SAS Journal of Medicine
Abbreviated Key Title: SAS J Med
ISSN 2454-5112
Journal homepage: https://saspublishers.com

OPEN ACCESS

Pediatrics

The Clinical Predictors of Hypoxaemia in Children with WHO Defined Pneumonia Aged 2 Months to 59 Months

Azad, A. Z[1*], Prodhan, S[2], Islam, M[3], Shormin, S[4], Chowdhury, R. B[5], Mondal, A. R[6]

[1]Dr. Abu Zafur Md. Azad, MD, Pediatrics, Assistant Professor Rangpur Medical College, Rangpur, Bangladesh
[2]Dr. Md. Shamsuzzaman Prodhan, MD Pediatrics, Assistant Professor, Rangpur Medical College, Rangpur, Bangladesh
[3]Dr Md. Monowarul Islam, MD PEDIATRICS, Junior Consultant, Pachagorh Sadar Hospital, Panchagarh, Bangladesh
[4]Dr. Shangeeda Shormin, FCPS PEDIATRICS, Assistant Professor, Rangpur Medical College, Rangpur, Bangladesh
[5]Dr. Mst Rukhsana Begum Chowdhury, MD Pediatrics, Assistant Professor, Rangpur Medical College, Rangpur, Bangladesh
[6]Dr. Md. Ashikur Rahman, MD Pediatrics, Junior Consultant, Rangpur Medical College Hospital, Rangpur, Bangladesh

DOI: 10.36347/sasjm.2022.v08i07.008 | **Received:** 08.06.2022 | **Accepted:** 19.07.2022 | **Published:** 22.07.2022

***Corresponding author:** Azad, A. Z
MD, PEDIATRICS, Assistant Professor Rangpur Medical College, Rangpur, Bangladesh

Abstract **Original Research Article**

Introduction: Hypoxaemia is common in radiographically confirmed pneumonia. Children are mostly affected by this. Identification of the clinical signs in early stage can reduce the severity and death rate. ***Aim of the study:*** The aim of this study was to determine the clinical predictors of hypoxaemia in children with WHO defined pneumonia aged 2 months to 59 months. ***Methods:*** This cross-sectional type of descriptive study was conducted in Department of Pediatric, Rangpur Medical Collage and Hospital, Rangpur from July 2014 to June 2016. This study was carried out on 205 Children aged 2-59 months suffering from pneumonia. ***Result:*** Among 205 cases of pneumonia, hypoxeamia were 51(24.9%) & non hypoxeamia were 154(75.1%). It was observed that almost three fourth (72.2%) patients belonged to age 2-11 months. The mean age was found 9.2±10.0 months with range from 2 to 59 months. Almost two third (64.9%) patients were male. Majority (91.7%) patients had cough, 184(89.8%). Most of the patients (90.7%) had crepitations. Three (1.5%) patients were found pallor of palms, 178 (86.8%) patients were heart rate ≥100 beats per minute, 196(95.6%) were capillary refill time <3 second, 4(2.0%) hepatomegaly >2 cm and 131(63.9%) had temperature ≥ 38 °C. Mean age was found 8.5±8.0 months in hypoxemia group and 9.9±11.8 months in non hypoxemia group. More than half (52.9%) patients were male in hypoxemia group and 106(68.8%) in non hypoxemia group. Majority (84.3%) patients had severe pneumonia in hypoxemia group and 97(63.0%) in non hypoxemia group. Nearly two third (60.8%) patients had irritability in hypoxemia group and 58(37.7%) in non hypoxemia group. More than three fourth (76.5%) patients had severely reduced feeding in hypoxemia group and 65(42.2%) in non hypoxemia group. Forty five (88.2%) patients had inability to drink or feed in hypoxemia group and 51(33.1%) in non hypoxemia group. Four (7.8%) patients had unusually sleepy in hypoxemia group but not in non hypoxemia group. ***Conclusion:*** Hypoxaemia was more common in 2 - 11 months infant with pneumonia, male subject and severe pneumonia. Inability to drink, lethargy, nasal flaring and lower chest indrawing are clinical predictors of hypoxaemia in pneumonia though their sensitivity and specificity are not up to our expectation. So, those clinical features may be used as predictors of hypoxaemia in under 5 children with pneumonia in resources limited areas.

Keywords: Clinical Predictors, Hypoxaemia, Children, and Pneumonia.

