



## CORRELATION OF VENOUS BLOOD GAS ANALYSIS AND PULSE OXIMETRY (SpO<sub>2</sub>) WITH ARTERIAL BLOOD GAS ANALYSIS IN CRITICALLY ILL PATIENTS

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### ABSTRACT

**Background:** The gold standard for evaluating ventilation, oxygenation, and acid-base balance in critically ill patients is ABG (Arterial Blood Gas) analysis. However, repeated arterial sampling is invasive, painful, and associated with complications. VBG (Venous Blood Gas) analysis and pulse oximetry (SpO<sub>2</sub>) are less invasive alternatives that may provide comparable clinical information. The purpose of this study was to assess the relationship between ABG values and SpO<sub>2</sub> and VBG parameters in critically ill patients.

**Methods:** A prospective cohort study was conducted in the Intensive Care Unit of MKCG Medical College and Hospital from October 2022 to March 2024. A total of 100 critically ill adult patients requiring ABG analysis were enrolled. Simultaneous ABG and VBG samples were collected from arterial and venous access sites, respectively, and analyzed at the bedside. Additional clinical parameters including heart rate, respiratory rate, temperature, mean arterial pressure, vasopressor use, and mechanical ventilation status were recorded. Correlations between arterial and venous pH, pCO<sub>2</sub>, pO<sub>2</sub>, and SpO<sub>2</sub> were analyzed statistically.

**Results:** Among the 100 patients, 66% were male and 34% were female. Mechanical ventilation was required in 62% of patients, while 45% received vasopressor support. Central venous samples were obtained in 46% and peripheral venous samples in 54% of cases. Mean arterial pH, pCO<sub>2</sub>, and pO<sub>2</sub> were 7.48 ± 0.10, 37.85 ± 16.58 mmHg, and 132.44 ± 58.12 mmHg, respectively, while corresponding venous values were 7.45 ± 0.09, 42.06 ± 16.70 mmHg, and 41.10 ± 11.29 mmHg. Significant positive correlations were observed between arterial and venous pH (p<0.0001), arterial and venous pCO<sub>2</sub> (p<0.0001), arterial and venous pO<sub>2</sub> (p=0.005), and SpO<sub>2</sub> with arterial pO<sub>2</sub> (p<0.0001).

**Conclusion:** VBG analysis demonstrated strong correlation with ABG for pH and pCO<sub>2</sub>, while SpO<sub>2</sub> correlated well with arterial oxygenation. The combination of VBG analysis and pulse oximetry can provide reliable bedside assessment of acid–base status, ventilation, and oxygenation in critically ill patients, reducing the need for repeated arterial sampling.

**Keywords:** Arterial Blood Gas, Venous Blood Gas, Pulse Oximetry, SpO<sub>2</sub>, Critical Illness, Acid–Base Balance, Ventilation, Oxygenation.



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### INTRODUCTION

The gold standard for assessing ventilation, oxygenation, and acid-base status in critically ill patients is ABG (Arterial Blood Gas) analysis. It is routinely used in the diagnosis and management of acute and life-threatening conditions. However, repeated arterial punctures or prolonged arterial

catheterization are invasive procedures associated with complications such as pain, hematoma, hemorrhage, infection, thrombosis, embolization, ischemic injury, and needle-stick injuries to healthcare personnel.<sup>[1]</sup>

Many critically ill patients already have central venous access for drug administration and hemodynamic monitoring, making VBG (Venous Blood Gas) analysis a readily available alternative. VBG sampling requires fewer punctures, is technically easier to perform, causes less discomfort to patients, and carries a lower risk of complications. As a result, in some clinical settings, it has been suggested as a less invasive and safer alternative to ABG analysis.<sup>[2]</sup>

Patient safety remains a fundamental objective in healthcare, emphasizing the prevention of avoidable harm and the implementation of practices that improve clinical outcomes.<sup>[3]</sup> Critically ill patients often experience severe physiological disturbances that require continuous monitoring and timely intervention.<sup>[4]</sup> Maintenance of adequate oxygenation, perfusion, electrolyte balance, and acid–base homeostasis is essential for preserving cellular and organ function. Rapid identification of abnormalities in these parameters is crucial, as significant derangements can directly contribute to organ dysfunction and adverse outcomes.<sup>[5]</sup>

