Acta Biomed 2025; Vol. 96, N. 3: 16567 DOI: 10.23750/abm.v96i3.16567

Comparison of SpO_2/FiO_2 ratio and PAO_2/FIO_2 ratio as initial assessment in patients at risk of respiratory failure

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Abstract. *Introduction:* The risk of respiratory failure such as shortness of breath which causes difficulty in the breathing process, if not treated properly can result in respiratory failure, then organ failure with high morbidity and mortality. These risks can be identified by measuring oxygen saturation with oximetry. The purpose of this study is to determine and examine the comparison of the Oxygen saturation/Fraction of inspired oxygen (SpO_2/FiO_2) ratio and the Partial pressure of oxygen /Fraction of inspired oxygen (PaO_2/FiO_2) ratio as an initial assessment in patients at risk of respiratory failure. *Methods:* Cross-sectional study conducted among patients in the emergency room and treatment room at Wahidin Sudirohusodo Hospital Makassar and its network with symptoms of shortness of breath. The data collected from the results of blood gas analysis, oxygen saturation examinations, and patient medical records. *Results:* A total of 103 samples were obtained with an age range of 20-87 years. Based on the data, the mean SpO_2 value was 95.7%, PaO_2 was 163.3 mmHg, FiO_2 was 70.7%, SpO_2/FiO_2 ratio was 175.1 mmHg and PaO_2/FiO_2 ratio was 332.2 mmHg. The threshold value of the SpO_2/FiO_2 ratio for respiratory failure of 281 corresponds to the PaO_2/FiO_2 ratio of 300 with a sensitivity of around 93% and a specificity of 96%. *Conclusion:* The SpO_2/FiO_2 ratio was strongly correlated with the PaO_2/FiO_2 ratio in assessing respiratory failure. So, the SpO_2/FiO_2 ratio can be used as an alternative to the PaO_2/FiO_2 ratio for early detection in patients at risk of respiratory failure. (www.actabiomedica.it)

Key words: respiratory failure, SpO_2/FiO_2 ratio, PaO_2/FiO_2 ratio, shortness of breath

Introduction

Respiratory failure is a condition in which the respiratory system is unable to maintain oxygenation in the blood with/without accumulation of carbon dioxide (CO_2) caused by systemic or from the lungs themselves. The risk of respiratory failure is a condition of difficulty in the respiratory process characterized by shortness of breath, which can be caused by various etiologies from the lungs or extrapulmonary and can affect oxygenation in the blood. According to the American Thoracic Society (ATS), the definition of dyspnea is a subjective experience of discomfort in breathing with varying quality and intensity. Dyspnea or shortness of breath is an abnormal or uncomfortable breathing compared to a person's normal condition according to their fitness level (1). The condition of the risk of respiratory failure itself can develop into respiratory failure if not treated quickly. Respiratory failure is the most common cause of organ failure seen in the Intensive Care Unit (ICU). It is a severe condition associated with high morbidity and mortality (2). The high prevalence of this period is confirmed by 2 epidemiological studies reporting that 56% of all patients admitted to the ICU experienced respiratory failure at some time during their stay and that respiratory failure accounted for 69% of all ICU bed occupancy in a European population (3). Respiratory failure can be classified into two main types according to its cause, namely hypoxemic respiratory failure and hypercapnic respiratory failure. Hypoxemic respiratory failure is characterized by a partial pressure of oxygen (PaO_2) < 60 mmHg with a normal or low partial pressure of carbon dioxide ($PaCO_2$). Hypercapnic respiratory failure is characterized by a $PaCO_2$ > 45 mmHg (4). However, it requires invasive and expensive arterial blood sampling and analysis that are often unavailable, especially in areas with limited resources (5). Mostly ICUs in primary healthcare centers, Blood Gas Analysis (BGA) facilities are not available. Moreover, many patients are often unwilling to undergo BGA sampling. Therefore, to reduce the costs associated with repeated BGA measurements and to make the treatment more affordable for patients from low economic backgrounds and reduce the number of BGA samplings, oxygen saturation measurement can be considered (2). Oxygen saturation (SpO_2) can be measured with a simple device called pulse oximetry, thus allowing for an affordable and rapid assessment of the degree of hypoxemia and also helps in identifying patients at risk. It is indicated in any situation where monitoring of arterial oxygenation is considered essential. In critically ill patients, at least 15 clinical studies have confirmed that continuous SpO_2 monitoring with pulse oximetry is a much easier and safer approach than periodic blood gas measurements for detecting episodes of significant hypoxemia that are not continuous in nature. Pulse oximetry is very helpful not only in detecting early hypoxemia but also plays a key role in titrating Fraction of inspired oxygen (FiO_2) in mechanically ventilated patients (2). Previously research by Mehta T R et al. mentioned a specific threshold level for the SpO_2/FiO_2 ratio that can be used in patients with respiratory failure as a substitute when the Blood Gas Analysis examination as the gold standard for assessing the PaO_2/FiO_2 ratio is not available (2). Based on the introduction above, the SpO_2/FiO_2 ratio will be a reliable early independent predictor for the development of the risk of respiratory failure. Therefore, researchers are interested in determining and examining the comparison of the SpO_2/FiO_2 ratio and the PaO_2/FiO_2 ratio as an initial assessment in patients at risk of respiratory failure.

