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Diagnostic Performance of the Pulse Oxygen Saturation to Fraction of Inspired Oxygen Ratio in Adults with Acute Hypoxemic Respiratory Failure in an Intensive Care Unit in Sub-Saharan Africa

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Abstract

Introduction: The SpO_2/FiO_2 ratio (S/F) is a non-invasive tool for diagnosing acute hypoxemic respiratory failure, particularly valuable in resource-limited settings where arterial blood gas analysis is scarce. This study aims to determine S/F ratio cut-offs corresponding to PaO_2/FiO_2 (P/F) ratios used in AHRF patients in a Sub-Saharan African population, with a focus on defining thresholds for spontaneously ventilating patients. **Methods:** We conducted a retrospective cohort study in the intensive care unit at Douala General Hospital. Medical records of patients over 18 years of age, hospitalised between January 1, 2021 and July 30, 2022 and having benefited from at least one arterial blood gas measurement were reviewed. Documented arterial blood gas measurements were considered if the records had a traceable matched SpO_2 and FiO_2 recorded within 30 minutes of the measurement. Files with any documented cause of chronic respiratory failure were excluded. Data were analyzed using R version 4.5.1. Linear regression models were employed. The level of statistical significance was set at $P < 0.05$. **Results:** A very strong correlation was

found between the S/F and P/F ratios ($r > 0.8$). The equation of the straight line that characterised the linear relationship between S/F ratio and P/F ratio was $\ln(S/F) = 1.196 + 0.805 \ln(P/F)$ for spontaneously ventilating patients and $\ln(S/F) = 1.810 + 0.659 \ln(P/F)$ for mechanically ventilated patients, with R^2 values of 0.80 and 0.76, respectively. The S/F ratio cut-offs corresponding to P/F ratios of 300 mmHg, 200 mmHg, and 100 mmHg were approximately 325, 235, and 135 for spontaneously ventilating patients and 260, 200, and 125 for mechanically ventilated patients with PEEP > 5 cmH_2O. **Conclusion:** This study demonstrates a strong correlation between the S/F and P/F ratios in Sub-Saharan Africa. The findings highlight the clinical utility of the S/F ratio as a practical, non-invasive tool for diagnosing acute hypoxemic respiratory failure, particularly in resource-limited settings. Tailoring cut-offs according to ventilation status may optimise patient triage and treatment decisions, contributing to better outcomes.

Keywords

Respiratory Insufficiency, Respiratory Distress Syndrome, Hypoxaemia, Intensive Care Unit, Cameroon

1. Introduction

Respiratory failure occurs due to two main mechanisms: failure to oxygenate blood or to eliminate carbon dioxide. This condition can be categorised into two types: hypoxaemic respiratory failure (type 1, characterised by a $PaO_2 < 60$ mmHg) and hypercapnic respiratory failure (type 2, with a $PaCO_2 > 50$ mmHg), or a combination of both [1]. The prevalence of hypoxaemic respiratory failure in intensive care unit (ICU) patients has shown significant variation across regions. For instance, a study in France reported a 1-day point prevalence of 54% among ICU admissions [2]. In contrast, a tertiary hospital in Uganda recorded a hospital prevalence of 4.5% for hypoxaemic respiratory failure, coupled with a concerning mortality rate of nearly 80% in critically ill patients hospitalised in the emergency department [3].

Acute respiratory distress syndrome (ARDS) is the most severe form of acute hypoxemic respiratory failure [4]. It is a rapidly progressive interstitial lung disease for which prompt identification and treatment may avert fatal complications [5]. Coronavirus disease (COVID-19) emerged in 2019 as a significant cause of ARDS, seriously straining healthcare systems worldwide and resulting in high mortality rates [6] [7].

The partial arterial oxygen pressure-to-fraction of inspired oxygen ratio (P/F ratio) is a vital component of the 2012 Berlin criteria for diagnosing and prognosticating ARDS via intermittent arterial blood sampling [8]. However, in resource-constrained settings, the availability and affordability of arterial blood gas analysers are limited [9]-[11], necessitating the exploration of simpler and more acces-

sible methods for assessing tissue oxygenation.

Pulse oximeters have transformed modern medicine by enabling continuous monitoring of arterial blood oxygen saturation. This technology has become so prevalent that pulse oximetry is increasingly recognized as a vital sign [12]. For more than a decade, scientists have been investigating the potential of the pulse oxygen saturation to the fraction of inspired oxygen ratio (S/F ratio) as a surrogate for the partial arterial pressure of oxygen to the fraction of inspired oxygen ratio (P/F ratio) for the diagnosis, stratification, and monitoring of hypoxemic respiratory failure, attaining 72% sensitivity and 60% specificity in India [13]. Challenges in low- and middle-income countries, including but not limited to the scarcity of arterial blood gas equipment, mechanical ventilators, and radiographic imaging resources, call for context-friendly methods for assessing various forms of acute hypoxemic respiratory failure [14].

Arterial blood oxygen saturation is a critical parameter routinely monitored in ICUs, with pulse oximetry becoming a ubiquitous tool for its non-invasive assessment [15]. The ease of use and affordability of pulse oximeters have led to their widespread adoption across diverse healthcare settings, including remote communities [16]. Interest in pulse oximetry has surged over the past five years, driven by the need for social distancing and continuous patient monitoring [17] [18].

Despite the availability of pulse oximeters, diagnoses of acute hypoxemic respiratory failure (AHRF) are often missed. Thus, this study aimed to assess the reliability of pulse oximetry as a surrogate for arterial blood gases in diagnosing AHRF using the pulse oxygen saturation-to-fraction of inspired oxygen ratio (S/F) in a low-resource setting. Specifically, we aimed to determine whether patients on mechanical ventilation (MV) had a different S/F ratio cut-off for AHRF diagnosis compared to spontaneously ventilating patients (SV).

2. Methods

2.1. Study Design, Period, and Setting

We conducted a retrospective cohort study at the intensive care unit (ICU) of the Douala General Hospital (DGH), Littoral region, Cameroon. All medical records of patients hospitalised between January 1, 2021, and July 30, 2022, were considered.

The DGH is a tertiary care university teaching hospital with a 12-bed capacity ICU and serves as one of the major referral centres for critically ill patients in Cameroon and neighbouring countries. The ICU has eight ventilators, 12 multiparameter monitoring machines, and two functional arterial blood gas analysers. The unit is permanently run by eight physicians, fourteen nurses, and a variable number of interns and residents in internal medicine, anaesthesia, and intensive care medicine.

2.2. Participants

All patients aged 18 years or older admitted to the ICU with at least one arterial blood gas recording were included. All documented arterial blood gas (ABG) rec-

ords with traceable SpO_2 (oxygen saturation measured by pulse oximetry) and FiO_2 (fraction of inspired oxygen) registered within 30 minutes of the ABG measurement were recorded. SaO_2 (arterial oxygen saturation measured via ABG) was equally measured. We excluded records from patients with any documented cause of chronic respiratory failure (chronic obstructive lung disease, chronic interstitial lung disease, advanced lung cancer). Arterial blood measurements with matched SpO_2 showing hyperoxygenation ($SpO_2 > 98\%$) or suggesting a venous sample ($SaO_2 < 75\%$ with a $SpO_2 > 95\%$) or those for which the PaO_2 could not be read were excluded.