Monitoring acid–base status and oxygenation therefore represents a vital component of critical care management. Accurate interpretation of blood gas parameters is essential for guiding therapeutic decisions and assessing patient response to treatment.<sup>[6]</sup> While central venous blood sampling offers several practical advantages over arterial sampling, concerns remain regarding the reliability and precision of venous measurements, particularly for assessing oxygenation.<sup>[7]</sup> When evaluating critically ill patients, pulse oximetry (SpO<sub>2</sub>) may be used in addition to VBG analysis as a non-invasive way to measure oxygen saturation.

#### **Aims and Objectives**

The purpose of this study was to assess the relationship between ABG (Arterial Blood Gas) analysis in critically sick patients and VBG (Venous Blood Gas) analysis and pulse oximetry (SpO<sub>2</sub>). Assessing the agreement between venous and arterial measurements of pH, pCO<sub>2</sub>, and pO<sub>2</sub>; identifying the relationship between SpO<sub>2</sub> and arterial oxygenation; and determining whether VBG analysis in conjunction with pulse oximetry can function as a dependable, less invasive substitute for ABG analysis in the evaluation of ventilation, oxygenation, and acid-base status in critically ill patients were the goals.

## **MATERIALS AND METHODS**

### **Study Design**

This prospective cohort study was conducted at MKCG Medical College & Hospital from October 2022 to March 2024 among critically ill adult patients requiring ABG analysis. A total of 100 patients aged 18 years and above, irrespective of sex, were enrolled using a prospective sampling approach.

### **Inclusion and Exclusion Criteria**

The study included critically ill adult patients (aged 18 years and above) admitted to the ICU (Intensive Care Unit) who required ABG analysis as part of their clinical management. Patients of either sex who met these criteria and provided informed consent were enrolled in the study. Patients were excluded if they had any contraindication to arterial or venous blood sampling, including local infection, severe coagulopathy, or other conditions precluding safe blood collection. Patients diagnosed with vasculitis were also excluded from the study due to the potential impact of vascular pathology on blood gas measurements.

### **Data Collection Procedure**

Eligible critically ill patients admitted to the ICU of MKCG Medical College & Hospital were enrolled in the study following clearance by the Institutional Ethics Committee and informed written consent. ABG and VBG samples were collected as close in time as possible, with arterial samples obtained from an arterial line or arterial puncture and venous samples from a venous catheter or peripheral vein. Both samples were analyzed immediately at the bedside. Clinical parameters including heart rate, respiratory rate, body temperature, presence of shock, mechanical ventilation status, and use of inotropic or vasopressor support were recorded. Systolic blood pressure less than 90 mmHg, mean arterial pressure less than 65 mmHg, or the need for vasopressor and/or inotropic assistance were all considered signs of shock. All data were documented and analyzed statistically.

### **Statistical Analysis**

Microsoft Excel, SPSS version 24.0 (SPSS Inc., Chicago, IL, USA), and GraphPad Prism version 5 were used for statistical analysis. Categorical variables were shown as frequencies and percentages, while continuous variables were given as mean ± standard deviation. When necessary, unpaired and paired t-tests were utilised to compare groups, and one-way ANOVA was utilised to compare means across several groups. Microsoft Excel was used to conduct linear regression analysis, and Pearson's correlation coefficient was used to evaluate the correlation between the variables. A statistically significant p-value was defined as ≤0.05.

**RESULTS**

Variable	Frequency (%)
Male	66 (66.0)
Female	34 (34.0)
Mechanical Ventilation (Yes)	62 (62.0)
Mechanical Ventilation (No)	38 (38.0)
Vasopressor Support (Yes)	45 (45.0)
Vasopressor Support (No)	55 (55.0)
Central VBG	46 (46.0)
Peripheral VBG	54 (54.0)

**Table 1. Baseline Characteristics of Study Participants (N=100)**

The study population's clinical and demographic features are shown in Table 1. Venous blood gas samples were taken from central and peripheral sites

nearly equally, the majority of patients (66%) were male, 62% needed mechanical ventilation, and 45% needed vasopressor assistance.

