Agreement and Correlation Between Arterial and Venous Blood pH, PO2, PCO2, Lactate, and HCO3

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Abstract

Background: The aim of this study is to assess the correlation and agreement between venous blood gas (VBG) values and arterial blood gas (ABG) values in patients presented in the emergency department of the Indus Hospital, Karachi. This study also included the evaluation of specificity and sensitivity of VBGs values for the identification of abnormal ABG values.

Method: It was a retrospective, observational study conducted at the Indus Hospital and Health Network, Karachi, Pakistan. All VBG and ABG values in the same patient which were collected at the same time from April 2020 to May 2021 were included in the study.

Results: The study involved 377 patients; 52.8% of patients were female, while 47.2% were male. The mean age of patients was 55.4 years (±17.2). There is an acceptable agreement between the arterial and venous values of pH, bicarbonate (mEq/l), and lactate (mEq/l), respectively, and poor agreement in PCO2 (mmHg) and PO2.

Conclusion: The study found that analysis of VBG has the potential to be used in the emergency setting in general. Blood gas values of Lactate, HCO3, and pH have shown acceptable association and significant correlation, and they can be considered clinically interchangeable with ABGs values. However, venous PCO2 and PO2 were found to be different between the two.

Introduction

Blood is considered connective tissue. Blood’s main job is to deliver oxygen from the lungs to the body’s tissues and carbon dioxide from the tissues to the lungs [1]. This function is necessary in order to prevent tissue death due to hypoxia. If the body does not receive enough oxygen, it will lead to acid-base imbalance. The term blood gas is referred to the measurement of partial pressure of carbon dioxide and oxygen in the blood, and a determination of acid-base imbalance is an important part of the measurement of blood gas which occurs because of improper oxidation of fats and carbohydrates [2]. Estimation of H+ ion concentration or pH is an integral part of blood gas measurement. Arterial blood gas (ABG) monitoring is an important part of the care of critically ill patients and aesthetic management of high-risk patients. Because these areas exhibit abrupt and life-threatening changes in each system involved, every physician, including anesthesiologists and nurses, must have a good understanding of acid-base balance [1].

ABG monitoring is commonly performed in the clinical setting, but this procedure has some limitations. For instance, this procedure can be painful for patients, thus reducing their acceptability and the possibility of causing complications like reflex sympathetic dystrophy, median nerve damage, aneurysm, and distal ischemia [3]. Venous blood gas (VBG) is a relatively safer treatment since it requires fewer punctures, lowering the risk of needle stick damage to the health care provider [4].

VBG sampling for non-metabolic disorders like gas exchange assessment and acid-base assessment can avoid certain issues noted for ABGs, and it can be a part of the initial draw of venous blood. Therefore, previous studies have assessed the correlation and agreement between VBG and ABG results and evaluated whether VBG can replace ABG, but most of these studies were limited to a particular group of patients such as chronic obstructive respiratory diseases and trauma [5-7]. Very limited literature has existed which assessed the efficacy of VBG analysis in a diverse group of the population presented to the critical care units and emergency department. Even though these studies have identified good correlation and agreement between VBG and ABG when including values like PCO2, HCO3, pH, and Lactate. These studies did not assess the correlation and agreement of abnormal values separately.
The aim of this study is to assess the correlation and agreement between VBG values and ABG values in patients presented in the emergency department of the Indus Hospital, Karachi. This study also included the evaluation of specificity and sensitivity of VBGs values for the identification of abnormal ABG values.

**Materials And Methods**

It was a retrospective, observational study conducted at the Indus Hospital and Health Network, Karachi, Pakistan. All VBG and ABG values in the same patient that were collected at the same time from April 2020 to May 2021 were included in the study. All blood gas samples are sent ‘stat’ (without delay or batching) to the laboratory, all analyses of blood gas were performed within 20 minutes of sample collection time, and all blood gas analyses are processed as soon as possible after arrival in the laboratory, according to hospital and laboratory protocol. Because of the retrospective nature of the investigation, arterial and venous blood gases were taken per unit protocol but not directly observed. Patients of any clinical status were enrolled in the current research, as patient identifiers including name and hospital number were not used in the study. All data were taken from the Hospital Information Management System, including age, gender, systolic, and diastolic blood pressure at the time of presentation to the emergency department.

