Correlation between pulse oximetry and the clinical profile of children with acute lower respiratory tract infection

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Background. Hypoxaemia is a common predictor of mortality and a potent marker of severe illness in children with acute lower respiratory tract infection (ALRTI).
Objective. To determine the mean oxygen saturation (SpO2) in children with ALRTI and its correlation with selected clinical and anthropometric variables.
Methods. A cross-sectional study of 178 children, aged between 2 months and 5 years, treated in two teaching hospitals in southeast Nigeria. All patients were assessed for ALRTI, focusing on their clinical profile and sociodemographic risk factors. Student's *t*-test was used to compare means of discrete variables. Pearson correlation was used to express association between discrete variables and multiple regression was used to predict dependent variables.
Results. Patients with severe ALRTI had significantly lower oxygen saturation (SpO2=89%) than those with mild disease (SpO2=95%) (*p*=0.001). A negative correlation was found between oxygen saturation and respiratory rate. Multiple regression analysis showed respiratory rate to be the only variable predicting oxygen saturation in children with ALRTI, with a negative association between the two variables.
Conclusion. Low oxygen saturation is associated with decreased respiratory rate in children with ALRTI. Oxygen supplementation should always be considered in children with ALRTI, especially those with severe disease.
Key words: *acute lower respiratory infection, pulse oximetry, oxygen saturation*

Acute lower respiratory tract infection (ALRTI) is defined as an infection that affects the airways just below the epiglottis and the aryepiglottic fold and which lasts for 28 days, with the commonest forms being pneumonia and acute bronchiolitis.[1] ALRTIs are a major cause of morbidity and mortality in children under the age of 5 years worldwide[1] and as such are important indicators of health indices in developing countries.[2]

Hypoxaemia is a common predictor of mortality and a potent marker of severe illness in children with pneumonia and bronchiolitis.[3-5] Pulse oximetry is typically used to measure a patient's peripheral arterial oxygen saturation, which Modi *et al.*[6] noted as the best clinical predictor of pneumonia.

The use of pulse oximetry to predict the severity of symptoms in children with ALRTIs seems uncommon, with previous studies correlating oximetry readings with respiratory rate but without considering pulse rate and other clinical correlates. This current study therefore focused on determining mean oxygen saturation (SpO2) in children with ALRTIs and correlating findings with weight, height, respiratory rate, pulse rate and body temperature. An additional objective was to determine whether pulse oximetry readings have predictive value for respiratory rate.

Method
Study design and setting
This was a prospective, cross-sectional study to assess pulse oximetry readings and the clinical profile of children younger than 5 years with an ALRTI (pneumonia or bronchiolitis). The study was conducted at

the Enugu State University Teaching hospital, Enugu, and Ebonyi State University Teaching Hospital, Abakaliki, in southeast Nigeria. Enugu, the capital city of Enugu State, has an altitude of 180 metres above sea level and an average humidity of 94%.

The study population comprised children between 2 months and 5 years old who had been admitted to the paediatric emergency room or ward with an ALRTI. Children with a history of catarrh, wheezing, fever, cough and dyspnoea that lasted for up to 2 weeks were included in the study. Clinical features considered were tachypnoea, chest retractions (with or without crepitation or rhonchi) and chest X-rays showing bilateral patchy opacities, lobar opacification or hyperinflation of the lungs.

Children with personal or family history of asthma or other chronic lung or cardiac disease were excluded from the study, as were patients who were HIV positive or whose caregivers declined consent.

Measurements
Pulse oximetry
The pulse oximeter consists of a probe containing a photodetector and light-emitting diode (LED). The diode emits light at a specific wavelength while the photodetector measures the amount of light transmitted through a selected vascular bed such as in the earlobe, toes or fingertips.[7] According to the Beer–Lambert law of light absorption, light is absorbed when it passes through plasma that contains a solute (such as haemoglobin), which absorbs light at a specific wavelength. Arterial blood subsequently appears bright

red, whereas venous blood has a blue hue. The absorption readings are fed into an algorithm in a microprocessor to calculate the oxyhaemoglobin saturation, which is displayed to the user.[7]

To measure saturation, a patient's finger was wiped with alcohol and any nail polish was removed to allow for maximum light absorption. The fingers were also examined for features that could have influenced readings, such as excessive skin pigmentation.

The device was placed to fit the digit without restricting circulation, which could have resulted in a false reading. A pulse rate compatible with age and normal oxygen saturation was evidence of a correct reading.[8-10] We used normative values for heart rate and age to verify readings. The displayed pulse rate was cross-checked against radial pulsation, measured by palpation on the other hand.[8-10] The best of two SpO2 readings was recorded.

Anthropometry

Weight and height were measured using a stadiometer (Detecto, USA).[10] Recordings were made to the nearest 0.5 kg and 0.5 cm, respectively.[10] Body mass index (BMI) was calculated according to

the standard formula $BMI\ (m^2) = \dfrac{weight\ (kg)}{[height\ (m)]^2},$[11,12] while body surface

area (BSA) was calculated according to the Mosteller formula:[13]

$$BSA\ (m^2) = \sqrt{\frac{height\ (m) \times weight\ (kg)}{3600}}$$

Data analysis

Data were analysed using IBM Statistics for Windows, version 20 (IBM Statistics, Chicago). Categorical variables were expressed as proportions and percentages, whereas discrete variables were expressed as means and standard deviations (SDs) and compared for statistical difference using Student's t-test. Pearson's correlation coefficient was used to express the association between discrete variables, with a significance level of $p<0.05$, and multiple regression analysis was used to predict the dependent variable (SpO2) when other independent variables were kept constant.

