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Comparison of SpO_2/FiO_2 (Sf) Ratio and PaO_2/FiO_2 (Pf) Ratio in Mechanically Ventilated Patients with ARDS in Covid ICU for Prognosis of ARDS: A Prospective, Observational Study

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ABSTRACT
COVID-19 frequently manifests as silent hypoxia, in which the patient has no aberrant respiratory pattern despite severe hypoxia. Arterial blood gas analysis is complicated and time-consuming procedure for prognosis of acute respiratory distress syndrome. So, this study is aimed to derive the P/F values from S/F values which will be useful for determining the prognosis of ARDS patients on mechanical ventilation without any delay and complication. A hundred patients admitted in COVID ICU with ARDS requiring mechanical ventilation (invasive or non-invasive) were enrolled and followed up for 10 days. Continuous vital monitoring was done and alternate day ABG analysis was done during the course of disease. At same FiO_2, PaO_2 and SpO_2 of patients were noted and plotted on graph with SF ratio on X-axis and PF ratio on Y-axis. Receiver Operating Characteristic curve was plotted and linear regression equation was derived which can determine PF ratio from SF ratio. Patient's characteristics in terms of age and gender had no significant relationship with either SF ratio or PF ratio ($p>0.05$). A linear regression equation was derived which states the correlation of S/F ratio and P/F ratio and was found to be statistically significant ($p<0.001$) PF = 1.1597SF-35.211 (R^2 = 0.8994). The results show linear correlation of PF ratio with SF ratio and so PF ratio can be derived using the above equation. It avoids repeated arterial puncture to evaluate the prognosis of patient.

INTRODUCTION

Acute respiratory distress syndrome (ARDS) is characterised by bilateral non-cardiogenic lung infiltrates and severe increasing hypoxia without any signs of cardiogenic pulmonary oedema[1]. According to the American European Consensus Conference (AECC) in 1994, the diagnosis of ARDS requires acute onset of the illness, bilateral pulmonary infiltrates on a chest radiograph, the absence of significant left ventricular dysfunction and an arterial partial pressure of Oxygen/fraction of inspiratory oxygen (PaO_2/FiO_2) (PF) ratio of less than 300 for ALI or less than 200 for ARDS[1]. The first three elements can be determined using the clinical history or noninvasive methods like an echocardiogram or chest radiograph. However, arterial blood samples are necessary for PF criterion[3,4].

COVID-19 pneumonia is caused by an emerging beta-coronavirus known as Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2). The clinical manifestations might be lethal or asymptomatic. With ARDS, symptoms can range from mild hypoxia to severe symptoms. Since it only took nine days from the start of symptoms to the onset of ARDS, it is possible that the respiratory symptoms will worsen quickly[5].

Concerns about anaemia, excessive blood draws, associated consequences and a shift towards minimally invasive techniques have resulted in fewer arterial blood gas measures in critically sick patients and in big settings with many admissions, recurrent ABG analysis becomes onerous[3-7].

The most popular, secure and non-invasive method of monitoring oxygenation is pulse oximetry. By distinguishing between oxygenated and deoxygenated haemoglobin using their respective light absorption at wave lengths of 660 nm (red) and 940 nm (infra-red), arterial haemoglobin O2 saturation is evaluated using this approach[8,9]. Pulse oximetry is used to measure FiO_2 levels, diagnose hypoxia, avoid hyperoxia and wean patients off mechanical breathing[7-11]. The SF ratio, which is defined as the ratio of oxygen saturation (SpO_2)/fraction of inspired oxygen (FiO_2) to respiratory rate, has been proposed to be used to identify high-flow nasal cannula (HFNC) failure[12]. According to Roca *et al.*[12], the SF ratio may be used to help identify patients who are at high risk for intubation. They found that an SF cut-off of 4.88 assessed 12 hrs after the start of HFNC was related with a decreased likelihood of needing intubation[13]. However, it is still unclear if the SF ratio is useful for anticipating intubation and whether the cut-off for the SF ratio in patients with COVID-19 is suitable.

