Original Research Article

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Clinical predictors of hypoxemia in children with WHO classified pneumonia

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ABSTRACT

Background: In developing countries were health providers have to rely on signs and symptoms to identify hypoxemia in pneumonia and start oxygen therapy, this study was therefore conducted to assess the prevalence and predictors of hypoxemia with the hypothesis to design a severity score for hypoxemia in children with pneumonia. **Methods:** This prospective observational study was carried out at the paediatric emergency department of Gajra Raja Medical College, Gwalior, on children of age 1-60 months admitted with respiratory illness categorised on basis of "Revised WHO Classification of Pneumonia". Various demographic and clinical features were noted. Oxygen saturation was measured via a pulse oximeter. Hypoxemia was defined as SpO2 <90%. Statistical analysis was done. **Results:** Of the 200 children studied, 67 (33.5%) had hypoxemia. Fever, breathing difficulty, and crepitations were the most sensitive, while inability to feed, cyanosis, grunting, head nodding and impaired consciousness were the most specific indicators for hypoxemia. Fever, lethargy, inability to feed, nasal flaring, grunting, impaired consciousness and cyanosis were found significant (p value<0.05). Combinations of tachypnea with nasal flaring, grunting, cyanosis, and retractions with grunting were also found significant in predicting hypoxemia. Combinations of tachypnea with grunting (90.2%) and cyanosis (94.7%) were found highly specific. Using these combinations, a new hypoxemia scoring system was designed to predict the severity of hypoxemia.

Conclusions: Study suggested that combination of clinical signs may be utilized as markers for hypoxemia in conditions where pulse-oximeter is not available.

Keywords: Hypoxemia, Hypoxemic score, Pulse oximetry, Pneumonia

INTRODUCTION

Acute lower respiratory tract infection are the major cause of morbidity and mortality among children in developing countries, accounting for about 30% of mortality in children under 5 years of age. 1-3 Pneumonia contributes to significant mortality in developing countries and majority of this is secondary to hypoxemia. One of the serious manifestations of pneumonia is hypoxemia and it is a major risk factor for mortality. 4

Hypoxemia is defined as oxygen saturation less than 90%. 1,3,5 Early detection of hypoxemia and treatment improves outcome in these children. 3 The most reliable

way to detect hypoxemia is an arterial blood gas analysis or the determination of arterial haemoglobin saturation by pulse oximeter. Pulseoximeter is non-invasive, portable, and also better available for accurate measurements.

That is the reason some consider pulse oximeter reading as fifth vital sign.⁸ But in resource limited settings, even pulse oximeter and oxygen is not readily available. Hence in these facilities, health care workers have to rely on clinical signs and symptoms which can reliably predict hypoxemia in acutely ill children. In the past, some studies were done to identify these clinical signs and symptoms which can predict hypoxemia in children with

majority of these studies were done at higher altitude and data from studies done at sea level is limited. 1.2.6.3,5,9-14 It was found that no single sign/symptom reliably predicts hypoxemia. With this background, it was found appropriate to conduct this study to identify the clinical predictors of hypoxemia in children with pneumonia and to design a hypoxemic score to assess the severity of hypoxemia.

METHODS

Settings: All Children of age 1-60 months admitted with respiratory illness in Kamla Raja Hospital, GajraRaja Medical College Gwalior. The present study is a prospective observational hospital-based study of 1 year.

Inclusion criteria

 Children admitted with respiratory illness of age between 1-60 months categorised on basis of "Revised WHO classification of pneumonia".

Exclusion criteria

- Chronic respiratory illnesses (Bronchopulmonary dysplasia, cystic fibrosis, lung malformations, bronchial asthma).
- Congenital heart disease, cardiopulmonary resuscitation in the past.
- Severe dehydration.
- Shock.
- Congestive cardiac failure.
- CNS malformations.
- Neuron Muscular disorders.

Written informed consent taken from parents in their local language.

Methodology

On arrival to the emergency, a detailed history was obtained as per the proforma. Age, sex, weight and symptoms such as rapid breathing, difficulty in breathing, noisy breathing, feeding pattern, fever, cough, cold, letharginess was recorded.

