Original Article

Clinical predictors of hypoxemia in patients of acute lower respiratory tract infections: A hospital-based study

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ABSTRACT

Aim: The aim of this study was to study clinical predictors of hypoxemia in patients of acute lower respiratory infections in children. **Materials and Methods:** An observational prospective study was conducted for 8 months in the General Pediatric Ward and Pediatric Intensive Care Unit of Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, a tertiary care hospital in Rohilkhand region. This is a hospital-based study. All children admitted with acute lower respiratory tract infections between the age group of 1 month to 59 months of age and diagnosed with pneumonia and bronchiolitis were enrolled and oxygen saturation of patients was recorded and compared with arterial blood gas. **Results:** A total of 40 patients were enrolled in the study. More than 90% cases of pneumonia and bronchiolitis presented with difficulty in breathing followed by rapid breathing as the next most common symptom. The least common symptom was noisy breathing and pain in abdomen. The most common signs observed were tachypnea which was present in 100% cases of mild, moderate, and severe hypoxemia. Tachypnea (91%), pallor (89%) and nasal flaring (84%), crepitations (added sounds), and subcostal retractions had better sensitivity for detecting hypoxemia. **Conclusion:** It was observed that a combination of clinical signs and symptoms can be used to predict hypoxemia when facilities of pulse oximetry and arterial blood gas analysis are not available, especially in low-resource settings.

Key words: Bronchiolitis, Clinical predictors, Hypoxemia, Pneumonia

Acute lower respiratory tract infections are a major cause of morbidity and mortality among children in developing countries accounting for about 30% of mortality in children <5 years of age [1]. Acute respiratory infections (ARIs) contribute to 15–30% of all under-five deaths in India and most of these are preventable [2]. According to National Family Health Survey-4, the prevalence of ARI is 3.7% with a maximum rate of acute respiratory tract infection in children at 4.7% [3]. While upper respiratory infections are often self-limiting, lower respiratory tract infections particularly pneumonia pose life-threatening situations. For the effective management of all pneumonia cases, the Government of India has devised an ARI control program [4].

Hypoxemia is the most serious manifestation of severe respiratory illness in children and a strong risk factor for mortality [5-7]. Hypoxemia is defined as arterial oxygen saturation (SpO_2) <94% [8]. Oxygen is an essential medicine [7]. Since oxygen has to be administered to most children in developing countries on the basis of clinical signs and symptom without performing any investigations, and due to unavailability of pulse oximetry at peripheral level, it is important to study which clinical predictors of hypoxemia we can reliably sort out for initiation of oxygen therapy. The duration and severity of hypoxemia are important and its early recognition and appropriate treatment improve the outcome of these children. Although the most reliable way to detect hypoxemia is ABG, by which direct determination of arterial SpO_2 is done, machines to make these measurements are expensive and need constant maintenance and are not widely available in developing countries, thus making clinical predictors of hypoxemia important in the initiation of oxygen therapy. However, standard treatment guidelines [9,10] recommend that in all children with pneumonia admitted to in-patient care, pulse oximetry (non-invasive estimation of arterial oxygenation) should be used to guide oxygen therapy, but it is also not extensively available so the study was planned with the objectives to calculate the sensitivity, specificity, positive predictive value, and negative predictive value of clinical parameters in predicting hypoxemia – cyanosis, level of consciousness, tachypnea, retractions, head nodding, wheeze, and crepitations and to correlate the degree of hypoxemia. To help health-care professionals decide that children

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are hypoxemic and might benefit from oxygen, we have studied the signs and symptoms indicating hypoxemia in children with acute lower respiratory tract infections. The diagnosis is clinical and is made on the basis of symptoms and signs such as fever, cough, rapid breathing, grunting, wheeze, crepitations without performing any investigations, and due to the unavailability of pulse oximetry at peripheral level, it is important to study which clinical predictors of hypoxemia we can reliably sort out for initiation of oxygen therapy. The duration and severity of hypoxemia is important and its early recognition and appropriate treatment improve the outcome of these children.

MATERIALS AND METHODS

The study was conducted in the General Pediatric Ward and Pediatric Intensive Care Unit of a tertiary care hospital in Rohilkhand region in the year 2019–2020. This is a hospital-based study completed for 8 months. It was an observational prospective study. All children admitted with acute lower respiratory tract infections between the age group of 1 month to 59 months of age and diagnosed with pneumonia or bronchiolitis were included in the study. Any child suffering from chronic respiratory illness, congenital heart disease, severe dehydration, severe anemia, and congestive cardiac failure or shock were excluded from the study. Diagnosis of acute lower respiratory tract infection is purely clinical on the basis of the presence of symptoms such as fever, cough, rapid breathing, noisy breathing, difficulty in breathing, refusal to feed, and convulsions and signs such as tachypnea, cyanosis, wheezing, grunting, use of accessory muscles of respiration, and presence of added sounds on auscultation or abnormal sounds [10].