Another prognostic indicator for acute hypoxemic respiratory failure/ARDS is the SpO_2/FiO_2 (SF) ratio, which corresponds with the PaO_2/FiO_2 (PF) ratio for partial pressure of oxygen[14,15]. Notably, when arterial blood gas sampling is not easily accessible, the SF ratio has been described as a valid indicator for predicting failure of HFNC[16] or non-invasive ventilation[17]. Furthermore, unlike conventional respiratory failure, COVID-19 frequently manifests as silent hypoxia, in which the patient has no aberrant respiratory pattern despite severe hypoxia[18]. As a result, respiratory rate could not be an important factor in predicting HFNC failure in COVID-19. Therefore, we predicted that patients with COVID-19 would have a similar capacity to predict using the SF ratio.

The study's objective is to compare the PF (PaO_2/FiO_2) and SF (SpO_2/FiO_2) ratios to ascertain if the S/F ratio is a trustworthy and non-invasive substitute for the P/F ratio for the prognosis of ARDS patients receiving mechanical ventilation in the COVID ICU.

MATERIALS AND METHODS

This prospective observational study was carried out at ICU, Anaesthesiology department, Sir Takhtsinhji hospital, Government Medical College, Bhavnagar, Gujarat, India. This present study was conducted in accordance of International Conference on Harmonization Good Clinical Practice (ICH-GCP) guidelines, catering for all its precautions. This study was approved by the Institution Review Board / Institutional Ethics Committee with number 1015/2020. Study was conducted January 2021 to June 2021 after taking written and informed consent from all the patients. All the patients admitted in COVID ICU on invasive or non-invasive mechanical ventilation were enrolled in this study over the period of 5 months. Inclusion criteria were, age: 18-60 years of either gender, patients with COVID positive status, with moderate to severe ARDS and requiring either Non-Invasive or Invasive mechanical ventilation. Exclusion criteria were, patients with hypotension in whom SpO_2 is not recordable, patients with haemoglobin abnormalities (meth-haemoglobin, carboxy-haemoglobin) in whom there is variation in SpO_2 detection, patients with pulmonary oedema due to heart failure and congenital heart disease, patient's anatomic anomalies of lung or airways.

In this study, patients with underlying ARDS who required any type of mechanical ventilation (invasive or non-invasive) and were admitted to the COVID ICU were included and monitored for up to 10 days. Patients whose samples were taken during the follow-up period and who defaulted (deteriorated) were included. All mechanically ventilated patients underwent continuous vital signs monitoring, including blood pressure, heart rate, oxygen saturation and electrocardiograms. To assess the progression of ARDS, an alternate day arterial blood gas study was performed. Every day, the PF ratio and SF ratio were computed and correlatingly correlated to determine the progress of the disease. PaO_2 and SpO_2 at the same FiO_2 at the same time were also obtained. All of the SF threshold values corresponding to PF of RADS were displayed against ROC (Receiver Operating Characteristic) curves. The graph was plotted for all SF values on X-axis against PF values on Y-axis. On basis of it, equation is derived suggesting the relationship between SF ratio and PF ratio. On basis of ROC curves, equation is derived suggesting the relationship between SF ratio and PF ratio. Management in the form of change of ventilator settings to improve the prognosis of the patient was done.

Statistical analysis: Version 3.0 of GraphPad was used to conduct statistical analysis. While qualitative data were shown as frequency and percent (%), quantitative data were shown as mean standard deviation (SD). The continuous variables and categorical characteristics were compared using independent t tests and two-tailed 2 tests, respectively. Statistics were deemed significant at p 0.05. Equation for linear regression describing the relationship between SF and PF. To ascertain the sensitivity and specificity of the SF threshold values associated with PF of 200 (ARDS), ROC curves were produced.

RESULT

A total of 100 patients with ARDS met the inclusion criteria and included in the current study. 58 patients were male (58%) and 42 patients were female (42%). Mean age of study population was 47.03±9.53 years (minimum 25 and maximum 60 years). Table 1 demonstrates baseline findings of the patients enrolled in the study.

Age had no significant relationship with either SF ratio (p = 0.14) or PF ratio (p = 0.26). Similarly, gender did not have a significant relationship with either SF ratio (p = 0.18) or PF ratio (p = 0.53) (Table 2 and 3).

In general, SF ratio could be predicted well from PF ratio, described by the linear regression equation (SF = 0.84 PF + 30.36 or PF = 1.1597 SF - 35.211) (Fig. 1).

