combination. Clinical features that showed a significant association with hypoxaemia in the univariate analyses at a significance level of ≤ 0.05 were evaluated for their independent ability to predict hypoxaemia with binary logistic regression analysis.

Results

Prevalence of hypoxaemia

Two hundred and ninety children were studied. The age range was 2-59 months, with a mean age of 15.77 months and a modal age range of 2-11 months. There were 166 (57.2%) males and 124 (42.8%) females, thus giving a male-to-female ratio of 1.3:1. One hundred and sixty-nine of the 290 subjects studied had hypoxaemia (SpO_2<92%), providing a prevalence rate of 58.3% (Table I).

Table I: Severity of hypoxaemia according to age

Age group (months)	Non-hypoxaemic	Hypoxaemic		
	Normal SpO^2	Mild	Moderate	Severe
	n (%)	n (%)	n (%)	n (%)
2-11	52 (17.9)	25 (8.6)	66 (22.8)	27 (9.3)
12-36	47 (16.2)	18 (6.2)	14 (4.8)	9 (3.1)
37-59	22 (7.6)	0 (0.0)	4 (1.4)	6 (2.1)
Total	121 (41.7)	43 (14.8)	84 (29.0)	42 (14.5)

Clinical features of pneumonia in hypoxaemic and non-hypoxaemic children

Table II shows that the clinical features significantly associated with hypoxaemia included inability to feed (p<0.001), cyanosis (p<0.001), head nodding (p<0.001) and impaired consciousness (p<0.001). Cyanosis and grunting respiration had high specificity values for indicating hypoxaemia (100% and 80%, respectively) and also had high positive predictive values (100% and 76%, respectively).

Clinical features of pneumonia predicting hypoxaemia

With binary logistic regression, a mother's report of a child's inability to feed (p<0.001), head nodding (p<0.001), and impaired consciousness (p<0.01), using a Paediatric Glasgow Coma score of ≤ 13 were found to be the most likely clinical predictors of hypoxaemia. As shown in Table III below, cyanosis (p = 0.99) was not a useful independent predictor in the regression model.

Table II: Clinical features of pneumonia in hypoxaemic and non-hypoxaemic children

Clinical features	n	Hypoxaemic	Non-hypoxaemic	*p*-value	Sensitivity	Specificity	PPV	NPV
		n (%)	n (%)		%	%	%	%
Symptoms								
Fast breathing	290	169 (58.3)	121 (41.7)		100.0	0.0	58.0	0.0
Inability to feed	174	122 (42.1)	52 (17.9)	0.00	72.0	57.0	70.0	59.0
Signs								
Nasal flaring	287	167 (57.6)	120 (41.4)	0.76	99.0	1.0	59.0	33.0
Cyanosis	13	13 (4.5)	0 (0.0)	0.00	8.0	100.0	100.0	44.0
Head nodding	99	75 (25.9)	24 (8.3)	0.00	44.0	80.0	76.0	51.0
Grunting respiration	15	11 (3.8)	4 (1.4)	0.22	7.0	97.0	73.0	43.0
Chest retraction	289	169 (58.3)	120 (41.7)	0.23	1.0	1.0	59.0	1.0
Wheezing	1	1 (0.4)	0 (0.0)	1.00	0.61	1.0	1.0	42.0
Bronchial breath sounds	32	20 (6.9)	12 (4.1)	0.71	12.0	90.0	63.0	42.0
Crepitations	253	153 (52.8)	100 (34.5)	0.07	91.0	17.0	61.0	57.0
Impaired consciousness	28	26 (9.0)	2 (0.7)	0.00	78.0	29.0	61.0	4.0

PPV - Positive Predictive Value, NPV - Negative Predictive Value

Table III: Clinical predictors of hypoxaemia in children with pneumonia by logistic regression analysis

Clinical features	B	χ^2	OR	95% CI Low-High	p-value
Cyanosis	20.87	9.75	0.00		0.99
Head nodding	0.79	18.89	6.83	1.194-3.828	<0.01
Inability to feed	1.10	25.08	16.33	1.759-4.989	<0.01
Impaired consciousness	1.83	15.24	0.63	0.036-0.745	0.01

B - Binary coefficient, OR - Odds ratio, χ2 – Chi-Square value, CI - Confidence interval

Precision of different combination models of clinical features at predicting hypoxaemia in children

Various combinations of clinical features of pneumonia were made to determine their ability to predict hypoxaemia in the children studied. The combination of cyanosis and head nodding was the most specific predictor with a high positive predictive value (specificity = 90%, PPV = 78.8%). The most sensitive predictors were the combination of impaired consciousness and inability to feed (sensitivity = 78%, PPV = 61%). No combination was both sensitive and specific enough to predict hypoxaemia, as Table IV depicts.

