A Comparative Study of Pulse Oximetry with Arterial Blood Gas Analysis in Patients with Acute Respiratory Tract Infections Coming to Paediatric Intensive Care Unit

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ABSTRACT

Introduction: In developing countries, Acute Respiratory tract infections are the leading cause of morbidity and mortality accounting for about 30 % of deaths under five years of age. Even though, better guidelines are framed through IMNCI, ARTI remains the leading cause of mortality. This is due to lack of knowledge and difficulty to identify hypoxia in ARTI cases. Objectives: 1.To know at which stage of ARTI (according to IMNCI guidelines), pulse oximetry is sensitive to predict hypoxia and it's correlation with ABG Analysis.
2.To correlate pulse oximetry finding with ABG Analysis for determining hypoxemia.

Material and methods: This was a hospital based prospective study done in Tertiary care Hospital, Kakinada, from 1st Dec 2017 to 1st June 2019. 300 ARTI cases out of the admitted cases in PICU in the age group 1 month to 5 years were studied.

Results: In the present study, there was a strong positive correlation (r = 0.981) in oxygen saturation measurement by pulse oximetry and ABG analysis.

Conclusion: Because of the strong positive correlation between pulse oximetry and ABG-Analysis in detecting hypoxemia, pulse oximetry can be considered as an appropriate substitute. The pulse oximeter is convenient for early detection of hypoxia even in the absence of danger signs, and this can decrease the morbidity and mortality of ARTI cases.

Keywords: Arterial Blood Gas Analysis (ABG), ARTI, Pulse Oximetry, Respiratory Rate (RR).

INTRODUCTION

Acute Respiratory tract infection was defined as acute onset of respiratory symptoms like cold, cough fast/difficulty in breathing, chest wall in-drawing, and wheeze of less than 14 days[1]. It is the major cause of morbidity and mortality in the under-five age group accounting for 30% of deaths worldwide[1,2,3].

Hypoxia increases the risk of death more than four-fold in children with ARTI[5]. Oxygen saturations less than 90% is defined as hypoxia[2,3,6].

The most accurate way to detect hypoxia is an Arterial Blood Gas analysis (or) peripheral capillary oxygen saturation by pulse oximetry[1,2,3,6,7]. We can use pulse oximetry reading as a referral indicator rather than merely relying on clinical signs and symptoms, which requires a lot of knowledge in training and implementing.

The simple signs of ARTI that can be easily identified were increased respiratory rate & chest in-drawing. But they vary in a crying child, and that accounts for misinterpretation by the gross root level workers. So a more straightforward method of detecting hypoxemia in ARTI by pulse oximetry was thought of, and that became the basis for this study.

Pulse oximetry is a useful tool for clinical and investigational purposes for indirect measurements of oxygen saturation[9,10,11].

Pulse oximetry allows non-invasive measurement of oxygen saturation(SpO_2), without the risks associated with arterial puncture[8].

Arterial Blood Gas analysis is an essential part of measuring a patient's oxygenation status. It is an invasive method, which requires skill and trained personnel for the collection of blood samples from the peripheral or central artery.

So this study was done to compare the pulse oximetry with Arterial Blood Gas Analysis in patients with ARTI coming to the paediatric intensive care unit and to identify the stage at which ARTI cases develop Hypoxia using both pulse oximetry and ABG.

MATERIAL AND METHODS

This is a hospital based prospective study done in Tertiary care Hospital, Kakinada, from 1st Dec 2017 to 1st June 2019. 300 ARTI cases out of the admitted cases in PICU in the age group 1 month to 5 years were studied.

Inclusion criteria

ARTI cases that were admitted in PICU
(1 month to 5 years of age)

Exclusion criteria

ARTI cases with underlying congenital and acquired cardiac diseases.

Study tools

Pulse oximeter, ABG machine, and other devices as required.

STATISTICAL ANALYSIS

SpO2 and SaO2 were measured simultaneously with the help

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How to cite this article: D. Lakshmi Vidya, M.S. Raju, Siva Kumar, K. Sai Surabhi. A comparative study of pulse oximetry with arterial blood gas analysis in patients with acute respiratory tract infections coming to paediatric intensive care unit. International Journal of Contemporary Medical Research 2022;9(10):J1-J6.