A linear regression equation was derived to explain the relation between SF ratio and PF ratio which is given below and found to be statistically significant ($p<0.001$).

$$PF = 1.1597\ SF - 35.211$$

DISCUSSION

In the prognostic criteria for ARDS, we hypothesised that the constantly accessible S/F ratio may act as a stand-in for the P/F ratio. Using information from ARDS patients who participated in this study, we discovered that the S/F ratio and a concurrently measured P/F ratio have a strong correlation. The oxygenation requirements for ARDS and ALI, respectively, were found to correlate to S/F ratios of 203 and 280 and P/F ratios of 200 and 300, respectively[2].

The frequency of arterial blood gas collection has decreased as a result of the common use of capnography and pulse oximetry. Pulse oximetry is commonly used in ICUs to continuously assess oxygenation status and is easily accessible[19-21]. The negative effects and expenses of arterial blood

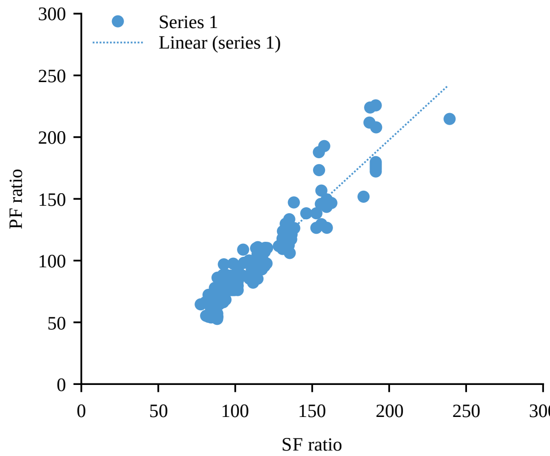

Fig. 1: Scatter plot constructed using the linear regression equation

Table 1: Patients Characteristics by age groups in PF and SF groups

Age	18-28 years	29-39 years	40-50 years	51-60 years	p-value
PF ratio	81.66±23.98	87.56±31.54	82.18±30.20	79.92±27.35	0.2616
SF ratio	102.15±21.26	104.34±24.6	102.02±25.93	99.10±21.91	0.1479

Data are expressed as Mean±SD

Table 2: Patients Characteristics by Gender in PF and SF group

Gender	Male	Female	p-value
PF ratio	78.94 ±23.45	83.99 ±31.38	0.526
SF ratio	99.00 ±19.01	101.85 ±25.99	0.1835

Data are expressed as Mean±SD

Table 3: Derivation of the linear regression equation and R square

	Mean	Standard error	95% confidence interval from	95% confidence interval to
PF ratio	101.114	1.086	79.44	84.652
SF ratio	82.047	1.329	98.985	103.24

collection are avoided with pulse oximetry[22]. Undiagnosed instances of the aforementioned disorders are found when ALI and ARDS are diagnosed using the SF ratio[23].

As an alternative to the PF ratio to determine the degree of hypoxemia, the SF ratio may be helpful in various organ failure scores, including lung damage scores, multi-organ dysfunction scores and sequential organ failure assessments[24-26]. The respiratory component is typically left out when these scores are frequently calculated since there are not enough repeated arterial blood gas studies. These scores might be computed without arterial blood gas collection if S/F ratio was used as a stand-in for hypoxemia. It should be emphasised, however, that these scoring systems are frequently used for critically sick patients with a wide range of medical conditions, not simply those with ALI/ARDS who require mechanical ventilation. The exception to this is the lung damage score.