I. INTRODUCTION

Globally, pneumonia is a leading cause of death among children <5 years old, accounting for >90% of acute lower respiratory infection-related deaths [1]. Hypoxaemia is a major complication of pneumonia, associated with an increase in the risk of death with increasing severity of hypoxaemia [2]. Definitions of hypoxaemia have not been uniform (being often based on the practicality of limited oxygen supplies) [3]. Investigators have defined hypoxaemia from <96.6% to <90% oxygen saturation at sea level and <85% to <88% at higher altitudes [4]. For simplicity, a couple of on-going international multicenter clinical trials for pneumonia therapy are using cut-offs of <90% at sea level and <88% at higher altitude to define hypoxaemia [5]. WHO defined hypoxemia as an $SaO_2 < 90\%$ by pulse oximetry [6]. Hypoxaemia is often associated with acidosis, organ

dysfunction and multiple complications. Acute Respiratory infection accounts for 4 million death that occur in children under 5 years of age each year, two thirds of these deaths are in infants. Almost all ARI deaths in young children are due to acute lower respiratory infection, mostly pneumonia [7]. One systematic review of the published literature of cohort studies reporting the frequency of hypoxaemia in children under 5 years of age with acute lower respiratory infection and the association between hypoxaemia and the risk of dying observed the prevalence of hypoxaemia 47.0% among hospitalized cases of ARI and 72.0% cases in those with radio graphically confirmed pneumonia in 23 health centers from 10 countries [4]. There are many studies which showed the prevalence of hypoxaemia in ALRI varying between 4%-83% of the cases [8, 9]. In our country a study done by Ahammad and Amin, found the prevalence of hypoxemia in 69.5% cases of pneumonia [10]. Hypoxaemia is a common and serious complication in severely ill children [8]. Most severely ill children with hypoxaemia present with clinical signs of pneumonia [8, 11]. Hypoxaemia is one of the major risks of death from pneumonia, and much work has been carried out looking at clinical signs of hypoxemia in patients with pneumonia [11-14]. Pulse oximetry is the most reliable, non-invasive, accurate method of measuring arterial hemoglobin oxygen saturation (SpO2) in pneumonia[12] and also in other illnesses in children [15, 16]. Nevertheless, many health facilities in developing countries, where the case fatality of sick children, including those with pneumonia, is high, do not have oximetry and experience limited availability and supply of oxygen [17, 18]. Such is generally the situation in most of the health centers and hospitals in Bangladesh. WHO guidelines were modified to include lethargy /unconsciousness, head nodding, vomiting everything or convulsion [19]. A recent review of predictors of hypoxaemia also identified grunting and nasal flaring along with above mentioned signs [4]. Pulse oximeters, although relatively expensive are very useful in the detection of early hypoxaemia and require little maintenance [5]. However, detection of hypoxemia by use of oxymetry is not feasible in most situations in developing countries. Therefore, it is important to accurately identify hypoxaemic children by use of clinical signs alone. The objective of the current study is to describe the clinical signs and symptoms for prediction of hypoxaemia in children with WHO defined pneumonia aged 2 months to 59 months in Bangladesh.

II. OBJECTIVES

To determine the clinical predictors of hypoxaemia in children with WHO defined pneumonia aged 2 months to 59 months.

III. METHODOLOGY & MATERIALS

This cross-sectional type of descriptive study was conducted in Department of Pediatric, Rangpur Medical Collage and Hospital, Rangpur from July 2014 to June 2016. This study was carried out on 205 Children aged 2-59 months suffering from pneumonia inpatient and outpatient of Pediatric department. All the clinical information was obtained by preformed structured questionnaire. During the physical examination, arterial oxygen saturation was recorded in all cases using a portable, electrical pulse oximeter (NONIN Model- 7500, USA) with the sensor device placed over the finger (index or middle) or the big toe. A reading was noted down. Hypoxemia was defined as an arterial oxygen saturation of <90% recorded by pulse oximeter. Pneumonia cases were then categorize into two groups:

- Pneumonia with hypoxemia
- Pneumonia without hypoxemia

Statistical analyses were carried out by using the Statistical Package for Social Sciences version 20.0 for Windows (SPSS Inc., Chicago, Illinois, USA). A descriptive analysis will be performed for all data. The mean values were calculated for continuous variables. The quantitative observations were indicated by frequencies and percentages. Unpaired t-test was used to compare continuous variables between hypoxemic and non-hypoxemic children. Chi-square test and fisher's exact test was used to compare categorical data like clinical signs and symptoms. Sensitivity, specificity, accuracy, positive predictive value (PPV), negative predictive value (NPV), and positive or negative likelihood ratios (+ LR) for different clinical signs and symptoms in predicting the hypoxemia in children with pneumonia were evaluated. Multiple logistic regression analysis were used to determine; which of the clinical sings and symptoms would be an independent predictors for predicting the hypoxemia in children with pneumonia. Results were summarized as odds-ratios (OR) and their respective 95% confidence interval (CI). A "p" value <0.05 was considered as significant.