2.3. Variables

2.3.1. Primary Variables

PaO_2 (mmHg), $PaCO_2$ (mmHg), SaO_2 (%), SpO_2 (%), and estimated FiO_2 based on flow rate using a conversion table for patients on oxygen (flow rate between 6 and 15 L/min) via mask [19] (see **Supplementary Table A1**). For patients receiving supplemental oxygen via nasal cannula (flow rate between 1 and 5 L/min), FiO_2 was estimated using the formula "20 + 4 × oxygen flow rate" [20]. In mechanically ventilated patients, FiO_2 was extracted from recorded ventilator parameters.

2.3.2. Secondary Variables

- $\text{P/F ratio} = \dfrac{PaO_2}{FiO_2}$
- $\text{S/F ratio} = \dfrac{SpO_2}{FiO_2}$

2.4. Data Sources/Measurements

SpO_2 measurement in this ICU follows standard operating procedures as outlined in the World Health Organisation (2011) pulse oximetry training manual [21]. Blood drawing for arterial blood gas measurements followed a strict procedure as outlined by the WHO guidelines on blood drawing [22]. Routinely sampled sites were the radial artery, femoral artery, or an arterial line placed in these areas, with the collected blood analysed immediately on an ABG analyser of brand name EIDANI15 and OPTI CCA-TS2. These procedures were performed by an accredited nurse, resident, or attending physician.

The SpO_2 recorded within 30 minutes of ABG sampling was noted. Other vital signs corresponding to each ABG-SpO_2 pair were recorded. All ABG-SpO_2 pairs recorded during the entire length of ICU stay for each patient were noted. The oxygen treatment modalities and ventilation modes were also noted.

2.5. Bias

This retrospective study may be subject to selection bias because only patients with arterial blood gas (ABG) measurements were included, potentially excluding milder cases or those unable to afford testing. We mitigated this by using a consecutive sampling design. Measurement bias could arise from timing discrepan-

cies between SpO_2 and ABG measurements or equipment variability. Standardised WHO protocols [22] were followed to minimise errors. Confounding bias may stem from unmeasured factors such as comorbidities or ventilation settings, which are addressed by excluding cases of chronic respiratory failure and stratifying by ventilation status. Information bias from incomplete records was reduced through rigorous data cleaning. Despite these efforts, residual biases may persist, and generalisability to other settings should be approached with caution. Further, excluding observations with $SpO_2 > 98\%$ limits the applicability of our equations in patients with mild hypoxemia. Because the oxyhemoglobin dissociation curve flattens at higher saturations [23], SpO_2 values above this range provide limited discriminatory power for estimating PaO_2 or P/F ratio. By removing these data points, optimising models for moderate-to-severe hypoxemia, but may not generalise to clinical scenarios where oxygenation impairment is mild, and SpO_2 remains high or near normal.

2.6. Study Size

Sampling was consecutive and exhaustive. The sample size was estimated for predicting the performance of the S/F ratio for a P/F ratio < 300. Using an online calculator, the area under the receiver operating characteristic curve (AUC) was used to estimate the minimum sample size of arterial blood gases required [24], assuming a power of 80%, an accuracy of 0.05, and a confidence interval width of 0.125. The hypothetical AUC used was 0.80, with an estimated 50% of patients having a P/F ratio < 300 [25]. The estimated minimum sample size obtained was 194 arterial blood gas measurements.

2.7. Quantitative Variables and Statistical Methods

Data from case report forms were entered into Excel spreadsheets, cleaned, and imported into R version 4.5.1 to complete cleaning and analysis. Medians and interquartile ranges, frequencies, and proportions were used to summarise the general characteristics and were presented in tables. Models were assessed using R^2, the area under the receiver operating characteristic curve (AUC). The level of statistical significance was set at $P < 0.05$.

The analysis focused on the relationship between arterial blood gas (ABG) and peripheral capillary oxygen saturation (SpO_2) in patients under positive pressure and spontaneous ventilation. The data was divided into training (85%) and testing (15%) sets through random selection. Using the training set, linear models were created to establish the relationship between P/F (PaO_2/FiO_2) and S/F (SpO_2/FiO_2) ratios. Oxygenation indices were log-transformed to address skewness in the data. Generalised linear models provided the best-fit regression lines to identify S/F ratio thresholds correlating with P/F ratios of 300, 200, and 100 mmHg, critical for acute hypoxemic respiratory failure (AHRF) grading.

Receiver operating characteristic (ROC) curves evaluated the discrimination between S/F and P/F ratios, optimising sensitivity and specificity for AHRF

thresholds. Predictions from the training set were validated against the testing set using the area under the ROC curve (AUC) and Bland-Altman statistics.

2.8. Ethical Considerations

Administrative approval was obtained from the Douala General Hospital. The research was conducted in accordance with the 2013 revised edition of the World Medical Association Declaration of Helsinki on ethical principles for research involving human subjects. Ethical approval was obtained from the Regional Ethics Committee for the Littoral under reference: N/2025/CE/CRERSH-LITTORAL. Informed consent was waived due to the retrospective design, with patient confidentiality ensured through anonymisation.

3. Results

3.1. Participants

During the study period, 405 ABG measurements were collected from 304 patients. Of these, 284 measurements from 121 patients met the predefined inclusion criteria, resulting in a measurement-to-patient ratio of 2.3. These included 140 measurements from 72 patients during spontaneous ventilation and 144 from 102 patients during mechanical ventilation. Consequently, 53 patients contributed measurements in both groups (Figure 1).