The SF ratio's high AUCs for PF ratios of 300 and 400 mmHg (0.918 and 0.901), according to Catoire et al., might be employed as a hypoxemia screening tool in the emergency room[27]. The SF ratio is a significant predictor of intubation probability in COVID-19-related hypoxemic patients, according to Patel *et al*.[28] study of multivariable logistic regression data[28]. The SF ratios demonstrated an adequate prognostic ability for ARDS prognosis in our study. According to Hu *et al*.[29], the SF and PF ratios at 6 hours accurately predict the failure of the HFNC and the requirement for a mechanical ventilator (AUC: SF ratio of 0.786 and PF ratio of 0.749). In this study we enrolled 100 patients SARS-Cov-2 with ARDS. PaO_2 and SpO_2 were measured with the same FiO_2 and SF and PF ratio were calculated. The relationship between SF and PF ratio was described with the following equation: PF = 1.1597 SF - 35.211. SF ratio threshold values for ALI was 290 ARDS was 205 corresponding to PF ratio 300 and 200. Because COVID-19 patients are confined in a closed room and the number of healthcare staff is restricted, arterial blood gas analysis cannot be conducted on a regular basis. Furthermore, respiratory rate may be difficult to objectively monitor due to the inadequate accuracy of respiratory rate assessments by healthcare professionals[29]. The SF ratio, on the other hand, may be estimated objectively by monitoring pulse oximetry and FiO_2; hence, we propose that SF ratios can be a valuable tool for predicting ARDS and intubation in COVID-19 patients. The SF ratio criteria obtained in this study were based on the AECC's suggested PF ratio.

This study has certain drawbacks. We did not control for PH, haemoglobin, $PaCo_2$, body temperature, or ventilator configuration. These variables may also have an impact on the link between SpO_2 and PaO_2. Because there have been less investigations on deriving PF values from SF values, further studies are needed to confirm the current study's findings.

CONCLUSION

According to this study, the SF ratio provides a reliable non-invasive and easily accessible predictor for the PF ratio for the prediction of ARDS in COVID-19 patients, replacing arterial blood sampling by pulse oximetry. Given the risks of anaemia and bleeding associated with arterial blood sampling in COVID-19 patients in critical care, pulse oximetry is a viable alternative.

REFERENCES

1. ARABI, Y., 2002. A prospective study of prolonged stay in the intensive care unit: Predictors and impact on resource utilization. Int. J. Qual. Health Care, 14: 403-410.
2. Bernard, G.R., A. Artigas, K.L. Brigham, J. Carlet and K. Falke *et al*., 1994. The American-european consensus conference on ards. definitions, mechanisms, relevant outcomes and clinical trial coordination. Am. J. Respir. Crit. Care Med., 149: 818-824.
3. Sinuff, T., J. Muscedere, D. Cook, P. Dodek and D. Heyland, 2008. Ventilator-associated pneumonia: Improving outcomes through guideline implementation. J. Crit. Care, 23: 118-125.
4. Jensen, L.A., J.E. Onyskiw and N.G.N. Prasad, 1998. Meta-analysis of arterial oxygen saturation monitoring by pulse oximetry in adults. Heart Lung, 27: 387-408.
5. Azer, S.A., 2020. COVID-19: Pathophysiology, diagnosis, complications and investigational therapeutics. New Microbes New Infec., Vol. 37. 10.1016/j.nmni.2020.100738
6. Merlani, P., P. Garnerin, M. Diby, M. Ferring and B. Ricou, 2001. Quality improvement report: Linking guideline to regular feedback to increase appropriate requests for clinical tests: Blood gas analysis in intensive care. BMJ, 323: 620-624.
7. Roberts, D., P. Ostryzniuk, E. Loewen, A. Shanks and T. Wasyluk *et al*., 1991. Control of blood gas measurements in intensive-care units. The Lancet, 337: 1580-1582.
8. Mortz, M., 2004. US patent 714,803, 2004 pulse oximeter probe off detection system.
9. Kliegman, R.M., B.F. Stanton, J.W.S. Geme, N.F. Schor and R.E. Behrman, 2011. Nelson Textbook of Pediatrics. 19th Edn., Saunders, Philadelphia, ISBN-14: 978-1437707557, Pages: 2680.
10. Perkins, G.D., D.F. McAuley, S. Giles, H. Routledge and F. Gao, 2003. Do changes in pulse oximeter oxygen saturation predict equivalent changes in arterial oxygen saturation?. Crit Care, 7:.

