International Journal of Biomedical and Advance Research
ISSN: 2229-3809 (Online); 2455-0558 (Print)
Journal DOI: 10.7439/ijbar
CODEN: IJBABN

Original Research Article

Can pulse oximetric saturation (SpO_2)/fraction of inspired oxygen (FiO_2) ratio surrogate PaO_2/ FiO_2 ratio in diagnosing acute respiratory failure?

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Abstract

Introduction: The condition of acute respiratory failure is one of the most common as well as serious condition that is encountered in the ICU. Diagnosis and immediate management can increase the rate of survival among these patients. Aiming to attain this goal and to ensure that no invasive procedure is tried on the patient several studies have tried to substitute the use of PaO_2/FiO_2 which is an invasive procedure and risky for patients who have severe blood loss or are anaemic by other reliable markers out of which SpO_2/FiO_2 has shown some promise in paediatric age groups. Another disadvantage of using PaO_2/FiO_2 is the time it takes to evaluate the condition and give us results that can help us diagnose the patient .This study explores the possibility of it being used for the adult age group.

Materials and methods: A sample size of 50 patients was taken and a total of 101 observations from these patients were recorded. The observations from these patients included SpO_2/FiO_2, PaO_2/FiO_2, vitals (heart rate, respiratory rate, SBC, blood pressure), presence of crepitations, chest X ray infiltrates and the use of ventilator. A statistical analysis was then undertaken comparing SpO_2/FiO_2 ratio and PaO_2/FiO_2 ratio. This correlation was statistically analysed by plotting graphs and was checked whether they are significant or insignificant.

Result: It was observed that SpO_2/FiO_2 ratio correlates very well with PaO_2/FiO_2 ratio (R = 0.375). A formula was also derived using the graph which could help us find value of SpO_2/FiO_2 ratio using PaO_2/FiO_2 ratio and vice versa. $SpO_2/FiO_2=0.559(PaO_2/FiO_2)+157.9$

Conclusion: From the above study we can conclude that PaO_2/FiO_2 can be surrogated by the use of SpO_2/FiO_2 ratio which is much more inexpensive, invasive and most of all saves the time required for doing ABG analysis in adult age group also.

Keywords: ABG, arterial oxygenation, fifth vital sign, hypoxemia, pulse oximetry, non invasive

1. Introduction

Acute respiratory failure is the most common organ failure seen in Intensive Care Unit (ICU). It is a devastating condition associated with high degree of morbidity and mortality. PaO_2/FiO_2 ratio which is measured by arterial blood gas(ABG) analysis is currently used to quantify the degree of hypoxemia.[1] However, repeated measurement leading to acute blood loss and an inclination touse a more minimally invasive approach have led to fewer ABG (Arterial Blood Gas) measurement in critically ill patients.[1]

In many ICUs at primary centre, ABG analysis facility is not available. Many times trained doctors are not available for drawing samples. Also, many patients cannot afford ABG analysis frequently. Hence, to cut down the cost associated with repeated ABG measurements and to make the treatment more affordable for patients with low economic background institutions have vastly reduced the number of ABG analysis.[1]

Non invasive nature of pulse oximetry allows for a much affordable and rapid assessment of the degree of hypoxemia and also helps in identification of the patients at risk.[2] Considering that the SpO_2 has been called the fifth vital sign, it is indicated in any situation where monitoring arterial oxygenation is considered important. In critically ill patients, at least 15 clinical studies have confirmed that continuous monitoring of SpO_2 with pulse oximetry is a much easier and safer approach to periodic blood gas measurements for detecting episodes of significant hypoxemia which are not continuous in nature but are performed in regular intervals.[3] Pulse oximetry when compared with the standard technique of serial arterial blood gas determinations employed during weaning from mechanical ventilation, has been shown to decrease the number of arterial blood gas determinations required, with no increase in adverse occurrences for the patient. Pulse oximetery is helpful not only in detection of early hypoxemia before manifestation of clinical signs but also plays a key role in titration of FiO2 in mechanically ventilated patients.[4] In many pediatric studies, the role of SpO_2/FiO_2 ratio has been proved to be of great importance in intensive care monitoring but so far only one study including adults suggests that they can be used in place of PaO2/FiO2 ratio.[1]