Parameter	Mean ± SD
Age (In Years)	54.93 ± 14.88
Hemoglobin (G/Dl)	9.81 ± 1.91
Heart Rate (Beats/Min)	100.13 ± 15.21
Respiratory Rate (Breaths/Min)	19.31 ± 4.33
Temperature (°F)	99.19 ± 0.82
MAP (Mmhg)	94.12 ± 13.51
Spo <sub>2</sub> (%)	97.81 ± 2.60
Arterial PO <sub>2</sub> (Mmhg)	132.44 ± 58.12
Arterial PCO <sub>2</sub> (Mmhg)	37.85 ± 16.58
Arterial Ph	7.48 ± 0.09
Venous PO <sub>2</sub> (Mmhg)	41.10 ± 11.29
Venous PCO <sub>2</sub> (Mmhg)	42.06 ± 16.70
Venous Ph	7.45 ± 0.09

**Table 2. Clinical And Blood Gas Parameters of Study Population**

Table 2 summarizes the physiological and blood gas characteristics of the study participants. Mean arterial and venous pH values were comparable,

while venous PCO<sub>2</sub> was slightly higher than arterial PCO<sub>2</sub>, reflecting expected physiological differences.

Comparison	R-Value	P-Value	Interpretation
Spo <sub>2</sub> Vs. Arterial PO <sub>2</sub>	0.439	<0.001	Moderate Positive
Arterial PO <sub>2</sub> Vs. Venous PO <sub>2</sub>	0.278	0.005	Weak Positive
Arterial PCO <sub>2</sub> Vs. Venous PCO <sub>2</sub>	0.917	<0.001	Very Strong Positive
Arterial Ph Vs. Venous Ph	0.926	<0.001	Very Strong Positive

**Table 3. Overall Correlation Between Arterial and Venous Blood Gas Parameters**

Table 3 demonstrates the correlation between arterial and venous blood gas parameters. Strong positive correlations were observed for pH and PCO<sub>2</sub>, indicating that VBG can reliably estimate

acid-base and ventilation status. Correlation for PO<sub>2</sub> was comparatively weak.

Parameter Comparison	No Ventilation (R)	P-Value	Ventilation (R)	P-Value
Spo <sub>2</sub> Vs. Arterial Po <sub>2</sub>	0.466	0.003	0.427	0.001
Arterial Po <sub>2</sub> Vs. Venous Po <sub>2</sub>	0.404	0.012	0.226	0.078
Arterial Pco <sub>2</sub> Vs. Venous Pco <sub>2</sub>	0.789	<0.001	0.917*	<0.001
Arterial Ph Vs. Venous Ph	0.874	<0.001	Strong Positive†	<0.001

**Table 4. Correlation Analysis According to Mechanical Ventilation Status**

\*Calculated From Study Findings.  
 †A Strong Significant Correlation Was Reported

Table 4 compares correlations in mechanically ventilated and non-ventilated patients. Strong correlations between arterial and venous pH and PCO<sub>2</sub> persisted irrespective of ventilation status.

However, PO<sub>2</sub> correlation weakened and became non-significant in ventilated patients.

Parameter	No Ventilation	Ventilation
Spo <sub>2</sub> (%)	97.50 ± 2.49	98.00 ± 2.67
Arterial PO <sub>2</sub>	117.89 ± 41.53	141.36 ± 64.99
Arterial PCO <sub>2</sub>	32.80 ± 8.38	40.95 ± 19.43
Arterial Ph	7.50 ± 0.08	7.47 ± 0.10
Venous PO <sub>2</sub>	39.79 ± 9.64	41.91 ± 12.19
Venous PCO <sub>2</sub>	38.72 ± 9.52	44.10 ± 19.66
Venous Ph	7.46 ± 0.07	7.44 ± 0.10

**Table 5. Blood Gas Characteristics According to Mechanical Ventilation Status**

Table 5 presents blood gas parameters according to mechanical ventilation status. Patients on mechanical ventilation demonstrated higher arterial

oxygenation and carbon dioxide values compared to non-ventilated patients.