Age	Male	Female	Total
1month up to 2 months (young infant)	5 (62.5%)	3 (37.5%)	8
2 months up to 4 months (Infant)	35 (54.7%)	29 (45.3%)	64
4 months up to 8 months (Infant)	32 (55.2%)	26 (44.8%)	58
8 months up to 12 months (Infant)	17 (45.9%)	20 (54.1%)	37
1 year up to 3 years (Toddler)	36 (57.2%)	27 (42.8%)	63
3years to 5 years (Pre School)	32 (45.7%)	38 (54.3%)	70
Total	157 (52.3%)	143 (47.7%)	300

Table-1: Age wise and sex wise distribution of study population of arti cases

Methods	(Mean ± SD)
SpO_2 (Pulse oximetry)	90.82 ± 7.34%
SaO_2 (ABG)	90.91 ± 5.35%
PaO_2 (ABG)	67.06 ± 14.97 mm Hg
Hb% (ABG)	12.74 ± 0.43 grams.

Table-2: Statistical indices of SpO2, SaO2, PaO2, and Hb%.

S. No	Severity of Disease	Total n = 300
1	Fast Breathing only	133(44.3%)
2	Fast Breathing & Chest In-drawing without Danger signs	95(31.7%)
3.	Fast Breathing & Chest In-drawing with Danger signs	72(24%)

Table-3: Distribution of study population according to the severity of disease.

S. No	Severity of Disease	Oxygen saturations by Pulse oximetry (SpO_2)		Oxygen saturations by ABG analysis (SaO_2)	
		>90%	<90%	>90%	<90%
1	Fast Breathing only (n=133)	131 (98.5%)	2 (1.5%)	131 (98.5%)	2 (1.5%)
2	Fast Breathing & Chest in-drawing without Danger signs (n=95)	83 (87.5%)	12 (12.5%)	83 (87.5%)	12 (12.5%)
3	Fast Breathing & Chest In-drawing with Danger signs (n=72)	0 (0%)	72 (100%)	0 (0%)	72 (100%)
4	Total (n=300)	214 (71.3%)	86 (28.7%)	214 (71.3%)	86 (28.7%)

Table-4: Distribution of study population according to oxygen saturation by pulse oximetry (SpO_2) and ABG analysis (SaO_2)

Age group	Fast Breathing only (n=133)		Fast Breathing & Chest in-drawing without Danger signs (n= 95)		Fast Breathing & Chest In-drawing with Danger signs (n = 72)		Total (n=300)
	Oxygen saturations		Oxygen saturations		Oxygen saturations		
	>90%	<90%	>90%	<90%	>90%	<90%	
1month up to 2 months (Young Infant)	5 (62.5%)	2 (25%)	0 (100%)	0 (100%)	0 (100%)	1 (12.5%)	8
2 months up to 4 months (infant)	22 (34.5%)	0 (100%)	17 (26.5%)	6 (9.5%)	0 (100%)	19 (29.5%)	64
4 months up to 8 months (infant)	30 (51.7%)	0 (100%)	9 (15.5%)	6 (10.3%)	0 (100%)	13 (19.1%)	58
8months up to 12 months (infant)	17 (46%)	0 (100%)	12 (32.4%)	0 (100%)	0 (100%)	8 (21.6%)	37
1 year Up to 3 years (Toddler)	26 (41.5%)	0 (100%)	22 (35%)	0 (100%)	0 (100%)	15 (23.5%)	63
3 years to 5 years (preschool)	31 (44.2%)	0 (100%)	23 (32.8%)	0 (100%)	0 (100%)	16 (23%)	70
Total	131 (43.67%)	2 (0.66%)	83 (27.67%)	12 (4%)	0 (0%)	72 (24%)	300

Table-5: Age wise distribution of study population according to severity of disease their oxygen saturation by pulse oximetry and abg analysis

Groups	Pulse oximetry SpO_2 (Mean ± SD)	ABG SaO_2 (Mean ±SD)	*r*-value
SpO_2 95-100% (n = 140)	96.63 ± 1.04%	95.46 ± 1.42%	0.893
SpO_2 90-94.9% (n = 74)	92.47 ± 0.95%	91.12 ± 0.92%	0.708
SpO_2 85-89.9% (n = 8)	86.25 ± 1.16%	88.32 ± 0.58%	0.687
SpO_2 80-84.9% (n = 46)	80.93 ± 0.97%	83.77 ± 0.59%	0.277
SpO_2 75-79.9% (n = 32)	76.93 ± 1.68%	81.41 ± 0.81%	0.276

Table-6: Correlation of oxygen saturation values by pulse oximetry and abg analysis.

of pulse oximeter and ABG, respectively. Mean + SD of SpO2 and SaO2 with Coefficient of correlation were measured and calculated. Means, SD, Percentages, the Pearson coefficient of correlation were the statistical methods used in this study.

DISCUSSION

Relationship of Hypoxia

Relationship with age

Basnet and colleagues[18] study showed that there was a significantly higher incidence of ARTI & hypoxemia in the age group of less than one year.