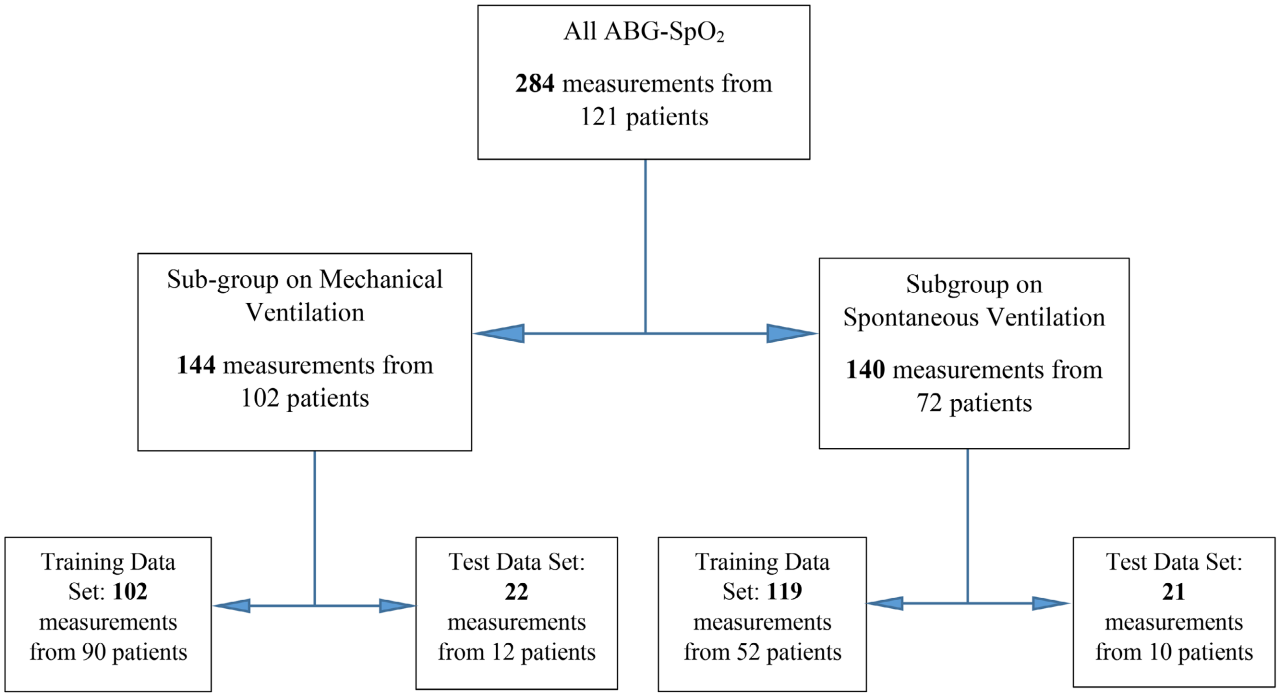


Figure 1. Distribution of observations according to the main and subgroup analyses.

3.2. Descriptive Data

On comparative analysis, significant differences between spontaneous and me-

chanical ventilation groups were observed in respiratory rate, FiO_2, body temperature, pH, arterial CO_2 levels ($PaCO_2$), and oxygenation indices (S/F and P/F ratios), reflecting distinct respiratory dynamics and varying levels of respiratory support (see Table 1).

During spontaneous ventilation, supplemental oxygen was primarily administered via nasal cannula (35.7%) and non-rebreather mask (36.4%), with 22.9% of measurements taken while patients were breathing ambient air. A smaller proportion (5.0%) received oxygen via a Venturi mask (see Table 2).

While on mechanical ventilation, volume-controlled ventilation (VCV) was the predominant mode, accounting for 61.1% of measurements, followed by intermittent volume-controlled ventilation (IVCV) at 20.8%. Other modes included synchronised intermittent mandatory ventilation with pressure support (SIMV + PS) at 11.8%, intermittent pressure-controlled ventilation (IPCV) at 2.8%, pressure-controlled ventilation (PCV) at 2.1%, and continuous positive airway pressure (CPAP) at 1.4% (see Table 2).

While analysing the density curves, the distributions of P/F and S/F ratios are quite similar overall, with large overlap across most values, as shown in Figure 2. Both ratios show a bimodal distribution with peaks roughly around 100 - 150 and 300 - 350. The S/F ratio has a slightly wider spread and a higher-density peak near 400, indicating more high-value observations than the P/F ratio.

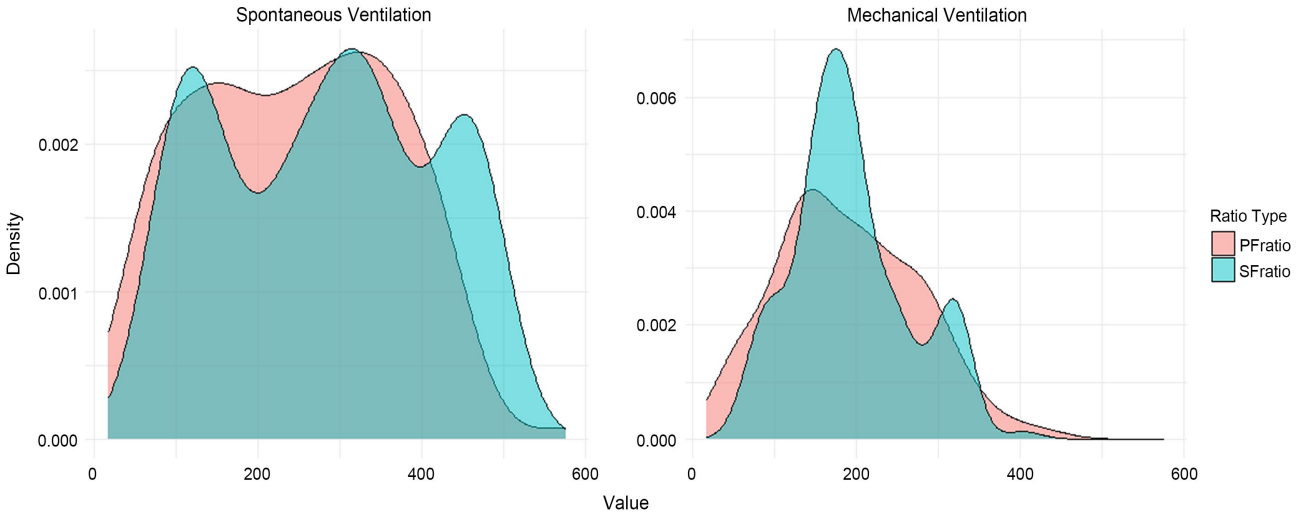


Figure 2. Density plots comparing the distribution of two oxygenation indices—the P/F ratio (PaO_2/FiO_2) in red and the S/F ratio (SpO_2/FiO_2) in blue—within the spontaneous ventilation (left panel) and mechanical ventilation (right panel) groups.

3.3. Outcome Data

The P/F and S/F ratio distributions show less overlap during mechanical ventilation compared to the spontaneous group. Both have a major peak around 150 - 200, but the S/F ratio density appears more sharply peaked and slightly shifted toward lower values compared to P/F. There is also a broader tail extending toward higher P/F ratios (above 300) during mechanical ventilation.

Table 1. Comparison of respiratory and clinical parameters measured during mechanical and spontaneous ventilation.