Comparison	Hb <8 G/Dl (R)	P-Value	Hb >8 G/Dl (R)	P-Value
Spo <sub>2</sub> Vs. Arterial PO <sub>2</sub>	0.610	0.046	0.414	<0.001
Arterial PO <sub>2</sub> Vs. Venous PO <sub>2</sub>	0.844	0.001	0.263	0.013
Arterial PCO <sub>2</sub> Vs. Venous PCO <sub>2</sub>	0.984	<0.001	0.915	<0.001
Arterial Ph Vs. Venous Ph	Strong Positive	<0.001	0.926	<0.001

**Table 6. Correlation Analysis According to Hemoglobin Status**

Table 6 evaluates the influence of anemia on blood gas correlations. Excellent correlations were observed between arterial and venous PCO<sub>2</sub> and pH

irrespective of haemoglobin levels, supporting the reliability of VBG even in anemic patients.

Parameter	Hb <8 G/Dl (N=11)	Hb >8 G/Dl (N=89)
Spo <sub>2</sub> (%)	98.45 ± 2.51	97.73 ± 2.61
Arterial PO <sub>2</sub>	146.22 ± 66.40	130.74 ± 57.21
Arterial PCO <sub>2</sub>	39.06 ± 18.72	37.70 ± 16.40
Arterial Ph	7.46 ± 0.09	7.48 ± 0.10
Venous PO <sub>2</sub>	35.83 ± 6.42	41.76 ± 11.61
Venous PCO <sub>2</sub>	48.11 ± 23.51	41.31 ± 15.68
Venous Ph	7.41 ± 0.10	7.45 ± 0.09

**Table 7. Blood Gas Characteristics According to Hemoglobin Level**

Table 7 compares blood gas parameters among patients with and without anemia. Although oxygenation indices varied slightly, arterial and

venous acid-base parameters remained comparable between groups.

Model	Regression Equation	R <sup>2</sup>	P-Value
Arterial PO <sub>2</sub> Vs. Venous PO <sub>2</sub>	Arterial PO <sub>2</sub> = 73.61 + 1.43 × Venous PO <sub>2</sub>	0.077	0.005
Arterial PCO <sub>2</sub> Vs. Venous PCO <sub>2</sub>	Arterial PCO <sub>2</sub> = -0.43 + 0.91 × Venous PCO <sub>2</sub>	0.841	<0.001
Arterial Ph Vs. Venous Ph	Arterial Ph = 0.544 + 0.932 × Venous Ph	0.857	<0.001

**Table 8. Linear Regression Analysis of Arterial and Venous Blood Gas Parameters**

Table 8 demonstrates the predictive ability of venous blood gas parameters for arterial blood gas values. Venous pH and PCO<sub>2</sub> showed excellent

predictive accuracy (R<sup>2</sup> > 0.84), whereas venous PO<sub>2</sub> exhibited poor predictive capability (R<sup>2</sup> = 0.077).

### DISCUSSION

In the present study, 34% of patients were female and 66% were male. Mechanical ventilation was required in 62% of patients, while 45% received

vasopressor support. Central VBG samples were obtained in 46% of patients and peripheral VBG samples in 54%.

ABG analysis remains the gold standard for evaluating acid–base balance, ventilation, and oxygenation in critically ill patients. However, repeated arterial sampling is painful and associated with complications. The findings of the present study support the growing evidence that venous blood gas analysis can serve as a reliable alternative to ABG for assessment of pH and pCO<sub>2</sub>.