Inclusion criteria

- Children aged 2 - 59 months suffering from pneumonia on the basis of WHO guideline-2005).

Exclusion criteria

- Age under 2 months and ≥60 months.
- Any patients having precodial murmur.
- H/O repeated breathlessness.
- Playful children with breathlessness and rhonchi
- Children with underlying pathology such as congenital heart disease, asthma and severe malnourishment (60% standard weight for age)
- Parents unwilling to give informed written consent

IV. RESULT

Figure 1 shows distribution of hypoxaemia and non hypoxeamia. Among 205 cases of pneumonia, hypoxeamia were 51(24.9%) & non hypoxeamia were 154(75.1%). Table I shows socio demographic characteristics of the study patients. It was observed that almost three fourth (72.2%) patients belonged to age 2-11 months. The mean age was found 9.2±10.0 months with range from 2 to 59 months. Almost two third (64.9%) patients were male and 72(35.1%) were female. Male female ratio was 1.8:1. Majority (93.2%) patients come from rural area, 189(92.2%) patients had weight ≤10 kg, 140(68.3%) had sever pneumonia and 65(31.7%) had pneumonia. Table II shows symptoms and sign of the study patients, it was observed that majority (91.7%) patients had cough, 184(89.8%) had breathing difficulty, 173(84.4%) patients had fast breathing, 114(55.6%) had fever, 110(53.7%) had excessive crying, 104(55.6%) had severely reduced feeding, 96(46.4%) inability to drink or feed and 89(43.4%) had irritability. Other results depicted are in this table. Table III shows the distribution of the study patients by respiratory signs. Majority (90.7%) patients had crepitations, 123(60.0%) had rhonchi, 104(50.7%) had head nodding, 91(44.4%) had nasal flaring and 80(39.0%) intercostal indrawing, 39 (19.0%) had lower chest indrawing. Distribution of the study patients by physical signs is shown in table-IV. Three (1.5%) patients was found pallor of palms, 178 (86.8%) patients were heart rate ≥100 beats per minute, 196(95.6%) were capillary refill time <3 second, 4(2.0%) hepatomegaly >2 cm and 131(63.9%) had temperature ≥ 38 °C. Table V shows the association between socio demographic characteristics with hypoxemia. Mean age was found 8.5±8.0 months in hypoxemia group and 9.9±11.8 months in non hypoxemia group. More than half (52.9%) patients were male in hypoxemia group and 106(68.8%) in non hypoxemia group. Majority (96.1%) patients come from rural area in hypoxemia group and 142(92.2%) in non hypoxemia group. The mean weight was found 8.6±2.2 kg in hypoxemia group and 6.9±3.0 in non hypoxemia group. Majority (84.3%) patients had severe pneumonia in hypoxemia group and 97(63.0%) in non hypoxemia group. The pneumonia and weight were statistically significant ($p<0.05$) between two groups. The association between symptoms and signs complication with hypoxemia is shows in table-VI. Nearly two third (60.8%) patients had irritability in hypoxemia group and 58(37.7%) in non hypoxemia group. More than three fourth (76.5%) patients had severely reduced feeding in hypoxemia group and 65(42.2%) in non hypoxemia group. Forty five (88.2%) patients had inability to drink or feed in hypoxemia group and 51(33.1%) in non hypoxemia group. Four (7.8%) patients had unusually sleepy in hypoxemia group but not in non hypoxemia group. Which were statistically significant ($p<0.05$) but other complications were not statistically significant ($p>0.05$) between two groups.