Variable	Spontaneous Ventilation (N = 140) Median (Q1, Q3)	Mechanical Ventilation (N = 144) Median (Q1, Q3)	Total (N = 284) Median (Q1, Q3)	P-value
Respiratory rate (bpm)	25.0 (18.0, 32.0)	19.0 (16.0, 24.0)	21.0 (16.0, 28.0)	<0.0001
S_PO_2 (%)	97.0 (95.0, 98.0)	97.0 (94.8, 98.0)	97.0 (95.0, 98.0)	0.9688
FiO_2	0.32 (0.24, 0.70)	0.50 (0.40, 0.60)	0.48 (0.30, 0.60)	<0.0001
Oxygen flow rate (L/min)	5.0 (2.5, 10.0)	NA	5.0 (2.5, 10.0)	
PEEP (cmH_2O)	NA	6.0 (5.0, 8.0)	6.0 (5.0, 8.0)	
Tidal Volume	NA	400.0 (381.0, 450.0)	400.0 (381.0, 450.0)	
Temperature (˚C)	36.8 (36.2, 37.7)	37.4 (36.3, 38.7)	37.0 (36.3, 38.2)	<0.0001
MBP (mmHg)	85.0 (72.0, 101.0)	90.0 (77.0, 103.0)	88.0 (75.2, 102.0)	0.1187
Haemoglobin (g/dl)	10.5 (9.1, 12.6)	10.6 (9.2, 12.4)	10.6 (9.2, 12.5)	0.8080
Lactate (g/dl)	1.8 (1.3, 2.6)	1.8 (1.1, 3.1)	1.8 (1.2, 2.8)	0.8572
PH	7.4 (7.3, 7.4)	7.3 (7.2, 7.4)	7.4 (7.3, 7.4)	<0.0001
P_aCO_2 (mmHg)	35.5 (29.6, 42.0)	38.7 (34.0, 45.8)	37.7 (31.8, 43.1)	0.0178
P_aO_2 (mmHg)	80.2 (66.0, 96.0)	90.0 (74.0, 111.7)	85.0 (69.0, 106.0)	0.0434
S_aO_2 (%)	96.0 (92.0, 98.0)	96.2 (91.0, 98.0)	96.0 (92.0, 98.0)	0.0910
S/F ratio	298.4 (140.0, 393.8)	190.9 (154.6, 240.6)	199.0 (152.7, 320.8)	<0.0001
P/F ratio (mmHg)	246.3 (145.4, 343.9)	184.5 (130.0, 254.3)	209.7 (134.7, 293.5)	0.0021

SpO_2, Pulsed oxygen saturation; FiO_2, Fraction of inspired oxygen; PEEP, Positive End Expiratory Pressure; MBP, Mean Arterial Blood Pressure; $PaCO_2$, Partial pressure of carbon dioxide in arterial blood; P_aO_2, Partial pressure of oxygen in arterial blood; P/F, P_aO_2/FiO_2 ratio; S/F, S_PO_2/FiO_2 ratio; S_aO_2, Arterial oxygen saturation; NA, Not Applicable; Q1, 25th percentile; Q3, 75th percentile.

Table 2. Distribution of ventilation modes in mechanical and spontaneous ventilation.

Mechanical Ventilation (N = 144)		Spontaneous Ventilation (N = 140)	
Variable	**n (%)**	**Variable**	**n (%)**
PCV	3 (2.1)	Ambient Air	32 (22.9)
IPCV	4 (2.8)	Nasal Cannular	50 (35.7)
VCV	88 (61.1)	Venturi Mask	7 (5.0)
IVCV	30 (20.8)	Non-rebreather Mask	51 (36.4)
CPAP	2 (1.4)		
SIMV + PS	17 (11.8)		

PCV, pressure-controlled ventilation; IPCV, intermittent pressure-controlled ventilation; VCV, volume-controlled ventilation; IVCV, intermittent volume-controlled ventilation; SIMV + PS, synchronized intermittent mandatory ventilation with pressure support; CPAP, continuous positive airway pressure.

3.4. Main Results

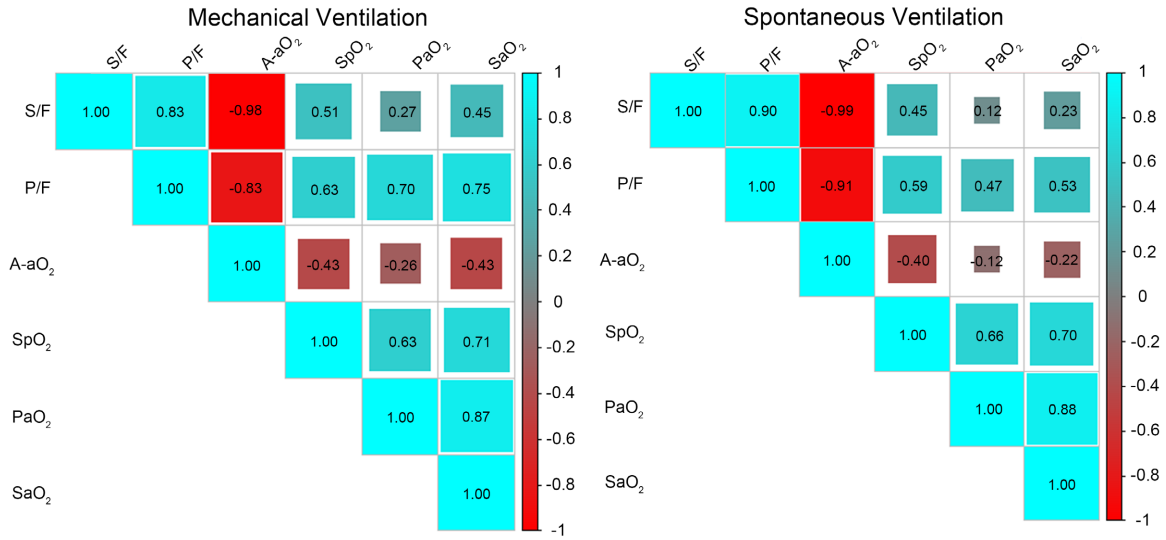
Pulse oximetry (SpO_2) showed strong positive correlations with arterial oxygen saturation (SaO_2) and PaO_2 in both groups, with correlation coefficients ranging from 0.6 to 0.7 (Figure 3). The S/F ratio exhibited a very strong positive correlation with the P/F ratio in both groups, with coefficients above 0.8, and was stronger (>0.9) in the spontaneous ventilation subgroup (Figure 3). The linear relationship between the S/F ratio and P/F ratio, modelled by the equation $\ln(S/F) = \beta_0 + \beta_1 \ln(P/F)$, was characterised by the following regression equations (Figure 4):

- For spontaneously ventilated (SV) patients: $\ln(S/F) = 1.196 + 0.805\ln(P/F)$ with $R^2 = 0.80$. (**Model 1**)
- For mechanically ventilated (MV) patients: $\ln(S/F) = 1.81 + 0.659\ln(P/F)$ with $R^2 = 0.76$. (**Model 2**)

Using these equations, the corresponding S/F ratio cut-offs for clinically relevant P/F thresholds of 300 mmHg, 200 mmHg, and 100 mmHg were estimated as follows (see Table 3):

- For SV patients, approximately 325, 235, and 135, respectively.
- For MV patients, approximately 260, 200, and 125, respectively (all with PEEP > 5 cmH_2O).

In model evaluation, the S/F ratio demonstrated excellent discriminative ability, with AUC values above 0.95 across all P/F ratio thresholds. The sensitivity and specificity were generally high (>0.85), with the highest sensitivity (0.91) and specificity (0.98) observed at P/F ratios <100 mmHg. The positive and negative predictive values were also strong, indicating the model's reliability across a range of cut-offs.