Hypoxemia has been defined as per Pediatric Advanced Life Support guidelines as SpO_2 less than 94% and classified as [8]-

- Mild – 94–90%
- Moderate – 85–90%
- Severe – <85%

After due approval from the Ethical Committee, any child presenting with difficulty in breathing and coughing as per the ARI control program and diagnosed with Pneumonia or bronchiolitis and after obtaining consent from parents were included in the study. He/she was subjected to detailed history and clinical examination for the presence of the above signs and symptoms. Arterial saturation of all patients was recorded using a portable pulse oximeter and ABG was done. The degree of hypoxemia between ABG and SpO_2 was correlated. After obtaining a detailed history, and examination, vital parameters were recorded such as the general condition of the child/infant, heart rate, respiratory rate, saturation (SpO_2), temperature, level of consciousness, pallor, cyanosis, and head nodding and other significant clinical findings such as tachypnea, retractions, adventitious sounds such as crepitations, wheeze, and rhonchi were also taken into account. Tachypnea which is considered to be a compensatory mechanism to maintain minute ventilation [11] was defined as per the WHO age-specific cutoff values [10].

ABG was recorded in all patients as it is the gold standard to diagnose hypoxemia to correlate the degree of hypoxemia as per the ABG with the clinical predictors mentioned above.

Sample size determination: The sample size taken for this study was 97. Calculated by the formula Z^2 PQ/E^2, where P is prevalence 2.7% as per NFHS-4 data. Q = 100-p, e = standard error which is taken as 5. The severity of symptoms and signs and arterial saturation will be tabulated and correlated. Analysis of the result will be done in the form of sensitivity, specificity, positive predictive value, and negative predictive value. p-value of <0.05% was considered to be statistically significant and the Chi-square test, t-test, and ANOVA will be used whenever required for data analysis. However, due to the COVID pandemic, only 40 cases could be enrolled in the study.

RESULTS

Demographic Details

A total of 40 cases were enrolled in the study, out of which 28 were male and 12 were female. Male: Female ratio of the study population was 2:1. Out of the 40 cases enrolled,19 were below the age of 12 months and 21 were above 12 months of age. The mean age was 18.3 months.

The most common and significant symptoms were rapid breathing and difficulty breathing. The least common symptom was noisy breathing (significant association) and pain in the abdomen (no significant association) (Table 1).

Tachypnea (91%), pallor (89%) and nasal flaring (84%), crepitations (added sounds), and subcostal retractions had better sensitivity for detecting hypoxemia. However, these signs had low specificity for hypoxemia. Head nodding (98%), intercostal retractions (85%), and cyanosis (86%) were highly specific for predicting hypoxemia (Table 2).

It was also observed in our study that SpO_2 and PaO_2 were directly proportional to each other, whereas SpO_2 and respiratory rate were inversely proportional to each other (Table 3).

Thirteen cases out of the total 40 were diagnosed to have bronchiolitis, whereas 27 cases had pneumonia. Males 25 (89%) out of 28 were significantly more hypoxemic than females ten out of 12 (83%). Most cases have moderate hypoxemia which includes 78.57% (Table 4).

DISCUSSION

The term hypoxia and hypoxemia are used to define two different entities. The two main causes are either defective delivery or defective utilization of oxygen by the tissues. Hypoxemia and hypoxia do not occur together. Patients can develop hypoxemia due to a compensatory increase in hemoglobin level and cardiac output. Thus, hypoxia can exist even without hypoxemia [12]. We found that 14 (35%) cases each were present in the mild and moderate hypoxemia categories (Table 1). Seven cases (17.5%) had severe hypoxemia and five (12.5%) cases had no hypoxemia (Table 1). We also observed that males were significantly more