Methods

Research design

This research is diagnostic research with a cross-sectional design, with the patients are examined by taking blood gas analysis samples and examining oxygen saturation to determine the SpO_2/FiO_2 (S/F) ratio and PaO_2/FiO_2 (P/F) ratio to assess patient oxygenation during treatment in the hospital.

Study setting

This study was conducted in the emergency room and treatment room at Wahidin Sudirohusodo Hospital Makassar and its network in South Sulawesi. Sampling was carried out starting from February 2024 until the minimum number of samples was met.

Study population and participants

All patients at risk of respiratory failure, especially treated in the emergency room and treatment toom at Wahidin Sudirohusodo Hospital Makassar and its network. All patients had symptoms of shortness of breath and were willing to participate in this study. Based on etiology, the subjects in this study were categorized as intrapulmonary and extrapulmonary. Intrapulmonary abnormalities include abnormalities in the lower respiratory tract, pulmonary circulation, interstitial tissue, alveolar capillaries. Extrapulmonary abnormalities are abnormalities in the respiratory core, neuromuscular, pleura or upper respiratory tract. The recording of SpO_2, FiO_2, and PaO_2 values was carried out once simultaneously when the subject complained of shortness of breath without looking at the patient's position when recording the sampling. Exclusion criteria included patients with anemia (Hb < 12gr/dl) and shock.

Sample size determination

The sample size was determined using Isaac and Michael formula with error tolerance 10%. Thus, it can be concluded that based on the results of the calculation, the minimum number of samples in conducting hypothesis testing is 79 samples.

Data sources, instrument, and collection

The types of data collected in this study are divided into primary data obtained from the results of blood gas analysis and the results of oxygen saturation examinations by patients at risk of respiratory failure who are treated in the emergency room and the treatment room at Wahidin Sudirohusodo Hospital Makassar and its network. And secondary data is obtained from patient medical record. The research instruments used were oximeter, disposable 3ml, BGA tube and Blood Gas Analyzer. Primary data collection was carried out by taking blood samples for Blood Gas Analysis examination along with measuring the patient's oxygen saturation with an oximetry and secondary data collection was carried out by taking data from the patient's medical records including age and gender in patients treated in the emergency installation room, and the treatment room at Wahidin Sudirohusodo Hospital Makassar and its network.

Data analysis

Data analysis was performed using SPSS version 25. The analysis method consists of descriptive methods and statistical tests. The descriptive method aims to obtain general information about the research sample. The statistical method used is the calculation of the mean value, standard deviation (SD), and frequency distribution. The statistical test used is Chi Square. The results of the statistical test are considered significant if the p-value of the test <0.05. The results obtained will be displayed in narrative form accompanied by tables and figures.

Ethical considerations

Before the implementation of the study, ethical clearance was submitted from the Human Biomedical Research Ethics Commission of the Faculty of Medicine, Hasanuddin University, Makassar and an ethical approval recommendation number of 759/UN4.6.4.5.31/PP36/2024 was obtained. Approval for medical procedures was obtained by first briefly explaining the background, objectives and benefits of the study, as well as the actions of taking and examining arterial blood samples that will be experienced by the research subjects. Subjects and/or families will be asked to sign a consent form after being given a thorough explanation of the study.