S/F, S_pO_2/FiO_2 ratio; P/F, P_aO_2/FiO_2 ratio; S_pO_2, oxygen saturation by pulse oximetry or plethysmographic oxygen saturation or pulse oxygen saturation or peripheral oxygen saturation; P_aO_2, partial pressure of oxygen in arterial blood; FiO_2, fraction of inspired oxygen; A-aO_2, A-a O_2 gradient; Red, negative correlation; Blue, positive correlation; colour coverage is proportionate to the strength of correlation.

Figure 3. Correlation Matrix of S/F Ratio, P/F Ratio, and Other Oxygenation Indices During Mechanical (Left) and Spontaneous (Right) Ventilation.

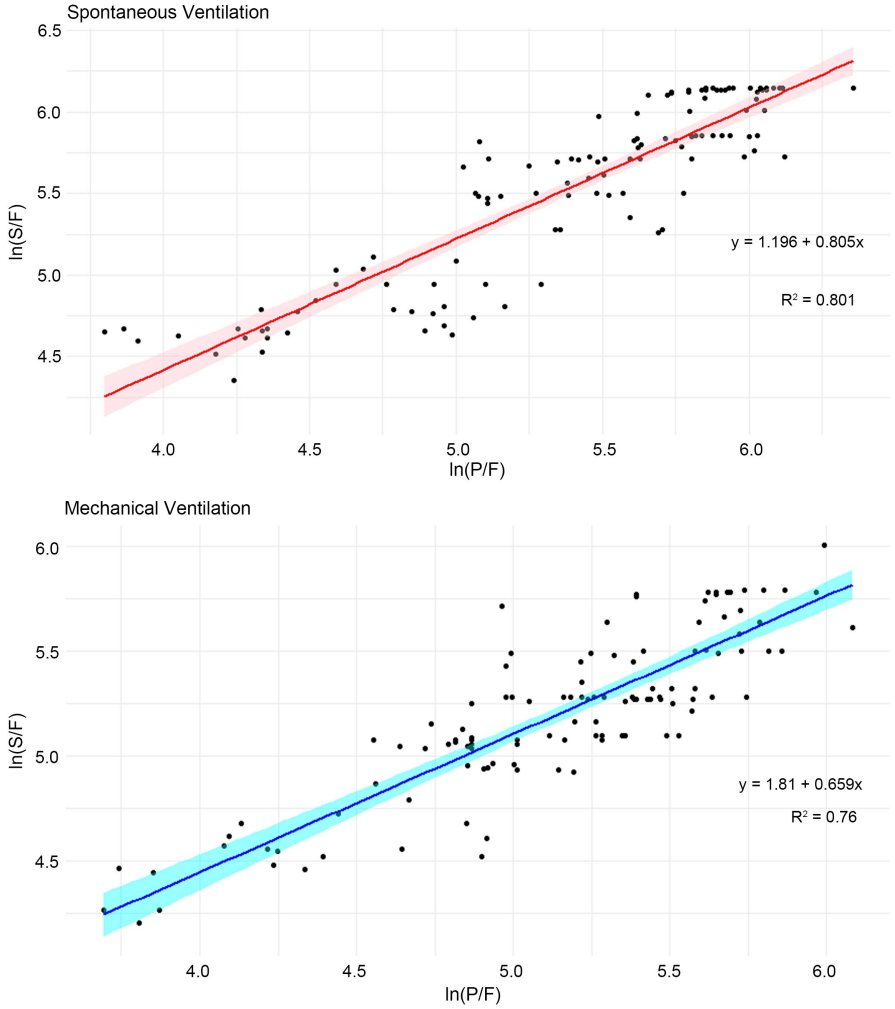


Figure 4. Scatter plot of the relationship between ln(P/F ratio) and ln(S/F ratio) during spontaneous (top image) and mechanical (lower image) ventilation in patients.

For measures on mechanical ventilation, moderate to excellent AUC values were observed (0.66 to 0.95), with lower accuracy at higher cut-offs (<300 and <200 mmHg). The sensitivity was notably lower for the P/F ratio threshold < 300 mmHg (0.42), but this improved to 0.9528 for the P/F ratio threshold < 100 mmHg. The specificity and predictive values generally remained high, suggesting the S/F ratio as reliable for identifying more severe hypoxemias.

Both linear models exhibited good predictive accuracy on the test datasets, with root-mean-square values below 0.23, indicating relatively low average prediction error (Table 4). Both models also showed excellent discriminative power for identifying hypoxemia at clinically relevant P/F thresholds. The model for spontaneous ventilation (**Model 1**) performed consistently well across P/F ratio thresholds (AUCs > 0.94), indicating strong classification ability. In contrast, the second model during mechanical ventilation showed relatively poorer discrimination at the lower P/F ratio thresholds (AUCs of 0.85 and 0.88).

In the Bland-Altman analysis using the test datasets (Figure 5), both the S/F

and P/F ratios show no significant bias (p-values > 0.05). During spontaneous ventilation, there was slightly better consistency and less variability than during mechanical ventilation. However, the wide range of agreement across both groups reveals considerable variability at the individual level. Spontaneous ventilation demonstrates slightly better consistency and less variability than mechanical ventilation.

Table 3. Performance of S/F ratio cut-offs in predicting P/F ratio thresholds in spontaneously and mechanically ventilated patients.

P/F Ratio Range (mmHg)	S/F Ratio Cut-off Estimates	AUC	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Training data set of the subgroup of spontaneously ventilating patients, n = 119 (model 1)						
<300	326.69	0.9555	0.8511	0.8889	0.8333	0.9014
<200	235.69	0.9577	0.9324	0.7778	0.8734	0.8750
<100	134.87	0.9700	0.9109	0.8889	0.9787	0.6400
Training dataset of the subgroup of mechanically ventilated patients, n = 120 (model 2)						
<300	261.70	0.7143	0.8704	0.4167	0.9592	0.9087
<200	200.36	0.6667	0.9118	0.8571	0.7750	0.8571
<100	126.91	0.9528	0.8750	0.9806	0.7368	0.9714

AUC, area under the receiver operating characteristics curve; S/F, SpO_2/FiO_2 ratio; P/F, PaO_2/FiO_2 ratio.

Table 4. Performance metrics of the predictive models on the test dataset.