Ethical considerations

Approval for the study was obtained from the University of Nigeria Teaching Hospital's Health Research and Ethics Committee (ref. no.: IRB00002323).

Results

A total of 178 patients were assessed for ALRTI, of whom 97 (54.5%) were male and 81 (45.5%) were female. The mean (SD) age across the sample was 13.1 (11.7) months. Other anthropometric indices are summarised in Table 1, with clinical parameters indicated in Table 2.

Table 3 shows the correlation between oxygen saturation and clinical parameters and anthropometric indices. Oxygen saturation was negatively correlated with respiratory rate($p=0.001$). Patients with severe ALRTI had significantly lower mean (SD) oxygen saturation (89% (8.0)) than those with mild disease (95% (4.0)) ($p<0.001$). Mean (SD) oxygen saturation was not significantly different between male (91% (7.0)) and female (91% (8.0)) patients ($p=0.9$).

Multiple regression analysis revealed a significant negative association between oxygen saturation and respiratory rate ($p=0.002$) (Table 4). This indicates that as respiratory rate decreases, the oxygen saturation also decreases when other variables are kept constant. A one-unit decrease in respiratory rate resulted in a 0.28% decrease in oxygen saturation.

Discussion

The mean oxygen saturation recorded across the sample was 90.6%. Respiratory rate and pulse rate were 61 breaths per minute and 140 beats per minute, respectively. These values suggest the action of cytokines and substances of acute respiratory phase reactants, which cause inflammatory changes in ALRTI.

Hypoxaemia determined by means of pulse oximetry has been used as clinical indicator in children with ALRTI who require hospitalisation.[3,14] The increased respiratory and pulse rate at a saturation level of 90% seen in this study agrees with findings from another study, which showed children with a saturation level <90% to have 5.4 times higher risk of mortality.[15]

Our results show a significant negative correlation between oxygen saturation and respiratory rate in the sample, with children with severe ALRTI having significantly lower saturation levels (SpO2=89%) than those with mild disease (SpO2=95%). According to a multiple regression analysis, respiratory rate was the only vital sign that predicted oxygen saturation. The findings suggest that using clinical signs to determine whether a patient needs oxygen is unreliable.[16] This is in line with findings from a systematic review, which showed that neither single nor combined symptoms are effective predictors of hypoxaemia in young children with ALRTI.[16,17]

In this study, a decrease of one breath per minute resulted in a

Table 1. Anthropometric parameters (N=178)

Variable	Mean (SD)
Age (months)	13.1 (11.7)
Weight (kg)	8.8 (4.5)
Height (cm)	72.1 (17.3)
Mid upper-arm circumference (cm)	14.4 (4.6)
Head circumference (cm)	44.5 (5.5)

SD = standard deviation.

Table 2. Clinical variables of patients presenting with an acute lower respiratory tract infection (N=178)

Variable	Mean (SD)
SpO2 (%)	90.6 (7.6)
Respiratory rate (breaths/min)	61 (17)
Pulse rate (beats/min)	140 (19)
Body temperature (°C)	38.2 (1.1)

SD = standard deviation; SpO2 = oxygen saturation.

Table 3. Correlation between oxygen saturation and clinical variables

Variable	Pearson correlation coefficient	p-value
Age (N=162)	0.09	0.2
Temperature (N=161)	0.1	0.1
Pulse rate (N=153)	−0.007	0.9
Respiratory rate (N=161)	−0.4	0.001
Weight (N=160)	0.01	0.8
Height (N=162)	0.09	0.2
Mid upper-arm circumference (N=140)	0.04	0.6
Head circumference (N=152)	0.1	0.2

Table 4. Multiple regression analysis showing association between the dependent variable (oxygen saturation) and various clinical and anthropometric variables

Variables	Unstandardised coefficients		Standardised coefficients		
	β	SE	β	t-statistic	p-value
Constant	91.376	10.485		8.715	0.000
Respiratory rate	−0.131	0.042	−0.280	−3.135	0.002
Pulse rate	0.004	0.034	0.010	0.116	0.908
Weight	−0.177	0.398	−0.071	−0.445	0.657
Height	0.065	0.063	0.142	1.018	0.311
Mid-arm circumference	0.011	0.161	0.006	0.071	0.944
Head circumference	0.078	0.237	0.045	0.330	0.742

SE = standard error.

0.28% decrease in oxygen saturation. This finding can be useful in calculating the exact amount of oxygen to be given to a paediatric patient with severe respiratory distress due to ALRTI.

Conclusion

Respiratory rate was found to be the only vital sign to accurately predict oxygen saturation in the sample of children with ALRTI. A decrease of one breath per minute was associated with a decrease of 0.28% in oxygen saturation.

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