

Comparison of Conventionally Measured Serum Bicarbonate Values with Bicarbonate Values Obtained in Arterial and Venous Blood Gas Analysis

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ABSTRACT

Bicarbonate (HCO_3^-) measurement in serum or plasma from a sample of venous blood is routinely practiced in hospital patient management. HCO_3^- status can also be assumed from Blood gas analysis requiring arterial blood as sample which is cumbersome for both patients and doctors. This study was undertaken to evaluate the extent of agreement among bicarbonate values obtained during venous, arterial blood gas analysis and conventionally measured serum bicarbonate levels in a group of intensive care unit (ICU) patients to determine whether conventionally measured serum HCO_3^- (from peripheral venous blood) and calculated HCO_3^- values (from arterial blood gas [ABG] analyzers) can be used interchangeably. A total of 51 adult patients with diverse medical conditions, presenting at a tertiary health centre ICU were enrolled in this study when deemed by the treating physician to have an ABG analysis. Arterial and venous samples were taken as close in time as possible for blood gas analysis and routine blood tests. Bland-Altman analyses were used to compare the three methods. The HCO_3^- levels from ABG, Venous Blood gas (VBG) and conventionally measured serum HCO_3^- showed acceptably narrow 95% limits of agreement using the Bland-Altman method. VBG reveals higher level of agreement with the ABG bicarbonate values compared to measured serum HCO_3^- . Thus, venous blood can be an alternate for arterial blood where ABG analyzer is available. conventionally serum HCO_3^- measurements can also be useful and used as substitute for an expensive ABG analyzer in resource constrained health care sectors when required.

Keywords: Arterial blood gas analysis, Venous blood gas analysis, Measured serum bicarbonate, Intensive Care Unit.

Introduction

The measurement of bicarbonate level in blood is extremely common and often provides vitally important data used in the care of critically ill patients. The bicarbonate level in blood can be directly measured or derived from calculations using the Henderson-Hasselbalch equation; mostly adopted by the blood gas analyzers¹. Arterial blood gas (ABG) analysis is commonly performed for clinical evaluation, but the procedure has certain limitations in the form of reduced patient acceptability because of painful procedure and the potential to cause complications such as arterial injury, thrombosis

with distal ischaemia, haemorrhage, aneurysm formation, median nerve damage and reflex sympathetic dystrophy^{2,3}. Venous blood gas (VBG) analysis is a relatively safer procedure as fewer punctures are required thus reducing the risk of needle stick injury to the health care workers.

Although various studies suggest that a venous sample is relatively accurate for acid-base assessment³⁻⁸, VBG analysis has not gained much acceptance as a substitute for ABG analysis. On the contrary, bicarbonate ions make

up ~ 95% of the total carbon dioxide of the plasma and hence both of them have been used interchangeably. Most blood gas analyzers use the Henderson-Hasselbach equation to calculate bicarbonate values based on the assumption that the dissociation constant (pK) and solubility coefficient (α) are invariant. However, pK is affected by changes in pH, ionic strength and temperature while the values of α varies with the composition of the solution such as the presence of increased salts proteins or lipids¹. Therefore, the calculated bicarbonate values irrespective of the type of sample, may have significant error under certain circumstances, making its reliability questionable. Previous studies using different statistical methods to assess the agreement between measured and calculated bicarbonate have shown conflicting results with some studies showing good agreement⁹⁻¹², while some studies showed otherwise¹³⁻¹⁵.

So far this study is concerned, the feasibility of such expensive procedure in a middle income country like ours is intended to be reconsidered. However, nearly all medical centers in Bangladesh have the conventional laboratory methods to determine the concentrations of this key analyte in routine venous blood. But arterial blood gas analyzers are still limited to a small number of referral hospitals. This study was aimed to investigate the extent of agreement among bicarbonate values obtained in venous and arterial blood gas analysis and conventionally measured serum bicarbonate levels in a group of intensive care unit (ICU) patients to determine whether conventionally measured serum HCO_3^- (from peripheral venous blood) and calculated HCO_3^- values (from ABG analyzers) can be used interchangeably.

Materials and Methods

This study was conducted in the intensive care unit of a tertiary care teaching hospital of central Bangladesh from July to December 2011. A total of 51 patients, deemed by their treating doctor to require blood gas analysis either

during initial evaluations or as part of their clinical care in ICU, were included in this study. After having the study explained, a verbal consent was obtained from the patient or their relative. Samples for arterial and venous blood gas analysis were obtained either by a registered nurse or a doctor as close as possible in time. The peripheral venous samples collected at the time of intravenous line insertion or as per recommendation were also used for other relevant blood tests. Multiple samples from the same patient at different dates were also accepted.

Calculated HCO_3^- concentrations were obtained from both arterial and venous blood gas samples using a Roche OPTI CCA op39090 instrument which calculates the HCO_3^- concentration from the arterial pH and PCO_2 . The HCO_3^- concentration was directly measured in the same venous serum or plasma by means of ion-selective electrodes (ISE). The samples were analyzed as quickly as possible using the blood gas analyzer routinely practiced in the ICU. Data were analyzed using SPSS version 12 and MedCal for Windows. Pearson's correlation and Bias plot (Bland & Altman)¹⁶ method was used to compare the three measurements.