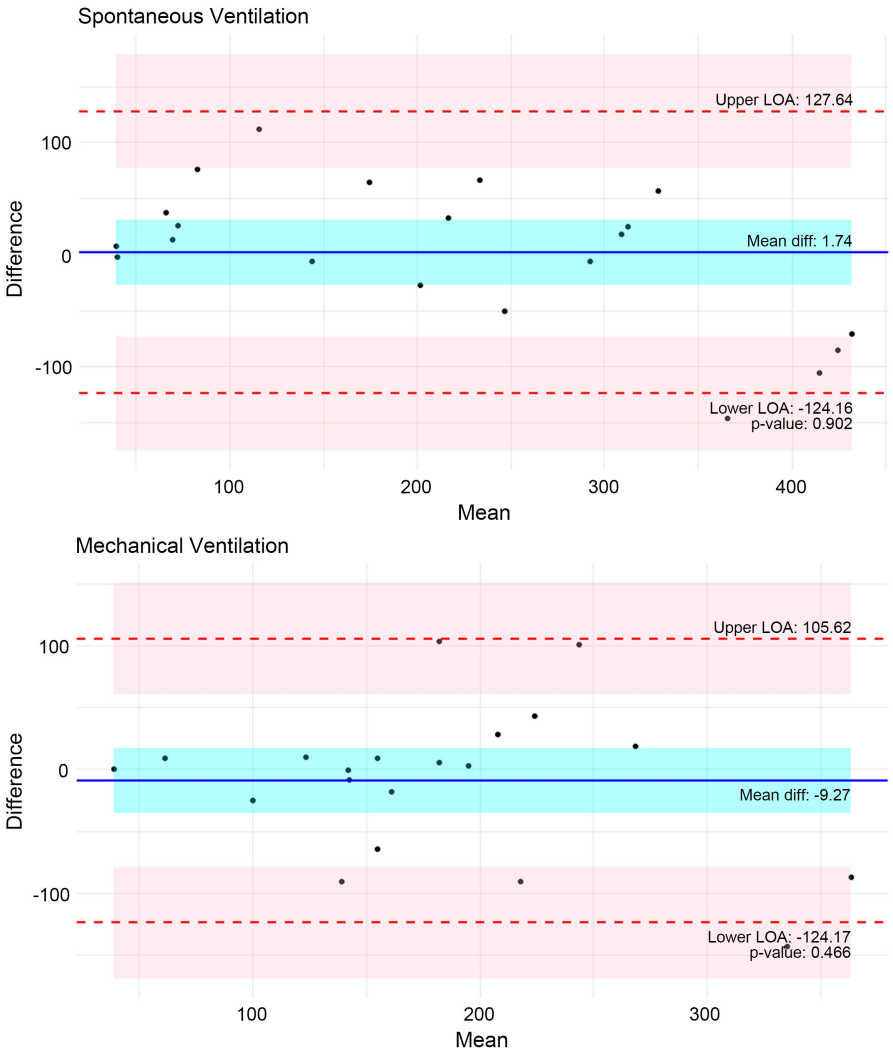
Metric	Model 1	Model 2
RMSE	0.2280	0.1919
R-squared	0.8912	0.8532
AUC (P/F < 300 mmHg)	0.9667	0.9762
AUC (P/F < 200 mmHg)	0.9630	0.8476
AUC (P/F < 100 mmHg)	0.9375	0.8750

AUC, Area under the receiver operating characteristic curve; P/F, PaO_2/FiO_2 ratio; RMSE, Root mean square error; Model 1, on spontaneous ventilation; Model 2, on mechanical ventilation.

3.5. Sensitivity Analysis

In a sensitivity analysis, we performed a disaggregated estimate of cut-offs for the various modes of oxygen delivery for patients on spontaneous ventilation. Across modes, the same P/F ratio yielded different S/F ratios, with ambient air and nasal cannula showing consistently higher S/F ratio values and non-rebreather masks showing the lowest (**Supplementary** Table A2). This pattern suggests that the oxygen-delivery mode may influence the apparent S/F ratio to P/F ratio relationship,

with higher-support devices displaying progressively lower S/F ratio values for any given P/F ratio.



Blue Line, Mean difference; Red Dashed Lines, Upper and Lower Limits of agreement; Shaded Areas, Confidence interval around the mean difference (cyan) and LOA (pink).

Figure 5. Bland-Altman plot of measurement agreement in spontaneously ventilating (Upper Image) and mechanically ventilating patients (Lower Image).

4. Discussion

This study reports a strong association between SpO_2/FiO_2 (S/F) and PaO_2/FiO_2 (P/F) ratios in adults with acute hypoxemic respiratory failure (AHRF) in a Sub-Saharan African intensive care unit (ICU). In spontaneously ventilating (SV) patients, threshold S/F levels of about 325, 235, and 135 were associated with P/F ratio levels of 300, 200, and 100 mmHg, respectively, with an R^2 of 0.80. In mechanically ventilated (MV) patients with positive end-expiratory pressure (PEEP) > 5 cmH_2O, the derived cut-off levels for S/F were 260, 200, and 125, with an R^2 value of 0.76. The S/F ratio showed good discriminative ability (with AUC > 0.95

for SV patients and 0.66 - 0.95 for MV patients), with high sensitivity and specificity (especially in severe hypoxemia) at P/F ratio levels below 100 mmHg. The findings highlight the utility of S/F as a reliable non-invasive diagnostic tool for AHRF in resource-poor settings with limited access to arterial blood gas (ABG) analysis.

Our findings align with previous studies from high-resource settings, which reported strong correlations between S/F and P/F ratios (r = 0.68 - 0.95) [26]-[29]. For instance, Venegas *et al*. [29] found correlations of 0.68 - 0.91 in MV trauma patients, while Rice *et al*. [27] reported similar S/F cut-offs (241 - 357 for P/F < 300 mmHg) in ARDS patients. However, most prior research focused on MV patients, with limited data on SV patients. Our study extends these findings by providing specific S/F ratio cut-offs for SV patients, a critical contribution for Sub-Saharan African settings where mechanical ventilation is often unavailable. Notably, the S/F ratio cut-off of ≤315 for ARDS diagnosis in an African cohort [14] [29] was derived from patients with MV. It may not be generalizable to SV patients, as our results suggest higher cut-offs for them (e.g., 325 vs 260 for P/F < 300 mmHg). This discrepancy highlights the importance of tailoring cut-offs to ventilation status.

The noted differences in S/F ratio cut-off levels between MV patients and SV patients might be explained by a mixture of technical and physiological factors. In MV patients, positive end-expiratory pressure (PEEP) and hemodynamic changes, most frequently related to sepsis or septic shock [30], might decrease SpO_2 without a simultaneous decrease in PaO_2, resulting in lower S/F ratio cut-offs. For example, Pandharipande *et al*. [31] reported that PEEP increments corresponding to decreased S/F ratio cut-off levels might be associated with changes in pulmonary perfusion. We may infer that in SV patients, PEEP abstinence, combined with decreased invasive respiratory support, is likely to produce higher S/F ratio levels, corresponding to a more accurate SpO_2-PaO_2 relationship. In addition to that, conditions frequently seen in severely ill patients that might represent difficulties for pulse oximetry accuracy for MV patients (for example, anaemia, hypoperfusion, or hyperbilirubinemia) [32] might explain inferior discriminative ability for increased P/F thresholds (AUC 0.66 - 0.85 for MV patients compared to >0.95 for SV patients) for the S/F ratio.

However, in the sensitivity analysis exploring oxygen-delivery-mode disaggregated thresholds for the S/F ratio in SV, we observe that across oxygen-delivery modes, the same P/F ratio yields markedly different S/F ratios. This suggests that the S/F ratio P/F ratio relationships may not be very much interchangeable. Ambient air and nasal cannula resulted in higher S/F values for a given P/F, while Venturi and non-rebreather masks yielded lower, more physiologically constrained responses, potentially due to differences in FiO_2 stability and the underlying severity of illness. Because oxygen-delivery mode often reflects disease severity—including shock, vasopressor exposure, impaired perfusion, and other markers of instability—the observed differences may yet still reflect underlying physiology rather than the device itself.