Another recent study also shows that the total and respiratory Sequential Organ Failure Assessment (SOFA) scores obtained with imputed SpO_2/FiO_2 ratio correlate with the corresponding SOFA score using PaO_2/FiO_2 ratios. Both the derived and original respiratory SOFA scores predict similar outcomes thereby confirming the relation between SpO_2/FiO_2 and PaO_2/FiO_2.[5]

Based on the above knowledge and reviewing literature our study's question was formed that can pulse oximetric saturation (SpO_2)/fraction of inspired oxygen (FiO_2) ratio surrogate PaO_2/ FiO_2 ratio in diagnosing acute respiratory failure?

2. Materials and Methods

2.1 Study design:

This cross sectional study was conducted in Intensive Care Unit of a 1000 bedded hospital. All patients with clinical diagnosis of acute respiratory failure primarily or as a part of MODS (Multiple Organ Dysfunction Syndrome) will be included in the study. This study was conducted in the Intensive Care Unit of Dhiraj General Hospital, Piparia which caters to the rural areas of Vadodara and Waghodia.

2.2 Study Subjects

The number of patients that satisfied the inclusion criteria were 50 and a total of 101 ABG observations from these patients were used in this study to determine the use of SpO_2/FiO_2 as a surrogate to PaO_2/FiO_2 in diagnosing Acute Respiratory Failure.

2.3 Inclusion Criteria

All patients presenting with the signs of acute respiratory failure which may be of primary nature or secondary nature presenting as a part of MODS (Multiple Organ Dysfunction Syndrome) were included in the study and were carefully monitored and all the important parameters included in the study (Pulse, BP, Respiratory Rate, Single Breath Count, Presence of cyanosis, Use of accessory muscle) will be observed and noted down after an Informed Consent Form is signed by the patient or his relative (in cases when the patient is not in a position to respond). This included patients admitted to the ICU whose ABG on room air suggestive of PaO_2<60mm Hg on 200m air and $PaCO_2$>50mm Hg.

2.4 Exclusion Criteria

All patients who are unwilling to give consent were not included in the study.

2.5 Ethical review and Approval

The patient and his relatives were notified about the procedure of taking observations by the student in the local language/language that they used. The patients were provided with an Informed Consent Form depicting the procedure of observation that was being followed. Duly signed consent forms were sought from patients or their relatives (in case the patient could not respond). The patient's name and his information were kept confidential and all observations were made. The participant had all the rights of withdrawing his name from the study whenever he wanted and no compulsion whatsoever was forced upon them.

Due to the nature of the research procedure no extra amount was charged upon the patients to take part in the study.

All the protocols and treatments were made by independent doctors and resident physician which did not belong to the study team.

2.6 Data collection

For each patient, baseline data recorded on the form included: (1) demography; (2) causes of acute respiratory failure; (3) precipitating causes;(4) co morbidities; (5) single breath count;(6) use of accessory muscle;(7) presence of cyanosis;(8)vital signs (9) auscultatory findings (10) need of ventilator support. Necessary investigation like total count, chest x ray, sputum and blood culture and other laboratory parameters will be done to confirm the diagnosis.

SpO_2 was measured bedside by pulse oximeter (BPL Instrument With NellcorProbe) using spectrophotometric principles which uses two wavelengths of light. The following measures were employed to improve the accuracy of the SpO_2 measurements: optimal position of probe and cleanliness of the sensor, removal of nail polish (if present)and satisfactory waveforms . Spo2 will be observed for a minimum of 1 min before the value is recorded.

PaO_2 was obtained by arterial blood gas analysis simultaneously. The Arterial Blood Gas (ABG) Analysis will be done on Stat Profile pHOx Analyser from Nova biomed. ABG sampling will be done by using heparinised syringe and will be processed immediately. FiO_2 was calculated depending upon the device, reservoir capacity and oxygen flow as demonstrated in [Table/Figure 1].[6]

Spo2 values for every patient were documented at the time of arterial blood gas sampling. Each time PaO_2/FiO_2 ratio was correlated with corresponding SpO_2/FiO_2 ratio.