Nutritional status, anthropometry, and vital signs were documented. Signs of respiratory illness such as tachypnea, chest wall indrawing, grunt, nasal flaring, wheeze, crepitations, head nodding, cyanosis and also nonspecific signs such as pallor, lethargy/level of consciousness was recorded.

Chest x-ray was taken, and findings were reported independently by a radiologist. Based on the history, clinical and radiological findings, a diagnosis was assigned. Respiratory rate (RR) was counted, without disturbing the child, for one full minute.

Tachypnea was described as a RR >60/min for age <2 months, RR>50 for age 2-12 months and RR >40/min for age 12-60 months. Chest wall retractions were defined as inward movement of lower chest during breathing. Central cyanosis was documented, when child has bluish discoloration of tongue or oral mucosa. Head nodding was described as synchronous movement of head with each breath which usually denotes a sign of severe respiratory distress. Presence of wheeze and crepitations was documented. Nasal flaring was defined as the visible movement of ala nasei.

Level of consciousness was recorded as per AVPU scale (Alert/Responsive to verbal stimulus/ Responsive to painful stimulus/Unresponsive). Child was described as having impaired consciousness when they were responsive only to painful stimuli/unresponsive to any kind of stimuli. After stabilizing, the oxygen saturation was recorded by keeping pulse oximeter probe at finger/toe. Reading which is stable for at least 3 minutes was noted. Hypoxemia was defined as arterial oxygen saturation (SpO₂) <90% as this usually indicates clinically significant hypoxemia in most children. ¹⁶

Based on above results statistical analysis was done. T test, chi-square/ fischer exact appropriate test were applied. Results were defined in terms of sensitivity, specificity, positive [PPV] or negative predictive value [NPV]. Each clinical finding was analyzed for association with hypoxemia using 2×2 table [chi-square test]. Data analysis was done using SPSS software. A probability below 0.05 was regarded as statistically significant. The strength of association of clinical risk factors with hypoxemia was determined by calculating odds ratio (OR) with their 95% confidence intervals (CIs). Pearson chi square and correlation test was applied to assess the correlation between severity scoring and hypoxemia.

RESULTS

The prevalence of hypoxemia was found to be 33.5% out of which 24.5% patients had pneumonia and 42.8% patients had severe/ very severe pneumonia. The result was statistically significant (p value=0.006). Mean age of hypoxemic population was 13.00±15.12 months and 13.79±15.5 months in non-hypoxemic group. In the study population majority (67.5%) subjects were male, with male to female ratio of 2.07:1. Hypoxemia was observed more in female population (43%), with no significant association of age and sex with hypoxemia.

Birth order was significantly (p value= 0.0382) associated with hypoxemia. More than half (52.2 %) of the population in hypoxemic group belongs to the lower socioeconomic class which had no significant association. About one-third (62.6%) mothers in hypoxemic group were illiterate. Also, the hypoxemic group had 22% unimmunized and 34.3% completely immunized children. Mother's Literacy and immunization had a statistically significant association

with the hypoxemia. The study showed 21.5% children under severe acute malnutrition (SAM), among which prevalence of hypoxemia was 35.8% in hypoxemic group

and 14.2% in non-hypoxemic group with the p value of 0.000 which was highly significant (Table 1).

Table 1: Sociodemographic variables in the study.

Variables	Total (n=200)	Hypoxemia (n=67)	Non hypoxemia (n=133)	P value	
Sex					
Male	135	39(28.8%)	96(71.1%)	0.055	
Female	65	28(43%)	37(56.9)		
Pneumonia	102	25(24.5%)	77(75.5%)		
Severe/very severe	98	42(42.8%)	56(57.2%)	0.006	
pneumonia		42(42.870)	30(37.2%)		
Mothers literacy					
Literate	97	25(24.5%)	77(75.5%)	0.0247	
Illiterate	103	42(42.8%)	61(57.2%)		
Immunization					
Complete	90	23(34.3%)	67(50.3%)		
Partial	76	29(43%)	47(35.3%)	0.01	
Unimmunized	34	15(22.3%)	19(14.2%)		
Nutritional status					
Normal	110	24(21.81%)	86(78.1%)	0.000	
MAM	47	19(40.41%) 28(59.5%)		0.000	
SAM	43	24(55.8%)	19(44.1%)		

Cough was present in 88 % population in hypoxemic group with no statistically significant (p value = 0.413) association. Difficulty in breathing was present in 89.5%

children with hypoxemia. Cough and difficulty in breathing was not found to have significant association (Table 2).