Therefore, hypothetically, as we move from breathing on ambient air to requiring more and more sophisticated devices or needing mechanical ventilation, we were more likely have poor peripheral perfusion, require vasopressors, have anaemia or hyperbilirubinaemia we are more likely to have and SpO_2 reading bias that yield lower values thus causing inaccuracies of the S/F ratio thresholds.

The study's modest sample size (284 ABGs from 121 patients) limits statistical power, and the retrospective design introduces potential information bias despite rigorous data cleaning. Economic constraints in this setting often delay or prevent mechanical ventilation, potentially skewing the MV cohort toward more severe illness. Unmeasured confounders—including comorbidities, variations in PEEP use, and differences in perfusion status—may also influence the observed relationships.

Despite these limitations, this study is among the first to establish S/F thresholds for both SV and MV patients in a Sub-Saharan African ICU, thereby addressing a critical gap in the literature. Standardised WHO-recommended procedures for SpO_2 and ABG measurement strengthen the reliability of the data. The high correlation coefficients and strong discriminative ability, particularly in SV patients, underscore the potential of S/F as a practical diagnostic tool in resource-constrained environments.

In such settings, clinicians can apply the proposed S/F thresholds (e.g., 325 for SV and 260 for MV for P/F < 300 mmHg) to identify AHRF, enabling earlier intervention and more accurate patient stratification. However, caution is warranted when interpreting S/F in MV patients, especially at higher P/F levels where accuracy declines. Future multicenter studies should validate these cut-offs, explore the impact of factors such as anaemia and sepsis on the SpO_2-PaO_2 relationship, and assess the prognostic value of S/F for AHRF outcomes.

5. Conclusion

This study demonstrates a strong correlation between the S/F and P/F ratios in Sub-Saharan Africa, with notable differences between ventilation modes. The findings highlight the clinical utility of the S/F ratio as a practical, non-invasive tool for diagnosing acute hypoxemic respiratory failure (AHRF), particularly in resource-limited settings. By offering a reliable alternative to arterial blood gas analysis, the S/F ratio could enhance early detection of respiratory failure and inform diagnostic guidelines for AHRF in similar settings.

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Authors' Contributions

Study concept and design: NSN, MBJ and ZMJ. Data collection: NSN. Analysis and interpretation of data: NSN. Manuscript writing: NSN and MMLE. Final ap-

proval of manuscript: NSN, MBJ, DA, MM, AO, NF, MMLE, ANEG, MSP, NRA, NSM and ZM. ZMJ supervised the study. NSN had full access to all study data and takes responsibility for the integrity and accuracy of the data analysis. All authors agreed to submit the manuscript in its current form.

Data Availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Regional Ethics Committee for the Littoral under reference: N/2025/CE/CRERSH-LITTORAL. Informed consent was waived due to the retrospective design, with patient confidentiality ensured through anonymisation.

Conflicts of Interest

The authors declare no competing interests.

References

[1] Lamba, T.S., Sharara, R.S., Singh, A.C. and Balaan, M. (2016) Pathophysiology and Classification of Respiratory Failure. *Critical Care Nursing Quarterly*, **39**, 85-93. https://doi.org/10.1097/cnq.0000000000000102

[2] Papazian, L., Pauly, V., Hamouda, I., Daviet, F., Orleans, V., Forel, J., *et al.* (2021) National Incidence Rate and Related Mortality for Acute Respiratory Distress Syndrome in France. *Anaesthesia Critical Care & Pain Medicine*, **40**, Article ID: 100795. https://doi.org/10.1016/j.accpm.2020.100795

[3] Kwizera, A., Nakibuuka, J., Nakiyingi, L., Sendagire, C., Tumukunde, J., Katabira, C., *et al.* (2020) Acute Hypoxaemic Respiratory Failure in a Low-Income Country: A Prospective Observational Study of Hospital Prevalence and Mortality. *BMJ Open Respiratory Research*, **7**, e000719. https://doi.org/10.1136/bmjresp-2020-000719

[4] Han, S. and Mallampalli, R.K. (2015) The Acute Respiratory Distress Syndrome: from Mechanism to Translation. *The Journal of Immunology*, **194**, 855-860. https://doi.org/10.4049/jimmunol.1402513

[5] Daniel, W., Oliver, D., Tommaso, M., Saskia von, S., Ignacio, I.L., Mirja, M., *et al.* (2021) SARS-CoV-2 Infection Triggers Profibrotic Macrophage Responses and Lung Fibrosis. *Cell*, **184**, 6243-6261.e27.

[6] Kaye, A.D., Okeagu, C.N., Pham, A.D., Silva, R.A., Hurley, J.J., Arron, B.L., *et al.* (2021) Economic Impact of COVID-19 Pandemic on Healthcare Facilities and Systems: International Perspectives. *Best Practice & Research Clinical Anaesthesiology*, **35**, 293-306. https://doi.org/10.1016/j.bpa.2020.11.009

[7] Carrieri, V., De Paola, M. and Gioia, F. (2021) The Health-Economy Trade-Off during the Covid-19 Pandemic: Communication Matters. *PLOS ONE*, **16**, e0256103. https://doi.org/10.1371/journal.pone.0256103

[8] The ARDS Definition Task Force (2012) Acute Respiratory Distress Syndrome: The Berlin Definition. *JAMA*, **307**, 2526-2533.

[9] Dünser, M.W., Bataar, O., Tsenddorj, G., Lundeg, G., Torgersen, C., Romand, J., *et al*. (2008) Differences in Critical Care Practice between an Industrialized and a Developing Country. *Wiener Klinische Wochenschrift*, **120**, 600-607. https://doi.org/10.1007/s00508-008-1064-8

[10] Dondorp, A.M., Iyer, S.S. and Schultz, M.J. (2016) Critical Care in Resource-Restricted Settings. *JAMA*, **315**, 753-754. https://doi.org/10.1001/jama.2016.0976

[11] Navuluri, N., Srour, M.L., Kussin, P.S., Murdoch, D.M., MacIntyre, N.R., Que, L.G., *et al*. (2021) Oxygen Delivery Systems for Adults in Sub-Saharan Africa: A Scoping Review. *Journal of Global Health*, **11**, Article No. 04018. https://doi.org/10.7189/jogh.11.04018

[12] Chan, E.D., Chan, M.M. and Chan, M.M. (2013) Pulse Oximetry: Understanding Its Basic Principles Facilitates Appreciation of Its Limitations. *Respiratory Medicine*, **107**, 789-799. https://doi.org/10.1016/j.rmed.2013.02.004

[13] Shah, N., Sarangi, B.U., Shankar, G.H. and Walimbe, A. (2024) Comparison of PaO_2/FiO_2 (PF Ratio) to SpO_2/FiO_2 (SF Ratio) and OI to OSI for Predicting Short Term Outcomes in Children with Acute Hypoxemic Respiratory Distress: A Prospective Observational Study. *Indian Journal of Pediatrics*, **92**, 823-829. https://doi.org/10.1007/s12098-024-05134-w

[14] Riviello, E.D., Kiviri, W., Twagirumugabe, T., Mueller, A., Banner-Goodspeed, V.M., Officer, L., *et al*. (2016) Hospital Incidence and Outcomes of the Acute Respiratory Distress Syndrome Using the Kigali Modification of the Berlin Definition. *American Journal of Respiratory and Critical Care Medicine*, **193**, 52-59. https://doi.org/10.1164/rccm.201503-0584oc

[15] Michard, F. (2021) Cover Story: Oxygen Therapy.

