Assessment of clinical features and haematocrit levels in detection of hypoxaemia in sick children

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Abstract

This cross-sectional study was to determine the prevalence of hypoxaemia among sick children in Enugu State University Teaching Hospital, Enugu, Nigeria and correlate it with clinical features and haematocrit levels.

Ninety-two (92) sick children aged 2–48 months hospitalised at the teaching hospital were recruited after obtaining consent from their carers.

The prevalence of hypoxaemia in this study, defined by oxygen saturation of less than 90%, was 13%, and was not dependent on age or sex. A higher proportion of subjects with hypoxaemia had tachypnoea (81.8%), compared with those without (18.2%) ($\chi^2 = 1.69$; p=0.19). The sensitivity of using tachypnoea alone to predict hypoxaemia was 18.4% while the specificity was 92.3%. The presence of hypoxaemia predicted poor outcome; 66.7% of those that died had hypoxaemia. The difference was statistically significant ($\chi^2 = 17.9$; p=0.00).

Tachypnoea had a poor sensitivity although good specificity in predicting hypoxaemia. Presence of hypoxaemia connotes poor prognosis. We recommend that finger pulse oximeters, which are cost effective, should be routinely available at hospitals in developing countries, so that hypoxaemia can be detected earlier and more intensive management instituted.

Introduction

Hypoxaemia is defined as a condition where the arterial oxygen tension (PaO_2) is below normal (normal PaO_2 = 80–100 mmHg), in contrast to hypoxia which is the failure of oxygenation at the tissue level.[1] Blood oxygen is measured directly by an arterial blood test or indirectly by an oximeter, a small device that is clipped to the finger tip or ear lobe and measures the oxygen saturation.[2] Normal blood oxygen readings using oximeters range from 95 to 100% at sea level.[2] Hypoxaemia and hypoxia are major risk factors for death in ill children[3] but can be detected early with pulse oximeters and appropriate management promptly instituted. Pulse oximeters are however not widely and routinely available at health facilities in developing countries. This is complicated by a limited supply of oxygen, a key therapy in combating hypoxaemia and hypoxia. Often, therefore, the decision to administer oxygen and pay special attention to critically ill children in low-income countries is dependent on sets of respiratory and non-respiratory signs that predict hypoxaemia,[4] most notably tachypnoea. These signs may not clearly and accurately predict hypoxaemia/hypoxia.[3] This study therefore, is aimed at evaluating the oxygen saturation of sick children admitted at the Enugu State University Teaching Hospital (ESUTH) in south-east Nigeria and correlating it with clinical features such as tachypnoea and haematocrit values.

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Methods

This cross-sectional study monitored 92 sick children aged 2–48 months admitted to the children's emergency unit of ESUTH, Enugu between September 2009 and March 2010. Exclusion criteria were children aged less than 2 months or more than 5 years and those who could not be enrolled within 24 hours of admission. The study used a structured questionnaire containing information on bio-data (age and sex), vital signs (respiratory and pulse rates), clinical diagnosis, and oxygen saturation. Baseline packed cell volume (PCV) was done for each patient at presentation. The enrolled patients were then monitored until the eventual outcome: survival and discharge, death or abandonment.

Oxygen saturation was determined using a Nellcor non-invasive pocket pulse oximeter with an in-built sensor that does not require recalibration before each use. Hypoxaemia was defined as oxygen saturation of less than 90% in line with World Health Organization (WHO) recommendations.[5] The packed cell volume at presentation was determined using the haematocrit centrifuge.

Medical staff then measured the oxygen saturation and haemoglobin levels before any treatment was administered. However, the results of these tests influenced the management such that oxygen therapy was given for hypoxaemia and blood transfusion for severe anaemia. Vital signs (respiratory and pulse rates) were also counted for 1 minute and tachypnoea defined based on WHO criteria. According to these criteria, respiratory rates

of more than 60 breaths/minute, more than 50 breaths/minute, and more than 40 breaths/minute for young infants (0–59 days), infants (60–365 days), and childhood (1–5 years), respectively, are regarded as being symptomatic of tachypnoea.[6] The questionnaire was then completed for the child.

Data were analysed using SPSS version 17. Descriptive statistics were used in reporting prevalences. Sensitivity and specificity of tachypnoea in detecting hypoxaemia were calculated. Chi-squared test was used for statistical significance of categorical variables. The level of statistical significance used was 0.05 and 95% confidence interval is reported where necessary.