Results

A total of 103 research subjects from emergency room and treatment room at Wahidin Sudirohusodo Hospital Makassar and its network who had complaints of shortness of breath participated in this study. The average age of the research subjects was 57.2+15.7 years with age range of 20-87 years. Based on gender, there were 54 male (52.4%) and 49 female (47.6%). Subjects with intra-pulmonary etiology were 44 people (42.7%) and extra-pulmonary were 59 people (57.3%) (Table 1).

The study characteristic that consists of SpO_2, PaO_2, FiO_2, SpO_2/FiO_2 ratio, and PaO_2/FiO_2 ratio were presented in Table 2. Based on the data, the mean SpO_2 value was 95.7%, PaO_2 was 163.3 mmHg, FiO_2 was 70.7%, SpO_2/FiO_2 ratio was 175.1 mmHg and PaO_2/FiO_2 ratio was 332.2 mmHg.

Correlation between SpO_2/FiO_2 ratio and PaO_2/FiO_2 ratio

Table 3 shows a significant positive correlation between the SpO_2/FiO_2 ratio and the PaO_2/FiO_2 ratio. A strong positive linear correlation was seen between the PaO_2/FiO_2 ratio and the SpO_2/FiO_2 ratio, with r = 0.949 ($p < 0.001$, significant). Therefore, the SpO_2/FiO_2 ratio can be used as a substitute for the PaO_2/FiO_2 ratio in patients with respiratory failure. Further analysis found a threshold value for the SpO_2/FiO_2 ratio against the PaO_2/FiO_2 ratio. Figure 1 shows the ROC curve of the SpO_2/FiO_2 ratio. The area under the curve (AUC) concluded that the SpO_2/FiO_2 ratio

Table 1. Research characteristics categorical

Variable	Category	n	%
Gender	Female	49	47.6
	Male	54	52.4
Etiology	Intra-pulmonary	44	42.7
	Extra-pulmonary	59	57.3

Table 2. Research characteristics numerically

Variable	Mean	Median	Standard Deviation	Min	Max
Age	57,2	60	15,7	20	87
PaO_2	163,3	179	46	33	240
FiO_2	70,7	80	31,6	21	100
SpO_2	95,7	98	5,4	71	100
SpO_2/FiO_2 ratio	175,1	100	124,2	60	471
PaO_2/FiO_2 ratio	332,3	213	241,2	42,5	986,2

Table 3. Correlation between SpO_2/FiO_2 ratio and PaO_2/FiO_2 ratio

Variable	mean	median	Std. Deviation	min	max	p	r
SpO_2/FiO_2 ratio	175,1	100	124,2	60	471	<0.001	0,949
PaO_2/FiO_2 ratio	332,3	213	241,2	42,5	986,2		

Spearman Corelation.

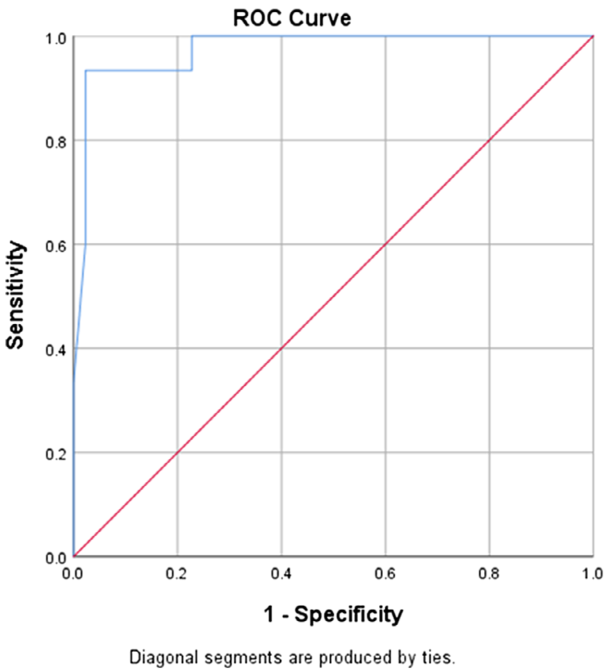

Figure 1. ROC curve of SpO_2/FiO_2 ratio for PaO_2/FiO_2 ratio <300. The AUC of 0.974 (0.9-1.0) shows the excellent discrimination ability of SpO_2/FiO_2 ratio for PaO_2/FiO_2 ratio <300.

has excellent discrimination ability; therefore, the diagnostic accuracy for Respiratory Failure (AUC of 0.974 for PaO_2/FiO_2 ratio values <300).