Table IV: Precision of different combination models of clinical features of pneumonia at predicting hypoxaemia

Combination of clinical features	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Inability to feed, cyanosis, fast breathing, chest retractions	70	39.5	61.5	48.5
Fast breathing, grunting, chest retractions	68.8	32.5	58.8	42.8
Cyanosis, head nodding, inability to feed	41.4	78.7	73.4	48.6
Cyanosis, head nodding, impaired consciousness	45.6	60.6	61.8	44.4
Cyanosis, head nodding	26	90	78.8	46.6
Impaired consciousness, fast breathing, head nodding	76.3	27.3	59.4	45.2
Inability to feed, impaired consciousness, head nodding	67	46	64	50
Impaired consciousness, inability to feed	78	29	61	49
Inability to feed, head nodding	58.3	68.6	72.1	54.1

PPV - Positive predictive value, NPV - Negative predictive value

Discussion

The prevalence rate of hypoxaemia in children with pneumonia in this study was 58.3%. This is close to 59% previously reported in Kenya by Onyango *et al.* and 52% reported by Duke *et al.* in Papua New Guinea. [1,2] In another Nigerian study, Abdulkadir *et al*. in Ilorin reported a prevalence rate of 41.5% using criteria similar to those used in the present study. [18] Lower prevalence rates of 20.6% and 28.6% were recorded in Ilesa and Ibadan, respectively. [19,20] The higher prevalence observed in the present study may be due to the fact that hypoxaemia was studied in only children less than five years of age with pneumonia. Children older than five years are known to have a lower prevalence of hypoxaemia.[21] Much lower prevalence rates were reported in Enugu, Nigeria (13%), Gambia (5.9%) and India (11.9%). [4,8,22] The difference in prevalence rates between the present study and the Enugu study may be due to the larger sample size used in the present study (290 versus 92 children) and the focus on only children with pneumonia in this study, unlike the Enugu study, which recruited all ill children irrespective of diagnosis.

In this study, a number of clinical features were found to be associated with hypoxaemia. These included inability to feed, cyanosis, head nodding and impaired consciousness, which, when present, were indications of hypoxaemia and, therefore, signal the need for oxygen therapy in children with pneumonia. [23] Nasal flaring and grunting respiration were not associated with hypoxaemia despite their high sensitivity and specificity. Cyanosis and head nodding were specific indicators of hypoxaemia but had poor sensitivity values as few (0 and 24, respectively) of the children seen with these symptoms did not have hypoxaemia. Several studies found similar specificity and sensitivity rates for cyanosis and head nodding. [2-7,9]

Cyanosis has long been known to be associated with hypoxaemia, but in dark-skinned children, it may be difficult to identify.[3] Despite these inadequacies, in most studies, cyanosis remains very useful, as it appears to have a higher specificity than other signs. This study showed that cyanosis, though associated with hypoxaemia, was seen in only a few children with pneumonia.[24] Nonetheless, using just this sign alone to guide treatment, especially when there is

a limited supply of oxygen, may lead to overuse of oxygen.

Another clinical feature statistically associated with hypoxaemia in this study was the inability to feed. It had a high sensitivity but low specificity, similar to the WHO and Kenyan studies. [2,23] Another study,[4], found contrasting results with a higher specificity and lower sensitivity (<50%). The children with the inability to feed in this study were mainly hypoxaemic, unlike the Gambian study, where most of the children with the inability to feed did not have hypoxaemia.[4] This may explain the contrast in findings.

Twenty-eight children with pneumonia had impaired consciousness in the present study, and most of them had hypoxaemia. Therefore, it may be a sensitive clinical feature for detecting hypoxaemia. This is similar to the findings of Onyango *et al.* [2] However, Usen *et al.* found higher specificity values for impaired consciousness.[4] The definition of impaired consciousness varied in the studies and may explain the difference in findings. Abnormal sleepiness or difficulty with arousal, which was used in the Gambian study, may be caused by the child being lethargic or exhausted and not unconscious.[4] The current study used the Paediatric Glasgow Scale to assess the level of consciousness objectively, and most of the children who had impaired consciousness were also found to be hypoxaemic.