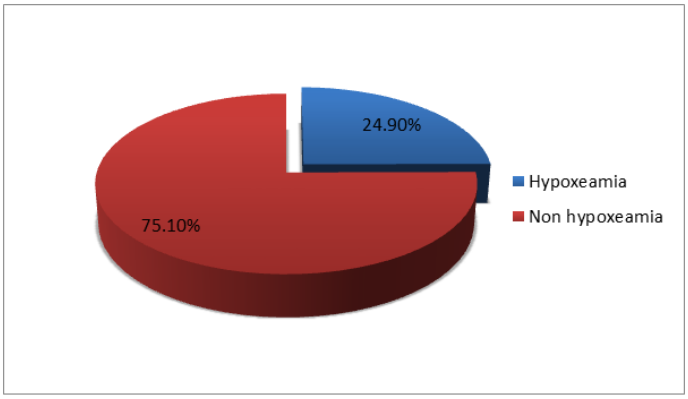

Figure I: Distribution of hypoxaemia and none hypoxeamia among the cases

Table I: Distribution of the study patients by socio demographic characteristics (n=205)

Socio demographic characteristics		Number of patients	Percentage
Age (months)	2-11	148	72.2
	≥12	57	27.8
	Mean±SD	9.2±10.0	
	Range (min, max)	2, 59	
Sex	Male	133	64.9
	Female	72	35.1
Residence	Urban	14	6.8
	Rural	191	93.2
Weight (kg)	≤10	189	92.2
	11-20	7	3.4
	>20	9	4.4
Pneumonia	Severe pneumonia	140	68.3
	Pneumonia	65	31.7

Table II: Distribution of the study patients by symptoms and sign (n=205)

Symptoms and signs	Number of patients	Percentage
Cough	188	91.7
Breathing difficulty	184	89.8
Fast breathing	173	84.4
Fever	114	55.6
Excessive crying	110	53.7
Severely reduced feeding	104	55.6
Inability to drink or feed	96	46.4
Irritability	89	43.4
Unusually sleepy	4	2.0

Table III: Distribution of the study patients by respiratory signs (n=205)

Respiratory signs		Number of patients	Percentage
Crepitations		186	90.7
Rhonchi		123	60
Head nodding		104	50.7
Nasal flaring		91	44.4
Intercostal indrawing		80	39
Lower chest indrawing		39	19
Bronchial breath sound		4	2
Diminished breath sounds		4	2
Central cyanosis		3	1.5
Wheeze		2	1
Continuous grunting		2	1
Respiratory rate (bpm)			
2-11 month	<50	0	0
	≥50	56	27.3
12-59 month	<40	0	0
	≥40	149	72.7

Table IV: Distribution of the study patients by physical signs (n=205)

Physical signs		Number of patients	Percentage
Pallor of palms	Present	3	1.5
	Absent	202	98.5
Heart rate (bpm)	<100	27	13.2
	≥100	178	86.8
Capillary refill time (sec)	<3	196	95.6
	≥3	9	4.4
Hepatomegaly (cm)	>2	4	2
	≤2	201	98
Temperature (°C)	< 38	74	36.1
	≥38	131	63.9

Table V: Association between socio demographic characteristics with hypoxemia (n=205)

Socio demographic characteristics		Hypoxemia (n=51)		Non hypoxemia (n=154)		P value
		n	%	n	%	
Age (in month)	2-11	38	74.5	44	28.6	
	≥12	13	25.5	110	71.4	
	Mean±SD	8.5±8.0		9.9±11.8		[a]0.431[ns]
	Range (min, max)	2, 45		2, 59		
Sex	Male	27	52.9	106	68.8	[b]0.039[s]
	Female	24	47.1	48	31.2	
Residence	Urban	2	3.9	12	7.8	[b]0.342[ns]
	Rural	49	96.1	142	92.2	
Weight (kg)	≤10	49	96.1	140	91	0.208[ns]
	11-20	2	3.9	5	3.2	
	>20	0	0	9	5.8	
	Mean±SD	8.6±2.2		6.9±3.0		[a]0.001[s]
	Range (min, max)	3.5, 13.0		3, 22.0		
Pneumonia	Severe pneumonia	43	84.3	97	63	[b]0.004[s]
	Pneumonia	8	15.7	57	37	

s=significant, ns= not significant

[a]P value reached from unpaired t-test

[b]P value reached from chi square test

Table VI: Association between symptoms and signs complication with hypoxemia (n=205)