[16] Pfurtscheller, T., Baker, K., Habte, T., Lasmi, K., Matata, L., Mucunguzi, A., *et al*. (2023) Usability of Pulse Oximeters Used by Community Health and Primary Care Workers as Screening Tools for Severe Illness in Children under Five in Low Resource Settings: A Cross-Sectional Study in Cambodia, Ethiopia, South Sudan, and Uganda. *PLOS Global Public Health*, **3**, e0001800. https://doi.org/10.1371/journal.pgph.0001800

[17] Michard, F., Shelley, K. and L'Her, E. (2020) COVID-19: Pulse Oximeters in the Spotlight. *Journal of Clinical Monitoring and Computing*, **35**, 11-14. https://doi.org/10.1007/s10877-020-00550-7

[18] Greenhalgh, T., Knight, M., Inada-Kim, M., Fulop, N.J., Leach, J. and Vindrola-Padros, C. (2021) Remote Management of Covid-19 Using Home Pulse Oximetry and Virtual Ward Support. *BMJ*, **372**, n677. https://doi.org/10.1136/bmj.n677

[19] Kallstrom, T.J. (2002) Oxygen Therapy for Adults in the Acute Care Facility—2002 Revision & Update. *Respiratory Care*, **47**, 717-720. https://doi.org/10.1177/002013240204700618

[20] Becker, D.E., Rosenberg, M.B. and Phero, J.C. (2014) Essentials of Airway Management, Oxygenation, and Ventilation: Part 1: Basic Equipment and Devices. *Anesthesia Progress*, **61**, 78-83. https://doi.org/10.2344/0003-3006-61.2.78

[21] World Health Organization (2011) Pulse Oximetry Training Manual [Internet]. https://cdn.who.int/media/docs/default-source/patient-safety/pulse-oximetry/who-ps-pulse-oxymetry-training-manual-en.pdf?sfvrsn=322cb7ae_6

[22] World Health Organization (2010) Arterial Blood Sampling. In: WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy [Internet]. https://www.ncbi.nlm.nih.gov/books/NBK138661/

[23] Collins, J., Rudenski, A., Gibson, J., Howard, L. and O'Driscoll, R. (2015) Relating Oxygen Partial Pressure, Saturation and Content: The Haemoglobin-Oxygen Dissociation Curve. *Breathe*, **11**, 194-201. https://doi.org/10.1183/20734735.001415

[24] Hulley, S.B. (2013) Designing Clinical Research. 4th Edition, Wolters Kluwer/Lippincott Williams & Wilkins.

[25] Gowri, M. and Babu, S. (2021) Association between SpO_2/FiO_2 Ratio and PaO_2/FiO_2 Ratio in Different Modes of Oxygen Supplementation. *Indian Journal of Critical Care Medicine*, **25**, 1001-1005. https://doi.org/10.5005/jp-journals-10071-23977

[26] Brown, S.M., Grissom, C.K., Moss, M., Rice, T.W., Schoenfeld, D., Hou, P.C., *et al*. (2016) Nonlinear Imputation of PaO_2/FiO_2 from SpO_2/FiO_2 among Patients with Acute Respiratory Distress Syndrome. *Chest*, **150**, 307-313. https://doi.org/10.1016/j.chest.2016.01.003

[27] Rice, T.W., Wheeler, A.P., Bernard, G.R., Hayden, D.L., Schoenfeld, D.A. and Ware, L.B. (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. https://doi.org/10.1378/chest.07-0617

[28] Schmidt, M.F.S., Gernand, J. and Kakarala, R. (2015) The Use of the Pulse Oximetric Saturation to Fraction of Inspired Oxygen Ratio in an Automated Acute Respiratory Distress Syndrome Screening Tool. *Journal of Critical Care*, **30**, 486-490. https://doi.org/10.1016/j.jcrc.2015.02.007

[29] Venegas Sosa, A.M.d.C., Cortés Munguía, J.A., Flores López, E.N. and Colín Rodríguez, J. (2018) Correlación de SpO_2/FiO_2 versus PaO_2/FiO_2 para monitoreo de la oxigenación en pacientes con trauma de tórax. *Medicina Crítica*, **32**, 201-207. https://doi.org/10.35366/ti184e

[30] Poor, H. (2018) Basics of Mechanical Ventilation. Springer, 132 p.

[31] Pandharipande, P.P., Shintani, A.K., Hagerman, H.E., St Jacques, P.J., Rice, T.W., Sanders, N.W., *et al*. (2009) Derivation and Validation of SpO_2/FiO_2 Ratio to Impute for PaO_2/FiO_2 Ratio in the Respiratory Component of the Sequential Organ Failure Assessment Score. *Critical Care Medicine*, **37**, 1317-1321. https://doi.org/10.1097/ccm.0b013e31819cefa9

[32] Carvalho, E.B.d., Leite, T.R.S., Sacramento, R.F.d.M., Nascimento, P.R.L.d., Samary, C.d.S., Rocco, P.R.M., *et al*. (2022) Rationale and Limitations of the SpO_2/FiO_2 as a Possible Substitute for PaO_2/FiO_2 in Different Preclinical and Clinical Scenarios. *Revista Brasileira de Terapia Intensiva*, **34**, 185-196. https://doi.org/10.5935/0103-507x.20220013-en

Appendix

Supplementary Table A1. Conversion Table for FiO_2 when on mask.

100 % O_2 flow rate (L/min)	FiO_2 (%)
Oxygen Mask	
5 - 6	40
6 - 7	50
7 - 8	60
9	90
10	99+
Mask with Reservoir Bag	
6	60
7	70
8	80

Supplementary Table A2. Disaggregated SF-ratio predictions across oxygen delivery modes.

			PF Ratio		
Mode of O_2 Delivery	**Regression Equation (lnscale)**	**N**	**100**	**200**	**300**
			SF Ratio Estimates		
Ambient Air	ln (SF) = 4.100421 + 0.3393968·ln (PF)	32	288	364	418
Nasal cannula	ln (SF) = 4.476567 + 0.2332743·ln (PF)	50	257	303	333
Venturi mask	ln (SF) = 2.549162 + 0.5598186·ln (PF)	7	169	248	312
Non-breathable mask	ln (SF) = 2.550275 + 0.4906502·ln (PF)	51	123	172	210