The patient was also be assessed as per use of ventilatory support their mode and their follow up.

Table 1: Calculation of FiO_2 on basis of device, reservoir capacity and oxygen flow

Low-Flow Oxygen Inhalation Systems			
Device	**Reservoir Capacity**	**Oxygen Flow (L/min)**	**Approximate (FiO_2)***
Nasal cannula	50 mL	1	0.21 to 0.24
		2	0.24 to 0.28
		3	0.28 to .34
		4	0.34 to 0.38
		5	0.38 to 0.42
		6	0.42 to 0.46
Oxygen face mask	250 mL	5 to 10	0.40 to 0.60
Mask reservoir bag:	1250 mL		
Partial rebreather		5 to 7	0.35 to 0.75
Non rebreather		5 to10	0.40 to 0.90

2.7 Statistical analysis

The statistical analysis was done by plotting a graph of SpO_2/FiO_2 ratio versus PaO_2/FiO_2 ratio. Correlation of SpO_2 with other clinical signs (cyanosis and use of accessory muscle) and vitals (Pulse, BP and Respiratory Rate) were also established by using Chi Square Test and Student t Test and Correlation Coefficient.

The use of SpO_2/FiO_2 ratio as surrogate of P/F ratio in areas that lack the necessary facilities will limit the use of ABG in patients of Acute Respiratory Failure which will be cost effective as well as non invasive.

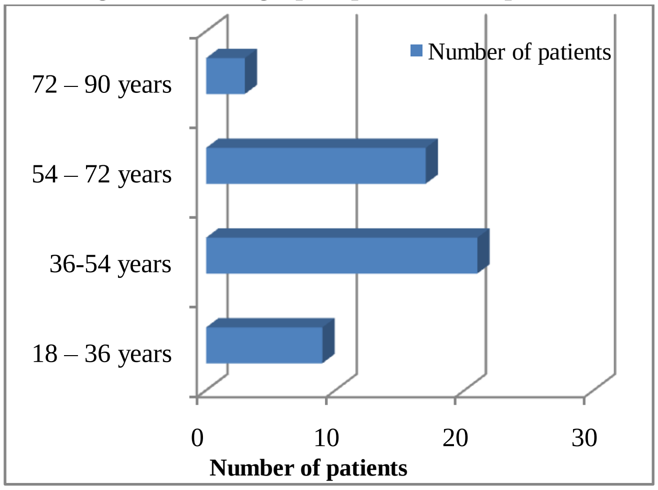
3. Observation and result

Demographic Profile of patients

Total number of patients: 50

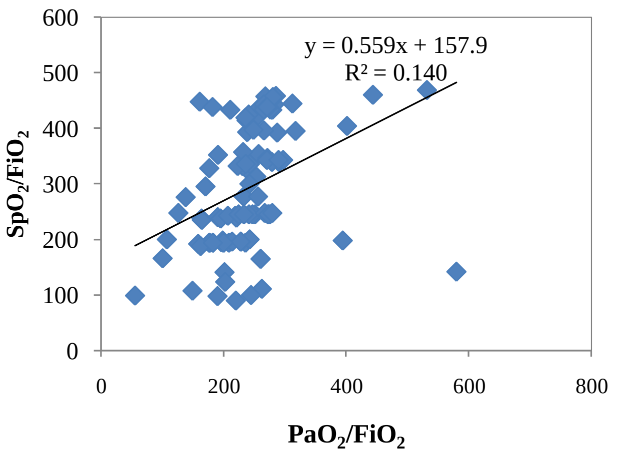
Total number of observation from these patients: 101

Figure 2: Demographic profile of the patient



As shown in Table/Figure 2 which describes the demographic profile of the patients included in the study, the maximum number of patients (42%) belonged to the age group of 36-54 years and the minimum number of patients (6%) belonged to the age group of 72-90 years. the number of patients in the age group of 18-36 years were 18% and those between 54-72 years of age were 34%.