Data collected from ABG and VBG were analyzed using Bland-Altman plots. Bland-Altman plots and analysis were used for the evaluation and visualization of the degree of agreement between venous and arterial $pO_2$, $pCO_2$, $HCO_3^-$, pH, and Lactate. The mean of all parameters of ABGs and VBGs were presented along with their standard deviation, and 95% limits of agreement (LOA) will be calculated. In addition, Pearson correlations were used for describing the strength of association between venous and arterial $pO_2$, $pCO_2$, $HCO_3^-$, pH, and Lactate. Sensitivity and specificity were analyzed for specific cutoffs of VBG values. Hypercarbia was defined as $pCO_2$ more than 45 mmHg, and acidemia was defined as pH less than 7.35. All analysis was done using STATA version 16.0 (StataCorp, College Station, TX). The level of significance was kept at P-value less than or equal to 0.05.

**Results**

The study involved 377 patients; 52.8% of patients were female, while 47.2% were male. The mean age of patients was 53.4 years (±17.2). The mean systolic and diastolic blood pressure of patients at the time of presentation is 133 mmHg (±33.2) and 80 mmHg (±20.9), respectively. Table 1 presents the mean VBG and ABG values of the $pO_2$, $pCO_2$, $HCO_3^-$, pH, and Lactate along with their standard deviation along with Bland-Altman 95% limits of agreement and Pearson correlation values.

| Parameters     | ABG (mean (SD)) | VBG (mean (SD)) | Bland–Altman limits of agreement | Pearson correlation (p-value) |
|----------------|-----------------|-----------------|---------------------------------|------------------------------|
| pH             | 7.38 (0.09)     | 7.35 (0.097)    | −0.08 to 0.15                   | 0.81 (0.001)*                |
| $pCO_2$ (mmHg) | 38.58 (13.90)   | 45.38 (14.37)   | −20.93 to 6.33                  | 0.88 (0.001)*                |
| Bicarbonate (mEq/l) | 23.18 (7.45) | 29.47 (23.05)   | −50.42 to 37.93                 | 0.23 (0.001)*                |
| $pO_2$ (mmHg)  | 75.29 (30.70)   | 37.74 (16.44)   | 101.71 to −26.61                | 0.11 (0.062)*                |
| Lactate (mEq/l)| 2.48 (2.32)     | 2.87 (1.92)     | −3.82 to 2.97                   | 0.88 (0.001)*                |

**TABLE 1: Mean and SD of parameters of ABG and VBG along with Bland–Altman limits of agreement and Pearson correlation**

*Significant at p-value<0.05.

The Bland-Altman plot for venous and arterial pH is shown in Figure 1. The mean difference between them is 0.03, with limits of agreement ranges from −0.08 to 0.15. There is a significant correlation between venous and arterial pH values (p-value=0.001), as shown in Table 1. A venous pH >7.35 had a sensitivity of 91.67% and specificity of 68.52% in identifying an arterial pH >7.35, as shown in Table 1.
FIGURE 1: The Bland-Altman plot of arterial and venous blood PH showing the limits of agreement

The Bland-Altman plot for venous and arterial PCO₂ is shown in Figure 2. The mean difference between them is 7.29, with Bland-Altman limits of agreement ranges from -20.93 to 6.33. There is a significant correlation between venous and arterial PCO₂ values (p-value=0.001), as shown in Table 1. Venous pCO₂ >45 mmHg had a sensitivity of 89.81% and a specificity of 61.34% of identifying an arterial pCO₂ >45 mmHg, as shown in Table 1.

FIGURE 2: The Bland-Altman plot of arterial and venous blood CO2 showing the limits of agreement

The Bland-Altman plot for venous and arterial bicarbonate is shown in Figure 3. The mean difference between them is 6.24, with Bland-Altman limits of agreement ranges from -50.42 to 37.93. There is a significant correlation between venous and arterial bicarbonate values (p-value=0.001), as shown in Table 1.
The Bland-Altman plot for venous and arterial PO$_2$ is shown in Figure 4. The mean difference between them is 31.45, with Bland-Altman limits of agreement ranges from 101.71 to -26.61. There is no significant correlation between venous and arterial PO$_2$ values (p-value=0.062), as shown in Table 1.