Table 2: Distribution of cases according to signs and symptoms in non-hypoxemic and hypoxemic group.

Signs and Symptom	Total	Non Hypoxemic (133)	Hypoxemic (67)	P Value	OR
Fever	187	120(90.2%)	67(100%)	0.005	13.78
Cough	170	111(83.4%)	59(88%)	0.413	1.461
Cold	112	73(54.8%)	39(58.2%)	0.763	1.145
Rapid/ Breathing difficulty	182	122(91.7%)	60(89.5%)	0.794	0.772
Lethargy	65	35(26.3%)	30(44.7%)	0.011	2.270
Inability to feed	49	25(18.7%)	24(35.8%)	0.010	2.411
Noisy breathing	63	39(29.3%)	24(35.8%)	0.420	1.345
Nasal flaring	103	61(45.8%)	42(62.6%)	0.024	1.983
Grunting	31	13(9.1%)	18(26.8%)	0.002	3.391
Wheezing	89	54(40.6%)	35(52.2%)	0.133	1.600
Crepitations	159	102(76.6%)	57(85.0%)	0.196	1.732
Cyanosis	22	07(5.2%)	15(22.3%)	0.000	5.192
Impaired consciousness	48	25(18.8%)	23(34.3%)	0.022	2.258
Head nodding	7	4(3%)	3(4.4%)	0.689	1.511
Chest retractions					
Lower chest retractions	106	79(74.5%)	27(25.4%)	0.002	3.345
Both upper and lower chest Retractions	35	15(42.9%)	20(57.1%)		

The prevalence of Nasal flaring (62.6%), grunting (26.8%), cyanosis (22.38%) and impaired consciousness

(34.3%) was significantly (p value < 0.05) higher in hypoxemic group. Specificity of grunting (90.266%),

cyanosis (94.737%), impaired consciousness (81.203%), and head nodding (96.992%) was high with a low sensitivity. In children with pneumonia crepitations were present in 85% of children in hypoxemic group when compared to 76.7% children in non-hypoxemic group, which was not statistically significant (p=0.196) with a sensitivity of 85% and a low specificity. Total 70.1 % children in hypoxemic group had chest retractions. The

children with both upper and lower chest retractions were more in (29.8%) hypoxemic group as compared to 11.2 % patients, which was statistically significant (p value= 0.002) (Table 3).

In present study, it was found that tachypnea was present uniformly in all age groups in both hypoxemic and nonhypoxemic group with pneumonia.

Table 3: Distribution of signs and symptoms according to sensitivity and specificity.

Sign and Symptoms	Sensitivity %	Specificity %	Positive Predictive Value %	Negative Predictive Value %		
Fever	100	9.774	35.829	100		
Cough	88	16.54	34.706	73.33		
Cold	58.2	45.1	34.8	68.18		
Rapid/ Breathing difficulty	89.55	8.271	32.967	61.11		
Lethargy	44.77	73.684	46.154	72.5		
Inability to feed	35.821	81.203	48.980	71.523		
Noisy breathing	35.82	70.67	38.09	68.613		
Nasal flaring	62.68	54.13	40.77	74.22		
Grunting	26.86	90.22	58.06	71.00		
Wheezing	52.23	59.39	39.32	71.17		
Crepitations	85.07	23.30	35.84	75.61		
Cyanosis	22.38	94.737	68.18	70.787		
Impaired consciousness	34.32	81.20	47.917	71.053		
Head nodding	4.47	96.99	42.857	66.839		
Age group (2-12 months) N=130						
RR>60 /min	90.7	21.8	36.4	82.6		
>70/min	51.2	62.1	40.0	72.0		
Age group 13-24 (N=32) RR						
>50/min	100	15	41.4	100		
>60/min	100	55	57.1	100		
Age group >24 (N=34)						
>50/min	100	41.7	41.7	100		
>60/min	70.0	62.5	43.8	83.3		

In infants between 2-12 months with hypoxemia out of 43 children respiratory rate more than >60 /min was present in 39 patients and in 22 patients it was >70/ min. which was not statistically significant but sensitivity of respiratory rate >60% was high (90.7%).