Figure 3: Correlation between SpO_2/FiO_2 and PaO_2/FiO_2



R=0.375

$SpO_2/FiO_2=0.559(PaO_2/FiO_2)+157.9$

Table/Figure 3 shows the correlation between SpO_2/FiO_2 and PaO_2/FiO_2. The value of R in this case is 0.375 which proves that there exists a positive correlation between SpO_2/FiO_2 and PaO_2/FiO_2.

In our study, SpO_2/FiO_2 ratio was predicted by PaO_2/FiO_2 value using linear regression equation which is $SpO_2/FiO_2 = 0.559(PaO_2/FiO_2) + 157.9$.So PaO_2/FiO_2 ratio of 300 corresponds to SpO_2/FiO_2 ratio of 325.6 and PaO_2/FiO_2 ratio of 200 corresponds to SpO_2/FiO_2 ratio of 269.7. The ALI SpO_2/FiO_2 cut off of 325.6 was correctly identified cases of $PaO_2/FiO_2<300$ and the ARDS cut off 269.7 correctly identified cases of $PaO_2/FiO_2<200$ in our study.

4. Discussion

In our study, PaO_2/FiO_2 ratio of 300 correlates very well with SpO_2/FiO_2 ratio of 325.6 and PaO_2/FiO_2 ratio of 200 correlates with S/F ratio of 269.7. Our observation is similar to the finding of Rice *et al* which also showed the linear relationship that did not change over varying levels of FiO2 or PEEP. A SpO_2/FiO_2 ratio of 235 correlates with P/F ratio of 235 with PaO_2/FiO_2 ratio of 200 and SpO_2/FiO_2 ratio of 315 correlated with PaO_2/FiO_2 of 300. PaO_2/FiO_2 remains a very important factor to assess the respiratory well being of a patient and was first described by Mohamad El-Khatib *et al* in one of their studies as an index to compare arterial oxygenation at different levels of FiO_2.[7] Since then, it has been commonly used to assess respiratory status as well as response to different therapies, whether the therapy is an increase in FiO_2 or changes in mechanical ventilation settings. Moreover, Pao_2/Fio_2 has been considered as the differentiating factor between establishing a diagnosis for acute lung injury ($PaO_2/FiO_2<300$) (ALI) or a diagnosis for ARDS ($PaO_2/FiO_2<200$).

To study the efficacy, effectiveness and efficiency of pulse oximetry as a necessary technology, Inman *et al* in 1993 for the first time studied pulse oximetry in a critical care unit.[8] Their hypothesis was that the implementation of pulse oximetry in a multidisciplinary CCU without guidelines for drawing ABG samples would not substantially reduce the use of ABG determinations. They collected charts from 50 admissions post oximetry phase and contrasted with 50 consecutive admissions of pre oximetry phase. They found that efficacy, effectiveness and efficiency of pulse oximetry as a necessary technology accompanied only by a strong educational component resulted in marginal reductions in ABG samples.

In 1995, Carruthers *et al* did a prospective study of 89 patients of acute respiratory failure with aim to determine whether ABG estimation was necessary or pulse oximetric saturation was a reliable alternative in predicting respiratory failure and also to determine the SaO_2 value below which ABG should be taken for safe management of the patient.[9] They performed ABG and pulse oximetry during initial assessment of patients presented with asthma and defined Acute Respiratory Failure as PaO_2<8kPa or $PaCO_2$>6kPa.The observations in the study suggested that out of 89 patients included in the study 17 patients had acute respiratory failure. Out of these, 3(4.2%) had SaO_2>90 and 8(9%) had SaO_2. Oxygen saturation ranged between 84% and 99% (median 95%); 17 patients had Sao2 <92%. Eight of the 89 patients were in respiratory failure (PaO_2<8 kPa and/or Paco2 >6 kPa). Five of the 17 patients with Sao2<92% had respiratory failure. Of the 72 patients with Sao2 >92% three (4 2%) had arterial gas tensions indicating respiratory failure. Ten patients had a Sao2 of 90-92%, and three of them had respiratory failure. The number of patients in respiratory failure with an Sao2 above 90% is significantly greater than those with Sao2 above 92% (p<0-005, X2 test).They suggested that when saturation is above 92% there are less chances of Respiratory failure and hence, ABG measurements in these cases are unnecessary but this study was conducted in patients of asthma and other cause of Acute Respiratory Failure were excluded in the study.