Singhi & colleagues[1] observed that hypoxemia was significantly more frequent in infants than children (1-5 Years of Age).

In the present study, 167 cases were in the age group less than 1 year, and the remaining 133 cases were in the age group 1yr to 5 years. The present study comparable to Basnet and colleagues study[18] which showed that there was a significantly higher incidence of ARTI in less than 1 year of age.

Relationship with respiratory rate

Fall in PaO_2 stimulates peripheral chemoreceptors leading to respiratory stimulation[35]. Rapid and shallow respirations (tachypnoea) characteristic of parenchymal disease[38].

Mulholland and other[19] studies showed that the presence of Rapid respiratory rate had sensitivity (90%), specificity(91%) to detect hypoxemia.

Duke and his co-workers[7] observed that in infants over the age of 1 month, RR > 60/min was the single most useful sign to predict hypoxemia.

Lozana et al[20] conducted a study of 200 children living at high altitudes with clinical symptoms & signs suggestive of pneumonia. They took radiological findings & hypoxemia as parameters, to predict Pneumonia. RR > 50/min stood as the single best parameter with a functional sensitivity of 76% - 71 % for hypoxemia.

Voets serge and colleagues[21] study observed that in children < 6 months, respiratory rate > 45/min & SpO_2 <95% are essential parameters to predict the need for admission.

Philip Ayeiko et al[22] study showed that R.R above age-specific cutoffs were the single most useful sign in predicting hypoxemia.

Smyths & colleagues[5] study found that R.R >70/min had 63% sensitivity and 89% specificity.

Weber & colleagues[6] study found that tachypnea in 2-12 months of age-predicted hypoxemia with sensitivity 90% specificity 43.6%.

Relationship with chest in-drawing

Chest wall in-drawing / retractions are due to increased negative intrathoracic pressure during inspiration. This occurs in diseases of decreased lung compliance[38].

Weber et al[6] showed that a severe chest in-drawing for children < 12 months was the single best predictor of hypoxemia.

Singhi et al[1] study showed that chest in-drawing was the most sensitive indicator of hypoxemia in ALRTI with sensitively 90% and negative predictive value of 98%.

Lodha et al[2] study observed that the presence of suprasternal in-drawing, ICR, SCR were significantly associated with hypoxemia with a sensitivity of 78.5% and specificity of 66.7%.

Onyango & colleagues[3] found that chest drawing as highly sensitive (88%) but poorly specific.

Reuland & colleagues[23] found that chest in-drawing as a predictor of hypoxemia had low sensitivity (35%) and high specificity.

Kabra et al[24] study found that chest in drawing had a sensitivity of 35.7% and specificity of 86.4% in children below five years.

Philip Ayeiko et al[22] study showed that chest indrawing and grunting although specific for hypoxemia were rare signs with very low sensitivity to predict hypoxemia.

Relationship with danger signs

Weber and Coworkers[6] observed that spo2 < 80% was identified by a combination of cyanosis, head-nodding & decreased crying. They also found moderately to severely reduced feeding was present is 42% of cases and 22% in the control group.

Singhi & his colleagues[1] study showed that cyanosis was the best predictor of hypoxemia with a predictive value of 71.4% and also showed that the inability to feed was most specific and adequate to detect hypoxemia.

Lodha & Colleagues[2] observed that cyanosis was significantly associated with hypoxemia, and ALRTI can be explained by cyanosis alone.

Duke et al[7] observed that cyanosis was much more specific, but if used alone have failed to detect >60% of children with hypoxemia. They also showed that reduced activity and inability to feed had high specificity but still failed to identify most children with hypoxemia.

Basnet & colleagues[18] study showed cyanosis was highly specific but relatively insensitive sign to predict hypoxemia in Acute lower respiratory tract infections. They also showed that the inability to feed has more specificity but relatively insensitive sign to predict hypoxemia.

In the present study, when the study population was distributed according to the severity of disease, 133 (44.3%) cases had fast breathing only, 95 (31.7%) cases had fast breathing and chest in-drawing without danger signs, 72(24%) cases had fast breathing and chest in-drawing with danger signs. As the disease severity increased, the percentage of cases decreased. This overall low percentage of fast breathing and chest in-drawing with danger sign cases in our study was due to the early use of oral antibiotics in the fast breathing stage itself by following IMNCI guidelines.

Relationship with SpO_2:-

Singhi& Colleagues[1] observed that SpO_2 ranged between 72-100% in children < 5 years, the prevalence was highest in very severe pneumonia, followed by severe pneumonia,bronchiolitis , &acute asthma.