To improve the validity of the study, improperly worded questions were rephrased and the questionnaire was pre-tested on five patients who were subsequently excluded from the study.

Ethical approval was obtained from the Health Research and Ethics Committee of the University of Nigeria Teaching Hospital, Ituku-Ozalla and ESUTH, Nigeria.

Results

A total of 92 children who met the inclusion criteria were consecutively enrolled into the study. They were aged 2 to 48 months (mean age 13.1 months). Fifty-four participants were males and 38 females (ratio 1.4:1). The majority (66%) were aged less than 12 months, 26% were aged 13 to 24 months, while 3% and 4% were aged 25 to 36 months and 37 to 48 months, respectively (see Table 1).

Common clinical diagnoses (see Table 2) at presentation in the hospital were gastroenteritis with dehydration, pneumonia, severe malaria with anaemia, central nervous system (CNS) infections, and sepsis.

Some of the independent (predictor) variables examined included haematocrit levels of the children, illness outcome (survived, abandoned, or died), clinical diagnosis and tachypnoea, while the outcome (dependent) variable was presence of hypoxaemia. Fifty (56%) participants had no anaemia defined as a haematocrit level above 30%. Only one child (1%) absconded, while 21% died. The majority of the patients (65%) had tachypnoea defined based on WHO age-specific criteria.

The prevalence of hypoxaemia in this study was 13%. An oxygen saturation of between 90 and 95% was recorded in 32% of the participants while 53% and 2% of the participants had oxygen saturations within the ranges of 96 to 100% and above 100%, respectively. About the same proportion (13%) of both genders had hypoxaemia, (χ^2=0.001; p=0.98). Among the various age groups, hypoxaemia was documented in 11.5% of those aged less than 12 months, 13% of those aged 13–24 months, 33% of those 25–36 months, and 25% of those 37–48 months. The observed differences among the various age groups were not statistically significant (χ^2=1.73; p=0.63).

The respiratory rate was documented in 76 subjects. A higher proportion of those that had tachypnoea (18%), compared with those without tachypnoea (7%) had hypoxaemia. This difference was however not statistically significant (χ=1.69; p=0.19) as shown in Table 3. The sensitivity of using tachypnoea alone to predict hypoxaemia was 18% while the specificity was 92%.

Among the various clinical diagnoses, hypoxaemia was documented in 4.8% of those with gastroenteritis and dehydration, severe acute malnutrition (0%), sepsis (12.5%), severe malaria with anaemia (8.3%), paediatric AIDS (50%), pneumonia (10.5%), acute bronchial asthma (100%), acute renal failure with shock (100%), encephalopathy (0%), meningitis (25%), and bronchopneumonia with heart failure (25%). These differences were not statistically significant (χ^2=22; p=0.83) however.

Hypoxaemia was more common in children with anaemia (82%) than without. Anaemia was defined as PCV of less than 30%. These differences were not statistically significant (χ=3.5; p=0.06).

In terms of the outcome, hypoxaemia was documented in 33% of those that survived and in 67% of those that died. This difference was statistically significant (χ^2=17.86; p=0.00).

Table 1 General characteristics of the study participants

Age (months)	Male (%)	Female (%)	Total (%)
0–12	33 (36)	28 (31)	61 (67)
13–24	15 (16)	9 (10)	24 (26)
25–36	3 (3)	0 (0)	3 (3)
37–48	3 (3)	1 (1)	4 (4)
Total	54 (58)	38 (41)	92 (100)

Table 2 Provisional clinical diagnosis of the subjects on presentation

Clinical diagnosis	Frequency (%)	Hypoxaemia (%)
Gastroenteritis with dehydration	21 (23)	1 (4.8)
Pneumonias	19 (21)	2 (10.5)
Severe malaria with anaemia	12 (13)	1 (8.3)
Sepsis	8 (9)	1 (12.5)
Pneumonia, gastroenteritis, malnutrition	9 (9)	2 (26.8)
Malaria	5 (5)	0 (0)
Central nervous system infections	8 (9)	1 (12.5)
Bronchopneumonia with heart failure	4 (4)	1 (25)
Others (asthma, renal failure,	6 (7)	3 (50)

Table 3 Relationship between hypoxaemia and tachypnea

Tachypnoea	Hypoxaemia		Total n (%)
	Yes	No	
Yes	9 (82)	40 (62)	49 (65)
No	2 (19)	25 (39)	27 (36)
Total	11 (100)	65 (100)	76 (100)
χ^2=1.69, df=1, p=0.19.			