Todd *et al* studied population using inclusion and exclusion criteria of ARDS network trial. The derivation data set was from patients that were involved in the ARDS network. 6 ml/kg Vs 12 ml/kg tidal volume trial while validated using similar data from patients that were enrolled in the ARDS net ALVEOLI (lower PEEP Vs higher PEEP) study.[1] The sensitivity and specificity of the threshold SpO_2/FiO_2 ratio of 235 and 315 derived in study done by Todd *et al* suggest that they are appropriate and surrogates for PaO_2/FiO_2 ratios of 200 and 300.

While recently published work by Neal *et al* also tried to derive formula utilising SpO2 instead of PaO2 in oxygenation index. They also used data from two large randomised controlled trials of interventions aimed at reducing mortality and days of mechanical ventilation in children with ALI or ARDS. Out of these, one study was a multicentered randomised trial that compared intrathecal installation of upto 2 doses of a lung surfactant with placebo while the second study was multicentered, randomised controlled and unmasked clinical trial for supine Vs prone positioning in patients with ALI.

Here also SpO2<97% was included. Data collection included PaO_2, $PaCO_2$, pH, FIO_2, SpO_2 and PaW. S/F, P/F, oxygenation index (FIO_2 X PaW/PaO_2) and oxygen saturation index (OSI) were calculated from the collected data. The fitted models were used to calculate and compute values of S/F, OI and OSI that correspond to P/F cut offs of 200 and 300.As an independent validation these cut offs of S/F, OI and OSI derived from the surfactant study data set were applied to prone study data set to calculate the sensitivity, specificity and 95% confidence intervals. [10]

In contrast to the above, we enrolled all patients whose PaO_2 was <60mm Hg on room air. We took all measurements of PaO_2 and SpO_2 and then correlated S/F and P/F ratios from the collected data.

Although studying respiratory SOFA score was not our aim, Pandharipande studied derivation and SpO_2/FiO_2 ratio to impute for PaO_2/FiO_2 ratio in respiratory component of SOFA score and found that both the derived and original respiratory SOFA scores predict similar outcomes. [6,10]

Similar study in infants and children by Khemani *et al* shows SpO_2/FiO_2 value of 263 and 201 which correspond well with PaO_2/FiO_2 ratio of 300 and 200.[11]

Due to its increasing importance in the field of paediatrics, pulse oximetry is now considered as a fifth vital sign in routine paediatric assessment.[12]

SpO_2/FiO_2 ratio has also proved as a valuable and easily obtainable specific pulmonary marker of disease severity of Acute hypoxemic respiratory failure alongwith oxygen saturation index for early identification of children at high risk of death.[13]

Apart from its wide spread use in paediatrics, it has also been used for adults to diagnose ALI and ARDS in critically ill patients with anaemia where avoiding excessive blood draws can serve as a boon to the patient.[14-16]

SpO_2/FiO_2 ratio may also be needful in other important clinical applications such as Lung Injury Score, Sequential Organ Failure Assessment, Simplified Acute Physiology Score II, or Multi Organ Dysfunction Score that utilise P/F ratios to quantify hypoxemia.[8,17-19]

5. Conclusion

After seeing the correlation of SpO_2/FiO_2 and PaO_2/FiO_2 ratio, it is evident that SpO_2/FiO_2 ratio can surrogate the use of PaO_2/FiO_2- in diagnosis of Acute Respiratory Failure not only in paediatric subjects as described in other studies but in adults also which may act as a boon in rapid as well as inexpensive way of diagnosing the same.

Acknowledgement

This was an ICMR (Indian Council of Medical Research) funded research under STS-2011. Authors would also like to acknowledge Dr. Ashish Trivedi, Asso. Prof. Department of Community Medicine, Sumandeep Vidyapeeth, for guidance with Statistics.

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