Lodha & colleagues[2] study showed that each clinical symptoms & signs alone (or) in combination do not have sensitivity & specificity to identify hypoxemia (SpO_2 <90%).

Kabra &colleagues[24] study observed that hypoxemia had a good sensitivity & specificity for pneumonia in infants.

Voets and Colleagues[21] found that oxygen saturation less than 95% is a vital parameter to predict hypoxemia , need for admission, and stress the severity of bronchiolitis , in the age group less than six months.

The correlation coefficient between oxygen saturations measured by pulse oximetry and ABG in the fast breathing only, fast breathing and chest in-drawing without danger signs and fast Breathing and chest in-drawing with danger signs groups were 0.921, 0.946 and 0.768 respectively.

Comparison of oxygen saturations measured by pulse oximetry and ABG

Ramy R. et al[28] study showed that mean of the oxygen saturation values measured by pulse oximetry was greater than those measured by the ABG and strong positive correlation,SpO_2 = 89.2 $\pm$ 6.3%, SaO_2 = 87.4 $\pm$ 7.3%; correlation coefficient = 0.98.

Razi et al[29] study showed that mean of the oxygen saturations measured by pulse oximetry was lesser than those measured by the ABG and had strong positive correlation in hypoxemic patients(based on SpO_2 values), SpO_2 = 70.63 $\pm$ 9.13%, SaO_2 = 74.40 $\pm$ 10.24%; correlation coefficient = 0.856 and in non hypoxemic patients(based on SpO_2 values), SpO_2 = 94.37 $\pm$ 2.18%, SaO_2 = 94.17 $\pm$ 3.71%; correlation coefficient = 0.95.

Chiappini et al[30] study showed that mean of oxygen saturation measured by pulse oximetry was lesser than those measured by ABG, SpO_2 = 90.58 $\pm$ 5.45%, SaO_2 = 92.14 $\pm$ 5.79%.

Smitha Ramachandran et al[31] study showed that pulse oximetry oxygen saturations had a significant correlation with arterial saturations statistically in cyanotic heart disease patients with oxygen saturations below 80%.

Lee et al[32] study showed that mainly when PaO_2 less than 54 mm Hg, SpO_2 correlates poorly with SaO_2.

Our study was comparable to Ramy et al[28], Razi et al[29] in a correlation between oxygen saturation measured by pulse oximetry and ABG analysis. Our study had a higher value of correlation coefficient than other studies.

Our study was comparable to Razi et al[29] in a correlation between oxygen saturations measured by Pulse oximetry and ABG analysis in Non-Hypoxic and Hypoxic groups.

This present study was comparable to Razi et al[29]., and they found that the mean oxygen saturation values measured by (SpO_2) pulse oximetry were lesser than those measured by the (SaO_2) ABG analysis: SpO_2 = 88.39 $\pm$ 9.13 SaO_2 = 89.14 $\pm$ 8.60 %; correlation coefficient = 0.935.

This present study was comparable to Chiappini et al[30] study showed that mean of oxygen saturation measured by Pulse oximetry(SpO_2) was lesser than those measured by ABG(SaO_2), SpO_2 = 90.58 $\pm$ 5.45%, SaO_2 = 92.14 $\pm$ 5.79%.

In all the age groups, the correlation between oxygen saturations by Pulse oximetry(SpO_2) and ABG analysis(SaO_2) was a strong positive correlation and almost equal.

Correlation decreases with decreasing oxygen saturations by both Pulse oximetry and ABG analysis.

In the present study inaccurate readings of pulse oximetry in SpO_2 75-79.9%, SpO_2 80-89.9%, SpO_2 90-94.9%, SpO_2 95-100% were 4.48 , 2.84, 2.07 , 1.35, 1.17 respectively. This shows that the greater the hypoxia level, the higher the rate of disturbances, which may occur in accuracy between SpO_2 and SaO_2 measurements.

In the study of Carter et al[36] when SpO_2 below 75%, the performance of pulse oximetry was deteriorated. Webb et al[37] reported that at low saturations, pulse oximetry is poorly calibrated and generally less precise and less accurate than at normal saturations. Our results showed that changes in pulse oximetry do not reliably predict equivalent changes in SaO_2 when oxygen saturations are below 85%.

The positive correlation of oxygen saturation measured by pulse oximetry and ABG analysis was seen for the whole study population but also when it was seen in the age group wise division of the population, severity wise division of the population and even in the non-hypoxic and hypoxic groups also.

A lot of explanations have been proposed for the limited performance of pulse oximeters at low saturations. One is the slight variations in the light-emitting diodes output wavelength, and this generates proportionally larger errors at low saturations. Another is due to the significant extinction of reduced hemoglobin at low saturations, and there is the generation of proportionally larger errors in the measurement of transmitted red light versus infra-red light.