Head nodding is an easily recognisable sign in young children, and was detected in 8.3% of children with pneumonia but without hypoxaemia in this study. There was limited data on the usefulness of head nodding as a clinical feature; it had a low sensitivity but higher specificity in the present study, and the findings were similar to those reported in Gambia.[3,4] The current and Gambian studies used a similar age group population in whom head nodding was easily recognisable.

Chest indrawing was an inclusion criterion for the current study and was observed in all the children studied. Nevertheless, it was not significantly associated with hypoxaemia in this study. Chest indrawing is a key sign in diagnosing and classifying pneumonia in children and is a convincingly helpful sign for detecting hypoxaemia.[24] A study by Onyango *et al.* conducted at a high altitude found chest indrawing to be a highly sensitive but poorly specific clinical sign amongst neonates. [2] The current study did not investigate hypoxaemia among neonates.

The study observed that inability to feed and head nodding are the most likely to predict hypoxaemia independently. This is similar to the findings by Usen *et al.* and Singhi *et al.* [4,8] These clinical features were all found to be significantly associated with hypoxaemia in the current study. They also had a high specificity or sensitivity in detecting hypoxaemia, as seen in the Gambian and Indian studies. [4,8] However, there were contrary findings from other reports. [2,19,20] Kuti *et al.* in Ilesa, southwest Nigeria, reported grunting respiration and cyanosis as the most likely independent predictors of hypoxaemia. [19] Grunting respiration and cyanosis were seen in only a few children in the current study.

Also, children with chronic respiratory diseases and cardiovascular diseases were excluded in the present study as those with primary cardiovascular disease could also present with respiratory symptoms, including cyanosis. Orimadegun *et al.* found that nasal flaring and chest retractions predicted hypoxaemia in children presenting with respiratory symptoms. In the present study, [20] Nasal flaring and chest retractions were not significantly associated with hypoxaemia, as almost all the children studied had both features. The current study did not investigate clinical features of pneumonia related to hypoxaemia based on stratification in different

age groups. A comparison of independent predictors of hypoxaemia to those found in the Kenyan study was, therefore, difficult.

This study showed that combining clinical features of pneumonia among children investigated did not improve their predictive values in identifying hypoxaemic children, as was also noticed by other authors. [3,4,7] The current study found that combining head nodding and cyanosis had a high specificity value with a higher positive predictive value when compared to other combinations of clinical features of pneumonia. This is similar to findings by Usen *et al.* [4] However, it had a low sensitivity in the present study. This model identified six out of every 10 hypoxaemic children, and if used as a predictor of hypoxaemia in pneumonia, it would minimise oxygen wastage. Adding the inability to feed to the model improved the sensitivity and positive predictive value, but specificity was compromised. The addition of other clinical features also increased sensitivity but reduced specificity. A combination of grunting, fast breathing, cyanosis and impaired consciousness for identifying hypoxaemia did not have high predictive values in this study. This same combination model had high predictive values in Kenya, Gambia and Papua New Guinea studies. [2,4,7]

Combining clinical features such as head nodding, inability to feed and impaired consciousness, which predicted hypoxaemia from the logistic regression analysis, also showed no improvement in predictive values. Though other studies showed improved sensitivity in their combination of symptoms, none was sufficiently sensitive and specific to predict hypoxaemia. [4,7] All the combination models used in the current study had very low predictive values except for the combination of head nodding, cyanosis and inability to feed. This would limit the utility of the other combination models in identifying hypoxaemia in children with pneumonia. This study found that cyanosis, when present and identified in addition to head nodding and inability to feed, may be useful features in predicting hypoxaemia in children with pneumonia. This model can be used where the pulse oximeter is unavailable, and oxygen is in limited supply.

Conclusion

The prevalence of hypoxaemia during the period of study was high. Inability to feed, head nodding, and impaired consciousness were the most likely independent predictors of hypoxaemia in children with pneumonia. However, no clinical feature, alone or in combination of two or more, was sufficiently sensitive and specific to predict hypoxaemia in children with pneumonia. The presence of a combination of cyanosis, head nodding, and inability to feed may be used to identify hypoxaemia and serve as a criterion for oxygen administration in children with pneumonia.

Authors' Contributions: YMO conceptualised and designed the study. She did the literature review. Both authors analysed and interpreted the data, drafted the manuscript, revised the draft for sound intellectual content and approved the final version of the manuscript.

Conflicts of Interest: None declared.

Financial supports: The authors did not receive financial supports for the research nor for the manuscript.

Accepted for publication: 30th March 2025.

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