

Correlation of Mean pH, HCO₃ and CO₂ Between Arterial Blood Gases and Venous Blood Gases in Critically Ill Patients

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ABSTRACT

Objective: To determine the correlation of mean pH, HCO₃ and CO₂ between arterial and venous blood specimens in critically ill patients.

Study Design: Cross-sectional study.

Place and Duration of Study: Department of Chemical Pathology and Endocrinology, Armed Forces Institute of Pathology (AFIP), Rawalpindi, from Apr to Oct 2015.

Methodology: Forty critically ill patients admitted to the Intensive Care Unit were selected. Analysis of arterial blood gases followed by venous blood gases of the same patient was carried out after collection in lithium heparin tubes. Specimens were analyzed on COBAS 221 fully automated ABGs and an electrolyte analyzer.

Results: Out of 40 patients, 30 (75%) were males. The average age was 57.78±7.64 years. The p-value of pH and HCO₃ was 0.259 and 0.921, respectively. The CO₂ in VBGs was 58.10±11.35 mm Hg versus 36.32±6.69 mm Hg in ABG, with a p-value of 0.001, which was statistically significant.

Conclusion: In critically ill patients, pH and HCO₃ levels of venous blood gases were comparable with ABG. VBG CO₂ was significantly higher than ABGs.

Keywords: Arterial blood gases, Critically ill patients, Venous blood gases.

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INTRODUCTION

Blood gas estimation is a very important tool in diagnosing acid-base imbalance and respiratory function in patients admitted to the emergency department.¹ Therefore, arterial blood gas (ABG) samples are collected to determine these patients' acid-base and oxygenation status.²

Arterial blood samples are considered the gold standard for ABG estimation. Still, it has drawbacks like painful arterial puncture, vascular and nerve injury, need for technical skills and expensive procedures.^{2,3}

Peripheral venous blood analysis is considered an alternative to arterial blood gas analysis. It is hence considered to be used as a substitute for the accurate assessment of acid-base status. However, comparability in different parameters of the two is still not established. Therefore, studies are being carried out on peripheral venous blood sampling as an alternative to arterial blood sampling.⁴ The use of venous blood sampling has an advantage over arterial blood as it is easier to draw, less painful, and has fewer

complications.¹

Studies have shown venous blood gas analysis as a good alternative to arterial blood gas analysis in many clinical situations like Diabetic ketoacidosis, chronic respiratory failure, Uremic acidosis, and patients on mechanical ventilation.^{5,6}

Studies showed a strong correlation between arterial pH, CO₂, and HCO₃ and venous blood in patients in the emergency department and intensive care unit. However, despite that, there is meagre data related to these values between arterial and venous samples of critically ill patients.⁷

Despite the good correlation of results of VBGs with that of ABGs, only 80% of paired samples are equivalent to VBG, and the remaining are widely unacceptable. So ABGs samples are preferably collected in seriously ill trauma patients if the clinician wants to know the accurate acid-base status.⁶

Apart from showing similar systemic differences (bias) between arterial and venous blood, it was concluded that the reliability and accuracy of VBGs are not comparable.²

However, there are studies which showed the increase of systemic differences in arterial and venous blood analysis in conditions with decreased peripheral

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tissue perfusion. Therefore, in hypotension, the correlation between arterial and venous blood values appeared to be weak.^{8,9}

As some researchers strongly suggest VBG estimation over ABG, while others concluded otherwise due to the weak correlation of blood parameters,⁸ hence this study was designed to determine the correlation of mean pH, HCO₃ and CO₂ between arterial and venous blood specimens in critically ill patients and also to assess whether venous blood gas estimation can be preferred over ABG estimation.

METHODOLOGY

The cross-sectional study was conducted from April to October 2015 at the Department of Chemical Pathology and Endocrinology, Armed Forces Institute of Pathology (AFIP), Rawalpindi Pakistan. The study was conducted after approval by the Ethical Committee of the institute. The sample size of fifty samples was calculated with the help of the WHO calculator with expected ABG PCO₂ 29.20±6.72 Vs VBG PCO₂ 34.90±7.50.³

Inclusion Criteria: Sample of patients of both gender aged >12 to 60 years admitted to the Intensive Care Units and advised ABGs by their treating physicians were included in the study, through non-probability consecutive sampling technique.

Exclusion Criteria: Nil.

Informed consent was taken by the attendants of all critically ill unconscious patients. Relevant demographics, identification number, age and gender were entered in a specific proforma. ABGs and VBGs were collected simultaneously and analysed in the Chemical Pathology and Endocrinology Department of AFIP. 2.5ml of blood was collected from each subject in a properly labelled Lithium heparin tube (a heparinized syringe was also used) for ABGs and VBGs. The blood samples were transported in ice packs to the laboratory within 15 minutes of the sample collection. Analysis of arterial blood gases followed by venous blood gases was carried out as soon as the specimen was received in the laboratory.