11. Slutsky, A.S., 1993. Mechanical ventilation. Chest, 104: 1833-1859.
12. Roca, O., J. Messika, B. Caralt, M. García-de-Acilu, B. Sztrymf, J.D. Ricard and J.R. Masclans, 2016. Predicting success of high-flow nasal cannula in pneumonia patients with hypoxemic respiratory failure: The utility of the ROX index. J. Crit. Care, 35: 200-205.
13. Roca, O., B. Caralt, J. Messika, M. Samper and B. Sztrymf *et al*., 2019. An index combining respiratory rate and oxygenation to predict outcome of nasal high-flow therapy. Am. J. Respir. Crit. Care Med., 199: 1368-1376.
14. Rice, T.W., A.P. Wheeler, G.R. Bernard, D.L. Hayden, D.A. Schoenfeld and L.B. Ware, 2007. Comparison of the SpO_2/FIO_2 ratio and the PaO_2/FIO_2 ratio in patients with acute lung injury or ARDS. Chest, 132: 410-417.
15. Fukuda, Y., A. Tanaka, T. Homma, K. Kaneko and T. Uno *et al*., 2021. SpO_2/FiO_2 ratio for acute hypoxemic respiratory failure with bilateral opacities in the ICU. Plos One, Vol. 16 .10.1371/journal.pone.0245927.
16. Kim, G.E., S.H. Choi, M. Park, J.H. Jung and M. Lee *et al*., 2021. SpO_2/FiO_2 as a predictor of high flow nasal cannula outcomes in children with acute hypoxemic respiratory failure. Sci. Rep., Vol. 11, No. 1 .10.1038/s41598-021-92893-7.
17. Mayordomo-Colunga, J., M. Pons, Y. López, M.J. Solana and C. Rey *et al*., 2013. Predicting non-invasive ventilation failure in children from the SpO_2/FiO_2 (SF) ratio. Intensive Care Med., 39: 1095-1103.
18. Tobin, M.J., A. Jubran and F. Laghi, 2020. Misconceptions of pathophysiology of happy hypoxemia and implications for management of COVID-19. Respir. Res., Vol. 21, No. 1 .10.1186/s12931-020-01520-y
19. Numa, A.H. and C.J.L. Newth, 1995. Assessment of lung function in the intensive care unit. Pediatr. Pulmonol., 19: 118-128.
20. Montgomery, A.B., M.A. Stager, C.J. Carrico and L.D. Hudson, 1985. Causes of mortality in patients with the adult respiratory distress syndrome. Am. Rev. Respir. Dis., 132: 485-489.
21. Jubran, A., 2004. Pulse oximetry. Intensive Care Med., 30: 2017-2020.
22. Jubran, A. and M.J. Tobin, 1990. Reliability of pulse oximetry in titrating supplemental oxygen therapy in ventilator-dependent patients. Chest, 97: 1420-1425.
23. Brower, R.G., M.A. Matthay, A. Morris, D. Schoenfeld, B.T. Thompson and A. Wheeler, 2000. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N. Engl. J. Med. 4: 1301-1308.
24. Murray, J.F., M.A. Matthay, J.M. Luce and M.R. Flick, 1988. An expanded definition of the adult respiratory distress syndrome. Am. Rev. Respir. Dis., 138: 720-723.
25. Marshall, J.C., D.J. Cook, N.V. Christou, G.R. Bernard, C.L. Sprung and W.J. Sibbald, 1995. Multiple organ dysfunction score. Crit. Care Med., 23: 1638-1652.
26. Gall, J.R.L., 1993. A new simplified acute physiology score (SAPS ii) based on a European /north American multicenter study. JAMA, 270: 2957-2963.
27. Catoire, P., E. Tellier, C.D. Rivière, M.C. Beauvieux and G. Valdenaire *et al*., 2021. Assessment of the SpO_2/FiO_2 ratio as a tool for hypoxemia screening in the emergency department. Am. J. Emergency Med., 44: 116-120.
28. Patel, M., A. Gangemi, R. Marron, J. Chowdhury and I. Yousef *et al*., 2020. Retrospective analysis of high flow nasal therapy in COVID-19-related moderate-to-severe hypoxaemic respiratory failure. BMJ Open Respir. Res., Vol. 7 .10.1136/bmjresp-2020-000650
29. Hu, M., Q. Zhou, R. Zheng, X. Li and J. Ling *et al*., 2020. Application of high-flow nasal cannula in hypoxemic patients with COVID-19: A retrospective cohort study. BMC Pulm. Med., Vol. 20 .10.1186/s12890-020-01354-w