Table 4 shows the threshold value of the SpO_2/FiO_2 ratio, which is less than 281 against the PaO_2/FiO_2 ratio of less than 300 with a sensitivity of 93% and a specificity of 96%. This proves that the SpO_2/FiO_2 ratio can be used as a substitute for the PaO_2/FiO_2 ratio.

Discussion

This study showed a positive correlation between the PaO_2/FiO_2 ratio and the SpO_2/FiO_2 ratio. This study obtained a threshold value of the SpO_2/FiO_2 ratio for respiratory failure of 281 which corresponds to the PaO_2/FiO_2 ratio of 300 with a sensitivity of around 93% and a specificity of 96%. So, it can be concluded that the SpO_2/FiO_2 ratio can be used for diagnosis as a substitute for the PaO_2/FiO_2 ratio.

These results are in line with research conducted by Sheetal Babu et al. (6) in patients with various methods

Table 4. Tthe threshold value of the average SpO_2/FiO_2 ratio to the PaO_2/FiO_2 ratio in the area under the curve, with sensitivity and specificity values

Rasio SpO_2/FiO_2	Rasio PaO_2/FiO_2		Total	p*	AUC	Spes	Sens	95% CI
	Gagal napas	Normal						
<281	67 (76.1)	21 (23.9)	88	<0.001	0.974	96%	93%	0.94-1.00
>281	0 (0)	15 (100)	15					
Total	67 (65)	36 (35)	103					

Fisher's Exact Test.

of oxygen supplementation (6). A strong positive correlation was found between the SpO_2/FiO_2 ratio and the PaO_2/FiO_2 ratio. Sheetal Babu et al. obtained the SpO_2/FiO_2 ratio threshold value for the PaO_2/FiO_2 ratio. The SpO_2/FiO_2 ratio of 285 corresponds to the PaO_2/FiO_2 ratio of 200 with a sensitivity of 73% and a specificity of 77%. Likewise, the SpO_2/FiO_2 ratio of 323 corresponds to the PaO_2/FiO_2 ratio of 300 with a sensitivity of 72% and a specificity of 73%. Sheetal Babu et al. also analyzed whether there was variation in different oxygen delivery methods. From 300 ABG samples, 174 (58%) used invasive methods and 126 (42%) used noninvasive methods. There was no statistically significant difference in the PF ratio ($p = 0.07$) and SF ratio ($p = 0.88$) implying that the SpO_2/FiO_2 ratio and PaO_2/FiO_2 ratio can be used universally, regardless of the type of oxygen delivery system used (6). In our study all correspondences used non-invasive oxygen modalities, so no analysis was performed. The results of this study are also in line with the study conducted by Luigi Pisani et al. (5) with risk stratification using the SpO_2/FiO_2 ratio Open Access and PEEP in the initial ARDS diagnosis and after 24 hours in patients with moderate or severe ARDS (5). Where a correlation was found between the SpO_2/FiO_2 ratio and the PaO_2/FiO_2 ratio was strong ($P <0.001$, $R2 = 0.676$) and can be explained in a linear regression equation. Luigi Pisani et al. also concluded that a PaO_2/FiO_2 ratio of 200 mmHg corresponds to a SpO_2/FiO_2 ratio of 243 [95% CI 220–265], a PaO_2/FiO_2 ratio of 150 mmHg to a SpO_2/FiO_2 ratio of 193 [95% CI 174–211] and a PaO_2/FiO_2 ratio of 100 mmHg to a SpO_2/FiO_2 ratio of 143 [95% CI 127–158]. However, the study by Luigi Pisani et al. did not include the category of mild ARDS. The study by Luigi Pisani et al. also used Positive End-Expiratory Pressure (PEEP) which affects oxygenation (5). The results of this study are also supported by research conducted by Mehta TR et al. whether the pulse oximetry saturation ratio (SpO_2)/fraction of inspired oxygen (FiO_2) can replace the PaO_2/FiO_2 ratio in diagnosing respiratory failure (2). Then, it was found that the SpO_2/FiO_2 ratio was predicted by the PaO_2/FiO_2 ratio value using a linear regression equation, namely the SpO_2/FiO_2 ratio = $0.559(PaO_2/FiO_2) + 157.9$. So, the PaO_2/FiO_2 ratio of 300 corresponds to the SpO_2/FiO_2 ratio of 325.6 and the PaO_2/FiO_2 ratio of 325.6. The PaO_2/FiO_2 ratio of 200 corresponds to the SpO_2/FiO_2 ratio of 269.7. The ALI SpO_2/FiO_2 ratio threshold value of 325.6 correctly identified cases of PaO_2/FiO_2 ratio < 300 and the Acute Respiratory Distress Syndrome (ARDS) threshold value of 269.7 correctly identified cases of PaO_2/FiO_2 ratio < 200 in the study by Mehta TR et al. (2) Michael A.Matthay et al. in the New Global Definition of Acute Respiratory Distress Syndrome mentioned and agreed to allow the use of oxygen saturation measured by pulse oximetry SpO_2/FiO_2 ratio as an alternative to PaO_2/FiO_2 ratio for the diagnosis of ARDS (7). Michael A. Matthay et al. mentioned that although blood gas measurement has been the gold standard for assessing hypoxemia in ARDS, the use of the alternative SpO_2/FiO_2 ratio was added for two reasons: 1) inconsistent availability of ABGs in resource-limited areas and 2) decreased frequency of ABG monitoring in high-income countries (7). Emir festic et al. in the study SpO_2/FiO_2 Ratio Upon Hospital Admission Is an Early Indicator of Acute Respiratory Disease Development of Distress Syndrome Among