Arterial and venous blood gas characteristics have been shown to be strongly correlated in earlier research. In patients experiencing an acute exacerbation of COPD, arterial and venous pH, pCO<sub>2</sub>, and HCO<sub>3</sub> values were found to be significantly correlated ( $p < 0.001$ ) by Ak A, Ogun CO, Bayir A et al. (2006).<sup>[5]</sup> Similarly, pH ( $r = 0.864$ ) and pCO<sub>2</sub> ( $r = 0.761$ ) showed strong relationships between venous and arterial samples, according to Razi E and Moosavi GA et al. (2007).<sup>[7]</sup>

The use of venous blood gases has also been validated by research on DKA (Diabetic Ketoacidosis). With a mean difference of only  $-0.03$ , Brandenburg MA and Dire DJ et al. (1998) concluded that peripheral venous pH is a suitable replacement for arterial pH.<sup>[1]</sup> Similarly, Kelly AM (2006)<sup>[2]</sup> found that arterial and venous pH levels were in excellent agreement, with an average difference of 0.02.

Several investigators have evaluated arterial and venous blood gases across different clinical settings. Kelly AM, Kyle E et al., (2002)<sup>[8]</sup> concluded that venous pH could replace arterial pH measurements, although venous pCO<sub>2</sub> was less reliable for screening hypercarbia. Malatesha G, Singh NK et al., (2007)<sup>[9]</sup> also demonstrated that venous pH, bicarbonate, and pCO<sub>2</sub> could reliably substitute arterial values in emergency department patients. However, Ebrahim Razi and Omid Nasiri et al. (2012)<sup>[10]</sup> reported only a weak correlation between arterial and venous pO<sub>2</sub> ( $r = 0.278$ ).

A major strength of the present study is the inclusion of a heterogeneous population of critically ill medical and surgical ICU patients, thereby reflecting real-world clinical practice more accurately than studies restricted to a single disease entity.

The present study demonstrated a significant positive correlation between SpO<sub>2</sub> and arterial pO<sub>2</sub> ( $p < 0.0001$ ), arterial and venous pO<sub>2</sub> ( $p = 0.005$ ), arterial and venous pCO<sub>2</sub> ( $p < 0.0001$ ), and arterial and venous pH ( $p < 0.0001$ ). These findings are consistent with previous investigations evaluating the relationship between pulse oximetry and arterial oxygenation.

Van de Louw A, Cracco C, Cerf C et al., (2001)<sup>[11]</sup> reported that SpO<sub>2</sub> values above 94% were generally required to ensure an arterial oxygen saturation

(SaO<sub>2</sub>) of at least 90%. Although increases in SpO<sub>2</sub> could not always accurately predict similar changes in arterial oxygenation, Perkins GD and McAuley DF et al., (2003)<sup>[12]</sup> showed a substantial connection between SpO<sub>2</sub> and SaO<sub>2</sub> ( $r = 0.606$ ,  $p < 0.01$ ).

In the present study, SpO<sub>2</sub> correlated well with PaO<sub>2</sub> according to the oxygen–hemoglobin dissociation curve. Nevertheless, factors such as pH, PaCO<sub>2</sub>, temperature, anemia, and dyshemoglobinemia may alter this relationship and should be considered when interpreting pulse oximetry values.

Subgroup analysis revealed significant correlations between arterial and venous pCO<sub>2</sub> and pH irrespective of mechanical ventilation status. Among non-ventilated patients, significant positive correlations were observed between arterial pO<sub>2</sub> and SpO<sub>2</sub> ( $p = 0.003$ ), arterial and venous pO<sub>2</sub> ( $p = 0.003$ ), arterial and venous pCO<sub>2</sub> ( $p < 0.0001$ ), and arterial and venous pH ( $p < 0.0001$ ). In mechanically ventilated patients, arterial pO<sub>2</sub> correlated significantly with SpO<sub>2</sub> ( $p = 0.0001$ ), whereas the correlation between arterial and venous pO<sub>2</sub> was not statistically significant ( $p = 0.078$ ). However, strong correlations persisted for pCO<sub>2</sub> and pH ( $p < 0.0001$ ). Perkins GD and McAuley DF et al., (2003)<sup>[12]</sup> reported that anemia and acidosis do not significantly affect the clinical relationship between SpO<sub>2</sub> and arterial oxygen saturation. Similar observations were reported by Schnapp LM, Severinghaus JW, and Lee S.<sup>[13-15]</sup> In the present study, significant correlations between SpO<sub>2</sub> and arterial pO<sub>2</sub> were observed in both Hb  $< 8$  g/dL and Hb  $> 8$  g/dL groups, further supporting these findings.