Results

In this study 57 matched sample pairs were collected from 51 patients (29 males 22 females) with mean (\pm SD) of age 54 ± 14 years. The presenting diagnosis of the patients were: acute respiratory distress (33%), acute coronary syndrome (27%), acute on chronic renal failure (19%), post-operative sepsis (15%) and other suspected metabolic derangements (1%). The mean (\pm SD) calculated HCO_3^- from arterial and venous gas analysis were $26.07 (\pm 3.8)$ mEq/L, $26.58 (\pm 3.9)$ mEq/L respectively and conventionally measured serum HCO_3^- value was $27.57 (\pm 4.04)$ mEq/L. The values shared highly significant correlation ($p < 0.0001$; r : ABG vs VBG = 0.998, measured serum vs ABG = 0.984 and measured serum vs VBG = 0.986). Table I shows the mean deference along with their 95% limits of agreement in Bland & Altman comparison of measurements.

Table I: Bland & Altman comparison of Bicarbonate values in different methods.

Bicarbonate Measurements	Mean Difference (SD)(mEq/L)	Bland - Altman 95% limits of Agreement (mEq/L)
Calculated Arterial vs Venous Blood Gas HCO ₃ ⁻	0.51 (0.22)	-0.07 to -0.95
Measured Serum vs Calculated Arterial Blood Gas HCO ₃ ⁻	1.5 (0.69)	--0.13 to -2.89
Measured Serum vs Calculated Venous Blood Gas HCO ₃ ⁻	- 0.99 (0.65)	0.29 to -2.27

The bias plots (figs 1, 2 and 3), demonstrates acceptable agreement for all values of bicarbonate (mEq/l) with relative poor agreement for Measured Serum vs Calculated Arterial Blood Gas HCO₃⁻ (fig 2).

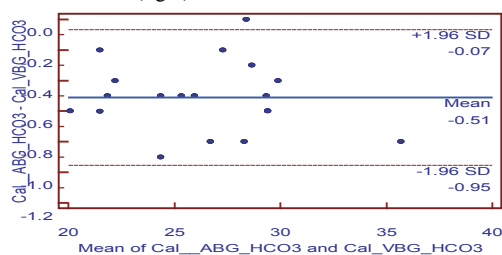


Figure 1: Bias plot comparing calculated arterial and venous blood gas HCO₃⁻ (Cal ABG: calculated arterial blood gas HCO₃⁻, Cal VBG: calculated venous blood gas HCO₃⁻)

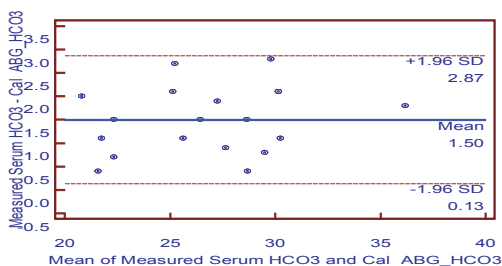


Figure 2: Bias plot comparing Measured Serum vs Calculated Arterial Blood Gas HCO₃⁻ (Cal ABG: calculated arterial blood gas HCO₃⁻)

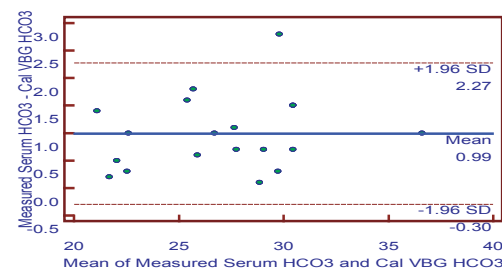


Figure 3: Bias plot comparing Measured Serum vs Calculated Venous Blood Gas HCO₃⁻ (Cal VBG: Calculated Venous blood gas HCO₃⁻)

Discussion

An important part of the assessment of the clinical status and progress of critically ill patients is timely assessment of acid-base status which is invariably practiced in arterial blood when it comes to blood gas analyzer. However, it may not always be practical to obtain arterial samples particularly in the early stages of resuscitation. Besides, such sophisticated device demands careful handling and adequate maintenance raising the cost of analysis. Plenty of reported evidence is available on agreement in ABG and VBG values but it does not reduce the cost load over a patient. So, this study was intended to focus on the unseen burdens over patient as well as the health care institutes and to look for a relatively easy, price-worthy and more specific way of measurement.

The agreement or discrepancy between measured and calculated bicarbonate and whether both can be used interchangeably has long been discussed since the 80's^{11,12,17,18} without any concrete conclusion. With the advancement in the methodology, this issue seemed to have resurfaced with a couple of articles published since 2008⁸⁻¹⁰.

The correlation coefficient between the measured and calculated bicarbonate revealed a good correlation ($r=0.977$, $p<0.001$). However the use of correlation coefficient alone to assess the agreement between two methods may not be appropriate as correlation depends on the range of values in the sample, a wide range of values like ours will yield a high correlation coefficient. Therefore, values which seem to be in poor agreement can produce high correlations provided the range is wide enough. Now, using Bland-Altman analysis, this study exhibited excellent agreement in the bicarbonate values. According the Bland-Altman analysis highest degree of agreement was found between VBG for ABG bicarbonates³⁻⁸ followed by measured serum versus VBG and measured serum versus ABG bicarbonate⁹⁻¹² estimates respectively unlike a few¹³⁻¹⁵. However, such comparisons of measured and calculated HCO₃⁻ values can be used to detect errors in the collection or analysis of blood samples.

In a resource constrained third world country like ours, health professionals are often expected to manage within the limited facilities available especially in peripheral hospitals. Hence, conventional methods for estimation of serum HCO₃⁻ in critically ill ICU patients can be a convenient substitute for ABG. However, more accurate assessments will require ABG for additional parameters. Here, venous blood can be introduced to improve patients-doctors' compliance. Large scale studies with the same may add to it in future.

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