Patients at Risk stated that there was a statistically significant, but unadjusted relationship between SpO_2/FiO_2 and the development of ARDS, (p 0.001) (8). Emir festic et al. also stated that there was a statistically significant, unadjusted relationship between SpO_2/FiO_2 and in-hospital mortality, (p 0.001). The use of different SpO_2/FiO_2 threshold values for predicting ARDS with sensitivity, specificity, positive and negative each showed good specificity (94%, 88%, and 78%, respectively) while the sensitivity was low (24%, 42%, and 53%, respectively) (8). Therefore, it is concluded that the SpO_2/FiO_2 ratio is a non-invasive early detection as an alternative examination to the invasive PaO_2/FiO_2 ratio in patients with suspected respiratory failure. The clinical implication of this study is the SpO_2/FiO_2 ratio can be used to detect respiratory failure early as an alternative to the PaO_2/FiO_2 ratio, especially in places or health centers where blood gas analysis is not available so that patients at risk of respiratory failure can be identified and managed more quickly by treating hypoxemia with oxygen therapy, namely replacing the oxygen modality, and treating the underlying disease-causing respiratory failure.

Conclusion

In this study, it was concluded that the SpO_2/FiO_2 ratio was strongly correlated with the PaO_2/FiO_2 ratio in assessing respiratory failure with the SpO_2/FiO_2 ratio threshold value being less than 281 against the PaO_2/FiO_2 ratio being less than 300 in all oxygen modalities. So that the SpO_2/FiO_2 ratio can be used as an alternative to the PaO_2/FiO_2 ratio for early detection in patients at risk of respiratory failure. Therefore, it can be faster to identify and manage patients at risk of respiratory failure quickly to prevent hypoxemia.

Acknowledgements: We are very grateful to all research assistants and all staff involved in the process of making this research. We also greatly appreciate all participants for their willingness to take the time and share their experiences to participate in this research.

Funding: None.

Ethics Committee Approval: This research was approved by the Ethics Committee for Biomedical Research on Humans, Faculty of Medicine, Hasanuddin University, Makassar, South Sulawesi, Indonesia. Based on recommendation letter Number: 759/UN4.6.4.5.31/PP36/2024, with protocol number: UH24080611.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interests, patent/licensing arrangements, etc.) that might give rise to a conflict of interest with respect to the submitted article.

Authors' Contributions: M.G.F.N.: concept, design, materials, sources, data processing, interpretation, and analysis; S.A.: literature research and manuscript editing; H.I.: concept, planning, guidance, interpretation, and analysis; S.B.: concept, planning, guidance, evaluation, and literature research; H.K.: concept, planning, guidance, evaluation, and literature research; A.A.Z.: concept, analysis and interpretation, and critical review. All authors read and approved the final version of the manuscript.

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Received: 15 October 2024
Accepted: 21 November 2024
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