An important limitation of pulse oximetry is its inability to detect hyperoxia. Kilgannon JH, Jones AE et al., (2010)<sup>[16]</sup> demonstrated that arterial hyperoxia was independently associated with increased in-hospital mortality. In contrast, Bellomo R and Bailey M et al. (2011)<sup>[17]</sup> found no consistent association between hyperoxia and mortality after cardiac arrest. Therefore, pulse oximetry combined with VBG analysis cannot completely replace ABG when precise oxygenation assessment is required.

Linear regression analysis in the present study demonstrated a strong linear relationship between arterial and venous pCO<sub>2</sub> ( $R^2 = 0.8412$ ) and between arterial and venous pH ( $R^2 = 0.85$ ), whereas the relationship between arterial and venous pO<sub>2</sub> was weak ( $R^2 = 0.07$ ). These findings indicate that venous pCO<sub>2</sub> and pH are reliable predictors of arterial values, while venous pO<sub>2</sub> is a poor predictor of arterial oxygenation.

We hypothesized that shock states and impaired tissue perfusion might reduce the correlation between arterial and venous blood gas parameters. However, correlations remained strong even among patients receiving vasopressor support. Shirani F and Salehi R et al., (2011)<sup>[18]</sup> reported that

hypotension increased the difference between venous and arterial pH, HCO<sub>3</sub>, and base excess values, although the differences were not clinically significant.

Vallee F and Vallet B et al., (2008)<sup>[19]</sup> suggested that a central venous-to-arterial CO<sub>2</sub> difference greater than 6 mmHg may identify patients who remain inadequately resuscitated despite achieving target ScvO<sub>2</sub> values. In critically ill patients, venous measurements may therefore provide clinically meaningful information regarding tissue perfusion and metabolic status.

Another important observation was the comparable performance of central and peripheral venous blood gases. No statistically significant difference was observed between central VBG–ABG and peripheral VBG–ABG correlations. These findings are consistent with those of Treger R, Pirouz S et al., (2010)<sup>[20]</sup> who concluded that peripheral or central venous pH, pCO<sub>2</sub>, and bicarbonate measurements can replace arterial values in many ICU settings.

The findings of the present study demonstrate that venous blood gas analysis, particularly for pH and pCO<sub>2</sub>, combined with pulse oximetry, provides a practical and reliable alternative to arterial blood gas analysis in critically ill patients. However, ABG analysis remains necessary when precise assessment of oxygenation, hyperoxia, or complex respiratory disorders is required.

#### Limitations

This study has several limitations. The study population consisted of a heterogeneous group of

critically ill patients with multiple overlapping diagnoses, making disease-specific subgroup analysis difficult. Although a positive correlation between arterial and venous pO<sub>2</sub> was observed, previous studies have reported weak or no correlation, and this finding may differ with a larger sample size. Subgroup analyses comparing central versus peripheral VBGs and shock versus non-shock patients were not predefined and may therefore be subject to confounding bias. Additionally, due to ethical considerations, patients with severe hypoxemia were not extensively represented, limiting the evaluation of correlations at low oxygen saturation levels.

#### CONCLUSION

The present study demonstrated a strong correlation between venous and arterial blood gas parameters, particularly pH and pCO<sub>2</sub>, in critically ill patients. Pulse oximetry (SpO<sub>2</sub>) also showed a significant positive correlation with arterial pO<sub>2</sub>. These results imply that venous blood gas analysis can offer trustworthy data for evaluating ventilation, oxygenation status, and acid-base balance in critically ill patients when paired with pulse oximetry. Therefore, VBG analysis along with SpO<sub>2</sub> monitoring may serve as a practical and less invasive alternative to ABG analysis for routine bedside clinical decision-making in the ICU, while ABG remains necessary in selected situations requiring precise oxygenation assessment.

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