Symptoms and signs		Hypoxemia (n=51)		Non hypoxemia (n=154)		P value
		n	%	n	%	
Cough	Present	45	88.2	143	92.9	0.222^{ns}
	Absent	6	11.8	11	7.1	
Fever	Present	31	60.8	83	53.9	0.390^{ns}
	Absent	20	39.2	71	46.1	
Fast breathing	Present	42	82.4	131	85.1	0.644^{ns}
	Absent	9	17.6	23	14.9	
Breathing difficulty	Present	46	90.2	138	89.6	0.905^{ns}
	Absent	5	9.8	16	10.4	
Irritability	Present	31	60.8	58	37.7	0.003^{s}
	Absent	20	39.2	96	62.3	
Severely reduced feeding	Present	39	76.5	65	42.2	0.001^{s}
	Absent	12	23.5	89	57.8	
Excessive crying	Present	31	60.8	79	51.3	0.239^{ns}
	Absent	20	39.2	75	48.7	
Inability to drink or feed	Present	45	88.2	51	33.1	0.001^{s}
	Absent	6	11.8	103	66.9	
Unusually sleepy	Present	4	7.8	0	0	0.003^{s}
	Absent	47	92.2	154	100	

s=significant, ns= not significant
P value reached from chi square test

V. DISCUSSION

This descriptive study was carried out with an aim to evaluate the clinical signs and symptoms of hypoxemia in children with WHO defined pneumonia and to assess the clinical signs and symptoms between hypoxemic with non-hypoxemic children of pneumonia aged 2-59 months. A total of 205 children aged 2-59 months suffering from pneumonia attended inpatient. Department of Pediatric, Rangpur Medical Collage Hospital, Rangpur, during July 2014 to June 2016, were included in this study. In this current study it was observed that almost three fourth (72.2%) patients belonged to age 2-11 months and the mean age was 9.2±10.0 months with ranged from 2 to 59 months. Similarly, Ahammad & Amin [10] conducted a cross-sectional study at Dhaka Shishu Hospital, a total of 164 cases of childhood pneumonia age belonged to 2-60months confirmed by chest radiograph. In this current series it was observed that pneumonia was more common in male subjects, where almost two third (64.9%) patients were male and 35.1% were female and male to female ratio was 1.8:1. Abdulkadir *et al*., [20] found similar results where 119 (59.5%) patients were male. In this present series it was observed that majority (93.2%) patients come from urban area and 92.2% patients had weight ≤10 kg. In this current study it was observed more than two third (68.3%) of the children had severe pneumonia, 31.7% had pneumonia. Fast breathing is a good indicator of radiological pneumonia [21]. It is used as a predictor of pneumonia has been evaluated in several studies [21-23]. In this study it was observed that majority (91.7%) patients had cough, 55.6% fever, 84.4% fast breathing, 89.8% breathing difficulty, 43.4% irritability, 50.7% severely reduced feeding and 53.7% had excessive crying. Ahammad & Amin [10] found the clinical symptoms and signs were evaluated for their ability to predict hypoxaemia. Oxygen saturation was determined by pulse oximeter. Hypoxaemia was defined as oxygen saturation less than 90%. Clinical predictors were evaluated by and also by determining sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). Few combination models were also evaluated for their ability to predict hypoxaemia. Regarding the respiratory signs it was observed that most (90.7%) of the patients had crepitations, 19.0% lower chest indrawing, 60.0% rhonchi, 50.7% head nodding and 44.4% had nasal flaring. Clinical signs that appeared predictive were lower chest wall indrawing, nasal flaring, central cyanosis, irregular breathing, deep breathing, stridor, auscultatory crackles, dullness on percussion, respiratory rate ≥ 60 breaths per min, weak pulse volume, delayed capillary refill (≥ 3 s), heart rate < 80 beats per min, impaired consciousness with a Blantyre coma scale < 3, prostration, convulsion on admission, restlessness and hypothermia [24]. In this present study, Three (1.5%) patients was found pallor of palms, 86.8% patients had heart rate ≥100 beats per minute, 95.6% capillary refill time <3 second, 2.0% hepatomegaly >2 cm and 63.9% had temperature ≥38 °C. Almost similar findings were also observed by Ahammad & Amin [10]. Children with pneumonia often presented with hypoxaemia and remained hypoxaemic for longer compared to those without pneumonia. Children with pneumonia present with inflammation in the lung parenchyma and often experience increased oxygen demand and inadequate oxygen supply due to the reduction of diffusion of oxygen at the level of the blood gas barrier at alveolar region of respiratory zone of lung leading to hypoxaemia. In this current study, it was observed that Mean age was found 8.5±8.0 months in hypoxemia group and 9.9±11.8 months in non hypoxemia group. More than half (52.9%) patients were male in hypoxemia group and 106(68.8%) in non hypoxemia group. Majority (96.1%) patients come from