Similarly, in the age group between 13 to 24 months 12 children had respiratory rate >50/min which was 100% sensitive, with a significant association on increasing respiratory rate. Similarly, in the children of age group >24 months with respiratory rate >50 had a statistically significant association with 100% sensitivity (Figure 1).

About one-third patients had abnormal chest x-rays finding. In the hypoxemic group 44.8% patients had abnormal radiological findings, with majority showing bilateral infiltrates (28.3%), followed by primary end point consolidation (8.9%) The difference was significant

with p value 0.000. In the present study the combinations of various signs were found to be statistically associated with hypoxemia (Figure 2).

Tachypnea with nasal flaring (p value=0.035), tachypnea with grunting (p value=0.003), tachypnea with cyanosis (p value=0.001) and retractions with grunting (p value=0.014) were found to be significantly associated with hypoxemia. The specificity of tachypnea with grunting and tachypnea with cyanosis was 90.2% and 94.7% respectively. The sensitivity of tachypnea with chest indrawing was 70.1% (Table 4).

Based on the results of statistical analysis each sign was assigned a score. Grunting, head nodding and cyanosis were assigned a score of 3, nasal flaring, impaired consciousness and both upper and lower chest retractions were assigned a score of 2, wheezing, lower chest

indrawing and crepitations were given a score of 1 and absence of any of these signs were taken as 0.

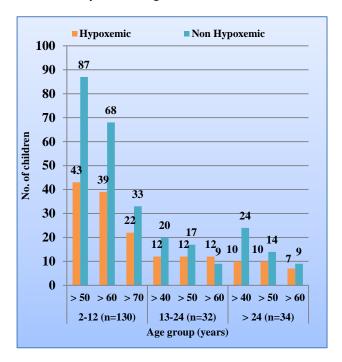


Figure 1: Relation of tachypnea with age group.

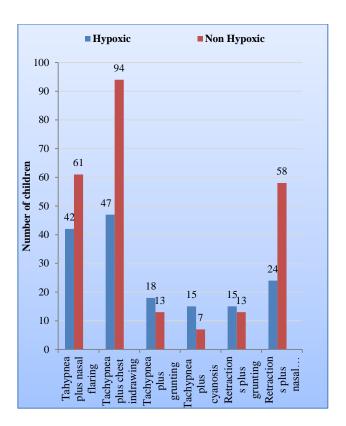


Figure 2: Various combinations of signs observed in the study.

Table 4: Distribution of various combination of signs.

Combinations Of Sign	Hypoxic	Non- Hypoxic	p- value	PPV	NPV	Sensitivity (%)	Specificity (%)	OR
Tachypnea plus nasal flaring	42	61	0.035	40.8	74.2	62.7	54.1	1.983
Tachypnea plus chest indrawing	47	94	1.000	33.3	66.1	70.1	29.3	0.975
Tachypnea plus grunting	18	13	0.003	58.1	71.0	26.9	90.2	3.391
Tachypnea plus cyanosis	15	7	0.001	68.2	70.8	22.4	94.7	5.192
Retractions plus grunting	15	13	0.014	53.6	71.7	31.9	66.7	2.921
Retractions plus nasal flaring	24	58	0.278	29.3	61.0	51.1	38.3	0.648

Tachypnea was scored between 0 to 3 depending on the age specific increase on every 10 breaths. The sum of these scores were done. Applying chi square and pearson correlation test the score was found to be significantly associated with hypoxemia and had a negative correlation with the oxygen saturation. With the increasing severity of score a drop-in oxygen saturation was observed which was significant. With the higher score the severity and association with hypoxemia increased. It was found that the clinical score was significantly associated with hypoxemia (p value=0.015).