ABGs and VBGs were analyzed on COBAS 221 fully automated ABGs and electrolyte analyzer utilizing Ion selective electrode method using Roche calibrator, controls, kits and reagents. The pathologist verified the results. Statistical Package for Social Sciences (SPSS) version 20:00 was used for the data analysis. Qualitative variables like gender were presented as frequencies and percentages. Mean, and SD

were calculated for all quantitative variables like age, pH, HCO₃ and CO₂. The pH, CO₂ and HCO₃ between arterial and venous blood gases were compared. Pearson correlation test was used to calculate the significance of descriptive data. An independent sample t-test was used for quantitative data. The *p*-value of ≤ 0.05 was considered significant.

RESULTS

Samples of 50 critically ill patients were included in our study. Thirty patients (75%) were males. However, ten samples were not included for analysis due to incomplete data. The average age of the study population was 57.78±7.64 years (Table-I).

Table-I: Descriptive Statistics (n=40)

Parameters	Frequency (%)
Age (years)	
Mean ± SD	57.78±7.64
Male	30 (75)
Female	10 (25)

The mean pH for ABGs was 7.38±0.12, and for VBGs, 7.39±0.10. The mean HCO₃⁻ for ABGs was 23.08±3.94 versus 24.46±4.16 mmol/L for VBGs. For pCO₂, the mean for ABGs was 36.32±6.69 and for VBGs 58.14±11.35 with a *p*-value of 0.001, which was statistically significant (Table-II).

Table-II: Mean Comparison of pH, CO₂ and HCO₃ between Arterial Blood Gases (ABGs) and Venous Blood Gases (VBGs) (n=40)

Parameters	Arterial Blood Gases (ABGs) (Mean± SD)	Venous Blood Gases (VBGs) (Mean±SD)	<i>p</i> -value
pH	7.38±0.12	7.39±0.10	0.259
CO ₂	36.32±6.69	58.14±11.35	0.001
HCO ₃	23.08±3.94	24.46±4.16	0.921

Pearson correlation test was applied, which showed a good correlation of ApH and VpH for gender with a *p*-value of 0.001 (Table-III).

Table-III: Correlation between Arterial pH and Venous pH as per Gender (n=40)

Gender	r-value	<i>p</i> -value
Male	0.729	0.001
Female	0.868	0.001

In contrast, a strong correlation was found between AHCO₃ and VHCO₃ with respect to age age with a *p*-value of 0.0001 (Table-IV).

DISCUSSION

Traditionally ABGs are being analyzed to determine the acid-base and oxygenation status of seriously

ill patients with different clinical conditions, including respiratory and metabolic disorders. Despite its usefulness, it offers complications which are very common because of needle pricks like bleeding, infection, blood vessel injury and nerve injury in arterial blood sampling. Blood gas analysis is also at risk of errors caused by improperly collected samples, transport and unacceptable conditions for storage.¹⁰

Table-IV: Correlation between Arterial HCO₃ and Venous HCO₃ as per Age Groups (n=40)

Age (years)	r-value	p-value
37-60 years	0.699	<0.001
61-73 years	0.946	<0.001

Additionally, arterial puncture causes more pain and needs more technical skills than venous sampling. For the last many years, researchers have been putting their efforts into searching for an alternative procedure to arterial puncture. In recent years, studies have shown that pH, HCO₃, and CO₂ analyzed in arterial blood correlate well with the values of the same parameters in venous blood. Although venous sampling is easy for sample collection, its procedure is less painful for patients and blood for other laboratory investigations can also be drawn simultaneously.¹¹

VBGs, as an alternative to ABGs testing, can be used as a substitute. However, comparability in different parameters of the two is still not well established. Nevertheless, studies have shown VBGs testing as a good alternative to ABGs testing in many critical situations like Diabetic ketoacidosis, Chronic respiratory failure, Uremic acidosis, and patients on mechanical ventilation.^{6,12}

Findings of this study demonstrated that VBG values like CO₂, HCO₃ and pH levels have a relatively good correlation with ABG values (r<0.001), Preference for venous blood sampling over arterial sampling can be considered if it can reveal the accurate status of patient's acid-base status and help in proper management. For this evaluation, various studies have been done on adults and children, showing a strong correlation between arterial pH, Carbon dioxide, and HCO₃ with blood collected from veins.^{8,12}

A study on 100 patients with respiratory or cardiac disorders revealed a high correlation between venous and arterial samples. Arterial and venous pH showed significant correlation (r=0.88) with strong correlation for CO₂ (r=0.92), however HCO₃ was poorly correlated with r=0.32 in their study.¹³