Table 1: Symptoms and their stages of appearance

S. No.	Symptoms	Mild (%)	Moderate (%)	Severe (%)	No (%)
1	Rapid breathing	14 (100)	13 (92.86)	07 (100)	04 (80)
		00 (00)	01 (7.14)	00 (00)	01 (20)
2	Fever	08 (57.14)	10 (71.43)	04 (57.14)	04 (80)
		06 (42.86)	04 (28.57)	03 (42.86)	01 (20)
3	Nasal discharge	09 (64.29)	06 (42.86)	04 (57.14)	04 (80)
		05 (35.71)	08 (57.14)	03 (42.86)	01 (20)
4	Feeding difficulty	08 (57.14)	08 (57.14)	04 (57.14)	01 (20)
		06 (42.86)	06 (42.86)	03 (42.86)	04 (80)
5	Cough	13 (92.86)	11 (78.57)	06 (85.71)	05 (100)
		01 (7.14)	03 (21.43)	01 (14.29)	00 (00)
6	Difficulty breathing	14 (100)	13 (92.86)	06 (85.71)	05 (100)
		00 (00)	01 (7.14)	01 (14.29)	00 (00)
7	Noisy breathing	02 (14.29)	05 (35.71)	05 (71.43)	00 (00)
		12 (85.71)	09 (64.29)	02 (28.57)	05 (100)
8	Pain in abdomen	13 (92.86)	00 (00)	01 (14.29)	00 (00)
		01 (7.14)	14 (100)	06 (85.71)	05 (100)

Table 2: Sensitivity and specificity of hypoxemic signs

S. No.	Signs	Sensitivity	Specificity
1	Pallor	89	38
2	Cyanosis	39	86
3	Level of consciousness	31	79
4	Tachypnea	91	27
5	Nasal flaring	84	42
6	Supraclavicular	79	37
7	Intercostal	58	85
8	Subcostal	74	21
9	Wheeze	29	92
10	Crepitations	79	19
11	Head nodding	16	98

Table 3: Karl Pearson's correlation coefficient

S. No.	Parameters	Karl Pearson's correlation coefficient
1	SpO_2 and PaO_2	0.0701 (+Ve Correlation)
2	SpO_2 and R.R.	−0.4865 (−Ve Correlation)

Table 4: Staging of hypoxemia and its gender-wise distribution

S. No.	Hypoxemia	Male (%)	Female	p-value
1	Mild (n=14)	10 (71.43)	04 (28.57)	p=0.0004*
2	Moderate (n=14)	11 (78.57)	03 (21.43)	
3	Severe (n=07)	04 (57.14)	03 (42.86)	
4	No (n=05)	03 (60)	02 (40)	

hypoxemic than females which may be due to the fact that more males (70%) were enrolled in the study than females (30%). Martin Weber et studied 69 hypoxic children between the age of 2 months to 5 years admitted and concluded that the incidence of hypoxemia was almost equal in males and females. In contrast, Motwani *et al*. [5], in their study of 204 cases, observed hypoxemia to be more common in females as compared to males.

Basnet *et al*. [13], in their study on 150 children under 5 years, assessed the accuracy of clinical signs to differentiate lower and upper respiratory tract infections and observed that rapid breathing and fast breathing were significantly associated with hypoxemia. Redd *et al*. [14] in their study on 950 children ascertained that the most common symptoms were cough (99%) and difficulty in breathing (17%), running nose was observed to be the next most common symptom in their study which is in contrast to our study (Table 3).

We also compared the sensitivity and specificity of various clinical signs to detect hypoxemia in detecting hypoxemia (Table 2). It was observed that tachypnea, pallor, nasal flaring, crepitations, supraclavicular, and subcostal retractions had better sensitivity for detecting hypoxemia which means that, in the presence of the above signs, one should have a high index of suspicion for hypoxemia and meticulous monitoring of the patient should be done. However, these signs had low specificity for hypoxemia. On the other hand, head nodding (98%), intercostal retractions (85%), and cyanosis (86%) were highly specific for predicting hypoxemia.

Association between various parameters were assessed using Karl Pearson's coefficient. As described in (Table 4), it was observed that SpO_2 and PaO_2 had a positive correlation which means that decreased levels of SpO_2 were associated with a decrease in PaO_2, whereas SpO_2 and respiratory rate had a negative correlation which means that a higher degree of tachypnea, lesser the SpO_2. A relatively smaller sample size and the short duration of the study are the two main limitations of this study.

CONCLUSION

It was observed that a combination of clinical signs and symptoms can be used to predict hypoxemia when facilities of pulse oximetry and ABG analysis are unavailable. Tachypnea, pallor and nasal flaring, crepitations, and subcostal retractions are highly sensitive, whereas head nodding, intercostal retractions, and cyanosis were highly specific clinical signs for predicting hypoxemia. However, ABG analysis remains the gold standard to predict hypoxemia. Early detection can lead to prompt intervention by instituting oxygen therapy, thus reducing mortality and morbidity due to acute lower respiratory tract infections.

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