The risk of death from ARTI increases significantly when hypoxemia present. Hypoxemia has been associated with impending respiratory failure, intensive care unit admission,

and mortality.

Kenneth P. Levin et al[33] study showed that even in the absence of risk factors like altered mental status, fast breathing for hypoxemia, 10% of these patients tested were found to be hypoxic. But this study was done in Adults.

The availability of Pulse oximeter is easy nowadays, with this the need for the arterial sampling will be minimized, and also it reduces the economic burden for ABG analysis on patients for oxygen saturation measurement. Several studies have described clinical signs such as increased respiratory rate, grunting, tachypnea, head–nodding and cyanosis as predictive of hypoxemia. However, these individual signs and their combination have low predictive power. Therefore, assessment of SpO_2 by pulse oximetry is superior in diagnosing hypoxemia and is often considered as a fifth vital sign.

Pulse oximetry can identify high-risk children with respiratory tract infections. This study concluded that the correlation coefficient between the two methods has a strong positive correlation, so pulse oximetry can be considered an appropriate substitute for ABG, especially in SpO_2 >85%. In conditions with low Oxygen saturation(<$SpO_2$85%) and critical status, SpO_2 is not sufficiently accurate to replace SaO_2 measured by ABG analyzer.

The study by Fouzas et al[27] stated that pulse-oximeter is a non-invasive device for measuring oxygen saturation is a handy and helpful tool, even though there are some errors because of some conditions like perfusion abnormality, skin pigmentation, nail polish, heart arrhythmias, and non-calibrated probe. The findings of our study also approved the usefulness of pulse-oximeter and its accuracy in evaluating oxygen saturation. Our study demonstrates a strong positive correlation between SpO_2 and SaO_2 confirms this study.

At a PaO_2 of 60 mm, Hg oxygen saturation is 90% according to the oxygen dissociation curve under the specific conditions. Less than 90% of SaO_2 was taken as hypoxemia[34] in IMNCI guidelines[4] in this study also SaO_2 less than 90% was considered as Hypoxemia.

Oxygen dissociation curve shows hemoglobin oxygen saturation at 10 mm Hg 10%; at 15 mm Hg, it is 20%; at 40 mm Hg, it is 75%, at 60 mm Hg, it is 90%, and at 100 mm Hg it is 100%[34]. The normal PaO_2 is about 100 mm Hg, and the value may drop by up to 15% in healthy elderly subjects due to an increase in ventilation-perfusion inequality .so the range of normal PaO_2 is between 80 -100 mm Hg[35].

This Study under discussion was an admixture of cases that don't need oxygen, which need oxygen by simple methods and which may go up to mechanical ventilation. Among the criteria for mechanical ventilation were PaO_2 <60 mm Hg and PCO_2 >55 mm Hg are also there Saturation comes because of the partial pressure of oxygen, but the partial pressure of oxygen value don't happen because of saturation. So for that purpose, ABG became the need for the study, not just only for academic purpose.

So the reasons for ABG analysis in the study under discussion were

1) The purpose of the study is to compare oxygen saturation measured by pulse oximetry(SpO_2) with ABG analysis(SaO_2).
2) Even in the 2 months, up to 4 months of age group infants with increased respiratory rate itself showed hypoxemia which may become an indication for mechanical ventilation,
3) The study was an admixture of cases that need oxygen by simple methods and cases which need mechanical ventilation.

So the use of the invasive methods of knowing SaO_2 is justifiable only. As the readings of SpO_2 and SaO_2 were correlating with each other, lastly, to recommend pulse oximetry for early referral.

CONCLUSIONS

Our results showed that Pulse oximetry was sensitive to detect hypoxia in possible serious bacterial infection having fast breathing only in a sick young infant and in pneumonia with fast breathing & chest in-drawing stage of ARTI (according to IMNCI) in a sick child.

In the present study, there was a strong positive correlation (r = 0.981) in oxygen saturation measurement by pulse oximetry and ABG analysis.

Our results showed that changes in pulse oximetry do not reliably predict equivalent changes in SaO2 when oxygen saturations are below 85%. The pulse oximeter remains a valuable tool in the care of patients, but an awareness of its limitations is an essential component of enhancing the quality of care.

However, it must be emphasized that direct measurement of SaO2 is necessary whenever the SpO2 does not confirm to the patient's clinical status.

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Source of Support: Nil; **Conflict of Interest:** None

Submitted: 22-08-2022; **Accepted:** 26-09-2022; **Published:** 30-10-2022