rural area in hypoxemia group and 142(92.2%) in non hypoxemia group. The mean weight was found 8.6±2.2 kg in hypoxemia group and 6.9±3.0 in non hypoxemia group. Majority (84.1%) patients had severe pneumonia in hypoxemia group and 97(63.0%) in non hypoxemia group. In this current study, 60.8% patients had irritability in hypoxemia group and 58(37.7%) in non hypoxemia group. More than three fourth (76.5%) patients had severely reduced feeding in hypoxemia group and 65(42.2%) in non hypoxemia group. Forty five (88.2%) patients had inability to drink or feed in hypoxemia group and 51(33.1%) in non hypoxemia group. Four (7.8%) patients had unusually sleepy in hypoxemia group but not in non hypoxemia group. Irritability, severely reduced feeding, inability to drink or feed and unusually sleepy were statistically significant ($p<0.05$) between two group but other complications were not statistically significant ($p>0.05$). In this present study, 11(21.6%) patients had movement during examination in hypoxemia group and 132(85.7%) in non hypoxemia group, was significantly ($p<0.05$) higher in Hypoxemia group but other general examinations were not statistically significant ($p>0.05$) between two groups.

Limitations of the study

In this study, all patient couldn't be recruited at the time of emergency admission which would yield better result. The study was uni-centered and short duration due to time constraint. So, generalization may not be achieved without multi centered and long duration study for seasonal and altitude variation. Confounders like bronchiolitis, asthma and other related reasons were poorly addressed. The present study was conducted at a very short period of time. Small sample size was also a limitation of the present study. Therefore, in future further study may be under taken with large sample size.

VI. CONCLUSION AND RECOMMENDATIONS

Hypoxaemia was more common in 2-11 months infant with pneumonia, male subject and severe pneumonia. Cough, breathing difficulty and fast breathing were significantly more common symptoms and signs of Hypoxaemia. Regarding the respiratory signs crepitations, rhonchi, and head nodding were significantly more common in hypoxaemia. Pallor of palms, Heart rate <100 bpm, Capillary refill time <3 sec, Hepatomegaly >2cm, Temperature <38°C were significantly more frequent physical signs in hypoxaemia. Inability to drink, lethargy, nasal flaring and lower chest indrawing are clinical predictors of hypoxaemia in pneumonia though their sensitivity and specificity are not up to our expectation. So, those clinical features may be used as predictors of hypoxaemia in under 5 children with pneumonia in resources limited areas. Visual media might be more effective for the proper education of the clinical signs of pneumonia as fast breathing and lower chest wall indrawing, the key signs of pneumonia. Further study is recommended hereby with greater methodological purity and addressing all the limitation to decide on hypoxemia in pneumonia.

REFERENCES

1. Rudan, I., Boschi-Pinto, C., Biloglav, Z., Mulholland, K., & Campbell, H. (2008). Epidemiology and etiology of childhood pneumonia. *Bulletin of the world health organization*, *86*, 408-416B.
2. Mower, W. R., Sachs, C., Nicklin, E. L., & Baraff, L. J. (1997). Pulse oximetry as a fifth pediatric vital sign. *Pediatrics*, *99*(5), 681-686.
3. Laman, M., Ripa, P., Vince, J., & Tefuarani, N. (2005). Can clinical signs predict hypoxaemia in Papua New Guinean children with moderate and severe pneumonia?. *Annals of tropical paediatrics*, *25*(1), 23-27.
4. Lozano, J. (2001). Epidemiology of hypoxaemia in children with acute lower respiratory infection [oxygen therapy in children]. *The international journal of tuberculosis and lung disease*, *5*(6), 496-504.
5. Qazi, S. (2002). Oxygen therapy for Acute Respiratory Infection in young children. *Indian Pediatrics*, 39, 909-913.
6. World Health Organization. (2005). *Pocket book of hospital care for children: guidelines for the management of common illnesses with limited resources*. World Health Organization.
7. Acute respiratory infection in children. Case management in small hospitals in developing countries. 1993. WHO/ ARI/ 90.5.
8. Weber, M. W., Usen, S., Palmer, A., Jaffar, S., & Mulholland, E. K. (1997). Predictors of hypoxaemia in hospital admissions with acute lower respiratory tract infection in a developing country. *Archives of disease in childhood*, *76*(4), 310-314.
9. Usen, S., Weber, M., Mulholland, K., Jaffar, S., Oparaugo, A., Omosigho, C., ... & Greenwood, B. (1999). Clinical predictors of hypoxaemia in Gambian children with acute lower respiratory tract infection: prospective cohort study. *Bmj*, *318*(7176), 86-91.
10. Ahammad, F., & Amin, M. R. (2010). Clinical predictors of hypoxaemia in radiology confirmed pneumonia in 2-60 months old children. *DS (Child) H J*, 26(2), 101-107.
11. Lodha, R., Bhadauria, P. S., Kuttikat, A. V., Puranik, M., Gupta, S., Pandey, R. M., & Kabra, S. K. (2004). Can clinical symptoms or signs accurately predict hypoxemia in children with acute lower respiratory tract infections?. *Indian pediatrics*, *41*(2), 129-136.
12. Duke, T., Mgone, J., & Frank, D. (2001). Hypoxaemia in children with severe pneumonia in Papua New Guinea [oxygen therapy in children]. *The International Journal of Tuberculosis and Lung Disease*, *5*(6), 511-519.