In the present study, the correlation of pH, CO₂ and HCO₃ was 0.783, 0.561 and 0.812, respectively, showing good but less correlation because r<0.90. The reason for less correlation of CO₂ is generally higher PCO₂ in venous blood compared to arterial blood. Hence, for accurate estimation of CO₂ in critical conditions, arterial sampling may be preferred.⁶ Another substantial difference between arterial and venous CO₂ levels was discussed in a systemic review in which they concluded that in circulatory failure patients, the difference between venous and arterial CO₂ was 4-times greater, giving poor correlation, while in hemodynamically stable patients, this difference is less.¹⁴ Hence this agrees with our finding of poor correlation of CO₂ levels in our critically ill patients.

Another meta-analysis of 18 studies concluded that venous and arterial pH could be comparable, but that is not true for CO₂, thus corresponding to our findings. Furthermore, they found non-comparable values of CO₂ between arterial and venous sampling, therefore stating that venous CO₂ should not be considered if an accurate CO₂ value is required.⁵

Another study done by Masip *et al.* on patients with acute heart failure with pulmonary oedema revealed high correlation values between arterial and venous blood gases for pH and HCO₃ but somewhat lower for CO₂ at the time of admission of patients, thus corresponding to the findings of this study. They supported the use of venous sampling over arterial estimation.⁶

Apart from studies on adult patients, researchers have also assessed the validity of VBG for substituting ABG values in the pediatric population. Singh *et al.* collected samples from patients in paediatric ICU and, after analyzing them, found a good correlation between arterial and venous samples. In their study, a significant match was noted in pH (R=0.9544), CO₂ (R=0.8738), and HCO₃ (R = 0.9650) between ABG and VBG values.¹⁵

However, there are studies which showed the increase of systemic differences in ABGs and VBGs testing in conditions with decreased peripheral tissue perfusion. Hence, the correlation between arterial and venous values was weak.^{9,16} This shows that even arterial blood values may not show the actual acid-base status at the peripheral tissue levels when cardiac output is reduced. A recent study concluded the efficacy of venous sampling and pulse oximetry compared to ABG para-meters and found them useful for evaluating blood gases in many clinical conditions. With

regard to this, screening and follow-up of patients may be facilitated with reduced chances of complications associated with arterial sampling.¹⁷

With recent advancements in equipment and devices, many studies recently carried out showed that newer systems may be more appropriate for seriously ill patients. However, there is no accuracy when the partial pressure of ABGs carbon dioxide (CO₂) is more than 56mmHg.¹⁸

Moreover, clinicians also stated that peripheral venous blood gases might be useful in subjects with exacerbation of COPD to evaluate their exchange of gases. Therefore, a study regarding the variability of ABGs and VBGs values in COPD patients was carried out in Spain. The study concluded that pH, serum bicarbonate, and haemoglobin variability are similar in both blood samples. Thus ABGs or VBGs values can be used interchangeably.¹⁹ Another misconception that can affect the interpretation of CO₂ during arterial sampling is the false assumption of clinicians regarding hyperventilation during arterial puncture, thus falsely interpreting CO₂ and pH levels in patients as respiratory acidosis corrected by respiratory alkalosis. In this study, the researchers concluded that slight hyperventilation during arterial puncture does not affect the values of CO₂.²⁰

Considering the importance of blood gas analysis for acid-base status evaluation in critically ill patients, the researchers found noncompliance and inappropriate testing in patients, including excessive testing in some patients and lack of testing in others. This disagreement reflects the difficulties of obtaining arterial blood samples, the gold standard method for this test. Nevertheless, in a retrospective study, Martin *et al.* concluded that venous blood gases are appropriate for the initial assessment of acid-base disorders in serious patients. Later on, based on clinical assessment, the sample from the artery can be collected for confirmation, and later on, VBGs would be enough for monitoring response to treatment in patients.²¹

In light of this study's findings, it can be suggested that venous blood gas estimation can be interchangeable with arterial sampling as it will reduce the risk of complications associated with an arterial puncture and is cost-effective for the financially deprived health system of this country.

CONCLUSION

In critically ill patients, pH and HCO₃ levels of venous blood gases were comparable with ABG. VBG CO₂ was significantly higher than ABGs.

Conflict of Interest: None.

Author's Contribution

Following authors have made substantial contributions to the manuscript as under:

SH: Conception, interpretation of data, drafting the manuscript, approval of the final version to be published.

RJ: Study design, data analysis, drafting the manuscript, critical review, approval of the final version to be published.

AI: Critical review, approval of the final version to be published.

QA: Data acquisition, interpretation of data, approval of the final version to be published.

SA: Study design, Drafting the manuscript, interpretation of data, approval of the final version to be published.

UA: Critical review, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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