DISCUSSION

The present study showed that the prevalence of hypoxemia (33.5%) was comparable with the previous studies.^{17,18} The dissimilarity with past studiesmay be explained by variation in the study population, altitude, characteristics of subjects, cut off value of hypoxemia and the setting of the study. 1,2,19 This study showed the prevalence of hypoxemia more with decreasing age with highest percentage in less than 6 months children (39%) may be because of their vulnerability to acute respiratory infection and incapability of verbal communication about respiratory distress they might experience, resulting in them being brought in by their parents in a late state of hypoxemia.

The prevalence of hypoxemia was significantly more (42.8%) in severe pneumonia as compared to 24.5% in pneumonia, comparable previous studies. 17,20 The results were not comparable with the study of Alwadhi et al

(50.9%) because of the fact that the definition of severe pneumonia used in their study was based on IMNCI guidelines, which uses a syndromic approach to identify sick children unlike the WHO algorithm used in present study. The study showed the increasing sensitivity with higher respiratory rate and a statistical association of tachypnea with hypoxemia comparable to previous studies which showed that age specific increase in respiratory rate, were single most useful signs to predict hypoxemia. This study had high sensitivity for tachypnea as in the study done by Motwani et al but lack specificity unlike Mulholand et al due to influence of fever over the respiratory rate.

The present study had 21.5% children under severe acute malnutrition (SAM), comparable with the study of Alwadhi et al.²¹ Malnourished children may be unable to exhibit chest indrawing, because of reduced serum potassium, magnesium and calcium levels, which may contribute to the reduced strength of accessory respiratory muscles and have generalized muscle wasting and hypotonia. However, Chisti, et al found chest indrawing to be a good clinical predictor for hypoxia in malnourished children with pneumonia.²²

Fever, lethargy and inability to feed were found to be statistically significant. The high sensitivity of fever, difficulty in breathing and cough was comparable with previous studies, while inability to feed was found specific as supported by Sah HD. ^{17,20,23}

Findings of the present study revealed that cyanosis had a very high association whereas grunting; chest retractions, nasal flaring and impaired consciousness were significantly associated with hypoxemia which is supported by various other studies as reported by the study by Onyango et al. 3,18,24 Sah HD also highlighted different predictors for hypoxemia which were inability to feed and drink lethargy, tachypnea, and central cyanosis, chest in-drawing and grunting. 23

This research has shown that the cyanosis (94.737%), head nodding (96.99%), grunting (90.22%) were highly specific but all were less sensitive sign as seen variably in the previous studies. ^{18,17,24} Kuti et al has also reported that children with grunting and cyanosis should preferentially be commenced on oxygen therapy even when there is no facility to confirm hypoxemia. ²⁴

Sensitivity of crepitation was high in the study of Motwani et al but was less comparable to the study of Lodha and associates and Basnet et al (96.4%) might be because many children with pneumonia were in the initial stages of pneumonia.^{2,17,18}

In earlier studies chest retractions have shown wide range of results, as in some studies it was highly sensitive (88% -90%) Onyango and associates (88%), Lodha and coworkers (78.5%) and Lozana et al (83%) in predicting

hypoxemia while in others it was reported to be more specific (87%). ^{2,3,10,14}

It was observed that various combinations of signs in the present study had significant association with hypoxemia, with high specificity which was partially supported by the study of Sah HD and Agrawal K et al. It seems acceptable to diagnose hypoxemia in children with pneumonia in resource poor settings. ^{23,25}

CONCLUSION

Thus the above study conclude that in settings where pulse oximetry cannot be performed for any reason combination of signs should be used for predicting hypoxemia, and a clinical hypoxemic scoring can be applied in assessing the severity of hypoxemia by the health worker for triage of the sick children and for implementing oxygen therapy.

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Ethical approval: The study was approved by the

Institutional Ethics Committee

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