13. Subhi, R., Adamson, M., Campbell, H., Weber, M., Smith, K., Duke, T., & Hypoxaemia in Developing Countries Study Group. (2009). The prevalence of hypoxaemia among ill children in developing countries: a systematic review. *The Lancet infectious diseases*, *9*(4), 219-227.
14. Onyango, F. E., Steinhoff, M. C., Wafula, E. M., Wariua, S., Musia, J., & Kitonyi, J. (1993). Hypoxaemia in young Kenyan children with acute lower respiratory infection. *British medical journal*, *306*(6878), 612-615.
15. Moller, J. T., Pedersen, T., Rasmussen, L. S., Jensen, P. F., Pedersen, B. D., Ravlo, O., ... & Johansen, S. H. (1993). Randomized evaluation of pulse oximetry in 20,802 patients; I: design, demography, pulse oximetry failure rate, and overall complication rate. *The Journal of the American Society of Anesthesiologists*, *78*(3), 436-444.
16. Thoms, G. M. M., McHugh, G. A., & O'sullivan, E. (2007). The global oximetry initiative. *Anaesthesia*, *62*, 75-77.
17. Wandi, F., Peel, D., & Duke, T. (2006). Hypoxaemia among children in rural hospitals in Papua New Guinea: epidemiology and resource availability—a study to support a national oxygen programme. *Annals of tropical paediatrics*, *26*(4), 277-284.
18. Matai, S., Peel, D., Wandi, F., Jonathan, M., Subhi, R., & Duke, T. (2008). Implementing an oxygen programme in hospitals in Papua New Guinea. *Annals of tropical paediatrics*, *28*(1), 71-78.
19. World Health Organization. (2000). Management of the child with a serious infection or severe malnutrition. Guidelines for care at the first-referral level in developing countries. WHO/FCH/CAH/00.1. Geneva. WHO.
20. Abdulkadir, M. B., Ibraheem, R. M., Gobir, A. A., & Johnson, W. B. R. (2015). Hypoxaemia as a measure of disease severity in young hospitalised Nigerian children with pneumonia: A cross-sectional study. *South African Journal of Child Health*, *9*(2), 53-56.
21. Lozano, J. M., Steinhoff, M., Ruiz, J. G., Mesa, M. L., Martinez, N., & Dussan, B. (1994). Clinical predictors of acute radiological pneumonia and hypoxaemia at high altitude. *Archives of disease in childhood*, *71*(4), 323-327.
22. Mulholland, E. K., Simoes, E. A., Costales, M. O., McGrath, E. J., Manalac, E. M., & Gove, S. (1992). Standardized diagnosis of pneumonia in developing countries. *The Pediatric infectious disease journal*, *11*(2), 77-81.
23. Singhi, S., Dhawan, A., Kataria, S., & Walia, B. N. S. (1994). Validity of clinical signs for the identification of pneumonia in children. *Annals of tropical paediatrics*, *14*(1), 53-58.
24. Mwaniki, M. K., Nokes, D. J., Ignas, J., Munywoki, P., Ngama, M., Newton, C. R., ... & Berkley, J. A. (2009). Emergency triage assessment for hypoxaemia in neonates and young children in a Kenyan hospital: an observational study. *Bulletin of the World Health Organization*, *87*(4), 263-270.