The Bland-Altman plot for venous and arterial Lactate is shown in Figure 5. The mean difference between them is 0.42, with Bland-Altman limits of agreement ranges from -3.82 to 2.97. There is a significant correlation between venous and arterial lactate values (p-value=0.001), as shown in Table 1.
Discussion

The current study was done to determine the correlation and agreement between VBG and ABG analysis among patients presenting at the emergency department of the Indus Hospital. The current study showed that the agreement between ABG and VBG analysis was strong for pH, Lactate, and bicarbonate and poor agreement in PCO\(_2\) and PO\(_2\). The study conducted by Koul et al. [10] also found no acceptable clinical evidence to support the utilization of Venous PO\(_2\) rather than arterial PO\(_2\) in clinical settings. Results obtained from this study are completely predictable on a physiological basis. VBG values depend on the local blood flow, cardiac output, arterial tissue exchange, and arterial PO\(_2\). Usually, other parameters, including pH, Lactate, and bicarbonate, do not differ significantly due to effective regulatory and buffering mechanisms. On the other hand, oxygen differs between ABGs and VBGs due to the normal values differ in arterial level and at the tissue level.

The agreement is there between venous and arterial values for bicarbonate and pH that are consistent with the findings of different studies [11]. On the other hand, a study conducted by Malinoski et al. found poor agreement between pH of VBGs and ABGs, even though the correlation was found to be significant between the two [5]. In relation to ABG, our study shows that the association is there between venous and arterial bicarbonate levels in which arterial bicarbonate levels are lesser than venous bicarbonate levels, and the association is significant. There is an acceptable agreement reported in our study between venous and arterial bicarbonate levels. Previous studies have also determined the agreement between venous and arterial bicarbonate levels [12]. It was concluded in the study that bicarbonate of VBGs could replace bicarbonate of ABGs in several clinical situations in the emergency department.

A number of studies evaluating the sensitivity and specificity of VBG pH and ABG pH are limited. The study conducted by McKeever et al. [13] suggested utilizing a cutoff of 7.35 of venous pH to manage chronic obstructive pulmonary disease (COPD) exacerbations due to the fact that this cutoff had a specificity of 95.6% and a sensitivity of 88.9% in identification of an arterial pH of more than and equal to 7.35 in their study. Our study has also found that venous pH <7.35 has a sensitivity of 91.67% and specificity of 68.52% in identifying an arterial pH of less than or equal to 7.35. Therefore, based on the predefined threshold, VBGs could be a tool that can be used for the identification of acidemia in a general population. A VBG should not be utilized if precision results are required, especially at pH <7.35.

Our study has shown that VBG pCO\(_2\) has a poor agreement with ABG pCO\(_2\), as seen by the wide 95% level of agreement. These findings are consistent with previous studies, including meta-analysis [14,15]. Despite some overlap in the papers included in the meta-analyses, we agree that the large LOA prevents the replacement of arterial pCO\(_2\) measurement with venous pCO\(_2\), especially when reliable pCO\(_2\) measurement is required. Past studies have used PCO\(_2\) to identify potential hypercarbia [15]. The study carried out by Ibrahim et al. [16] found that the cutoff of pCO\(_2\) >30 mmHg was 100% sensitive for pCO\(_2\) >45 mmHg. On the other hand, the cutoff of pCO\(_2\) >45 mmHg resulted in a sensitivity of 79%. Using a venous cutoff of pCO\(_2\) >45 mmHg
mmHg as a screen was 89.81% sensitive for an arterial pCO\textsubscript{2} >45 mmHg in our investigation, which included a heterogeneous sample. This can be used for ruling out hypercarbia. It shows that a VBG can be used as a screening tool to evaluate hypercarbia as the sensitivity is more than 80%.

The current study has certain limitations. First, we did not have any documentation regarding the collection of VBG. It means we do not have data on whether it was collected peripherally or centrally that could influence the variability of the values achieved. Second, the sample size is small, and the sample was collected from one site only. Third, it was a retrospective study. Subpopulation analysis was not possible in our study due to the retrospective de-identified technique, and some patients may have had two or more matched ABG-VBG samples.

Conclusions

The current study has shown that analysis of VBG has the potential to be used in the emergency setting in general. Blood gas values of Lactate, HCO\textsubscript{3}, and pH have shown acceptable association and significant correlation, and they can be considered clinically interchangeable with ABGs values. However, venous pCO\textsubscript{2} and PO\textsubscript{2} were found to be different between the two. Therefore, it is suggested that the possible execution of arterIALIZATION of VBGs will make all these values more accurate and will permit the utilization of venous pCO\textsubscript{2} in different clinical settings. With a more big and wide study population, and with comparative physiological conditions maybe we can establish the VBG use as a pathophysiological indicator.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue. Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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