Discussion

The prevalence of hypoxaemia in this study, defined as oxygen saturation of less than 90%, was 13%. This is lower than the 31–72% range reported by Ayieko and English[4] following a systematic review of 12 articles on hypoxaemia among children with acute lower respiratory tract infection (RTI). Values reported by the various authors were however dependent on definition of the hypoxaemia which ranged between SpO_2 of less than 85% to less than 92%. Notably the review excluded studies that looked at hypoxaemia in children with illnesses other than acute lower RTI. The inclusion of such children may have reduced the prevalence noted in this study. Another systematic review by Subhi and colleagues[5] reviewed studies on prevalence of hypoxaemia among ill children in developing countries. They noted that the median hypoxaemia prevalence among studies of children with severe pneumonia was 9.4% (interquartile range (IQR) 7.5–18.5%). In studies of pneumonia requiring hospitalisation the median hypoxaemia prevalence is 13.3% (IQR 9.3–37.5%), which was similar to our study prevalence of 13%.

Junge and colleagues[7] included children with both respiratory and non-respiratory illness in a study involving 3269 children in the Gambia. They documented an overall hypoxaemia prevalence of 19%, which is comparable to our study. While both studies included acute lower RTIs as well as other childhood diseases, the higher prevalence could be explained by their definition of hypoxaemia. They used an oxygen saturation cut-off point of below 95% and less than 90% to define severe hypoxaemia.

A wide range of childhood diseases can present with hypoxaemia. In this study, acute lower RTI alone or as a co-morbidity or associated with complications, such as heart failure, accounted for most of the hypoxaemia. However, many other childhood diseases such as paediatric AIDS, septicaemia, severe malaria with anaemia, and meningitis were associated with hypoxaemia. Our findings also agree with the results of the systematic review by Subhi and colleagues[5] where prevalence of hypoxaemia ranged from 2.9% to 17.1% for four studies of malaria, 2.7% to 14.6% for three studies of meningitis, and 1.8% to 8.3% for four studies of malnutrition.[5] Children with anaemia were more likely to have hypoxaemia, which could be a manifestation of disease severity.

There are a number of clinical signs that require oxygen therapy in resource-poor countries where pulse oximeters are not routinely available. These include central cyanosis, tachypnoea, severe chest in-drawing, restlessness, inability to drink/poor general health status, and head nodding.[4] Tachypnoea appears to be the most common, as respiratory rate is one of the vital signs routinely monitored in sick children. The systematic review by Ayieko and English[4] noted that central cyanosis has poor sensitivity and was able to detect a proportion of hypoxaemic children that varies widely (from 9–80%). In Africa, detecting and interpreting cyanosis could further be complicated in individuals with dark skins and high rates of endemic moderate/severe anaemia.[4] Inability to drink has both low sensitivity and specificity suggesting that children could erroneously be diagnosed as hypoxaemic, thereby potentially wasting oxygen while severe chest in-drawing has not been convincingly demonstrated to be helpful in the detection of hypoxaemia.[4] In terms of respiratory rate, sensitivity appears modest (4–57%) and specificity good (70–100%) for a threshold of greater than 70 breaths per minute, but reducing the threshold to greater than 60 breaths per minute, predictably increases sensitivity and reduces specificity, limiting the usefulness of very high respiratory rate thresholds in predicting hypoxaemia.[4] In this study, tachypnoea had a very low sensitivity (33%) but a good specificity (92%); this means that many hypoxaemic children will not be detected if tachypnoea alone is used as predictor of hypoxaemia. On the other hand, a specificity of 92% implies that those without tachypnoea are unlikely to have hypoxaemia. Hypoxaemia was associated with increased mortality, and was documented in 67% of the children that eventually died.

Conclusion

The commonly used clinical sign in developing countries to predict hypoxaemia, i.e. tachypnoea, has a poor sensitivity. The presence of hypoxaemia connotes poor prognosis.

Our sample size was rather small because the teaching hospital is still developing. Respiratory rates were documented in only 76 out of the 92 subjects further limiting the interpretation of the correlation between respiratory rates and hypoxaemia. Different levels of morbidities could have influenced the presence or absence of hypoxaemia although patients with various co-morbidities were specifically noted in the study.

We recommend that pulse oximeters, which are cost effective, should be routinely available at hospitals in developing countries. Oxygen saturation monitoring ensures that severely hypoxaemic children are promptly identified. This may help reduce the high mortality associated with hypoxaemia. A similar study with larger sample size would improve the power of the study.

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