Central Venous Blood Gas Analysis: An Alternative to Arterial Blood Gas Analysis for pH, PCO₂, Bicarbonate, Sodium, Potassium and Chloride in the Intensive Care Unit Patients

Mubina Begum Bijapur1, Nazeer Ahmed Kudligi2, Shaik Asma3

ABSTRACT

Aims: Arterial blood gas (ABG) analysis is a frequently ordered test in intensive care unit (ICU) and can analyze electrolyte in addition to pH and blood gases. Venous blood gas (VBG) analysis is a safer procedure and may be an alternative for ABG. Electrolyte estimation by auto analyzer usually takes 20–30 minutes. This study was aimed to investigate the correlation of pH, PCO₂, bicarbonate, sodium, potassium, and chloride (electrolytes) between ABG and central VBG in ICU patients.

Materials and methods: This was a prospective observational study conducted in medical college hospital ICU. Adult patients requiring ABG and electrolyte estimation as a part of their clinical care were consecutively included in the study. Patients having any intravenous infusion or who were pregnant were excluded. Venous samples were taken within 2 minutes of arterial sampling from in situ central line. Data were analyzed using Bland-Altman methods.

Results: A total of 110 patient’s paired blood samples were analyzed. The mean difference between arterial and central venous values of pH, PCO₂, bicarbonate, sodium, potassium, and chloride was 0.04 units, –5.84 mm Hg, –1.8 mmol/L, –0.04 mEq/L, –1.8 mEq/L, –0.04 mEq/L, and –0.89 mEq/L, respectively. The correlation coefficients for pH, PCO₂, HCO₃⁻, sodium, potassium, and chloride were 0.799, 0.831, 0.892, 0.652, 0.599 and 0.730, respectively. Limits of agreement (95%) were within acceptable limits.

Conclusion: Central venous pH, PCO₂, and bicarbonate may be an acceptable substitute for ABG in patients admitted in the ICU. However caution should be exercised while applying electrolyte measurements.

Keywords: Agreement, Arterial blood gas analysis, Central venous blood, Correlation, Electrolytes

Introduction

Arterial blood gas (ABG) analysis is a commonly performed test to evaluate respiratory and acid base status in critically ill patients admitted to intensive care unit (ICU). Though ABG analysis is rapid and reliable, the arterial puncture carries a risk of hemorrhage and other vascular complications,¹ which is painful and no longer necessary for diagnosing respiratory failure because of widespread use of pulse oximetry for measuring oxygen saturations. For these and other reasons such as ease of collection, the peripheral venous blood gas (VBG) analysis is increasingly being used as a replacement to the ABG especially in the emergency department. Sodium, potassium, and chloride (electrolytes) abnormalities⁴ are also one of the common causes of morbidity and mortality in ICU patients and are conventionally measured by auto analyzers available in hospital’s central laboratories. Typically, an average turnaround time of 20–30 minutes is noted in acute care laboratories of most tertiary care hospitals. Point of care testing for electrolytes is available, but cost is a major deterrent for their utilization in developing countries.

Earlier studies have shown good correlation between ABG and VBG values with respect to pH, PCO₂, and bicarbonate in adult patients admitted to the emergency department and ICU.¹³ Studies involving ICU patients have shown good correlation for potassium measured between ABG machine and point of care analyzers.⁵⁻⁶ However, there is limited information regarding relationship between the venous and arterial values for pH, PCO₂, bicarbonate, and electrolytes in critically ill patients. Central venous catheter (CVC) is inserted for central venous pressure measurement, which is painful and no longer necessary for diagnosing respiratory failure because of widespread use of pulse oximetry for measuring oxygen saturations. For these and other reasons such as ease of collection, the peripheral venous blood gas (VBG) analysis is increasingly being used as a replacement to the ABG especially in the emergency department. Sodium, potassium, and chloride (electrolytes) abnormalities are also one of the common causes of morbidity and mortality in ICU patients and are conventionally measured by auto analyzers available in hospital’s central laboratories. Typically, an average turnaround time of 20–30 minutes is noted in acute care laboratories of most tertiary care hospitals. Point of care testing for electrolytes is available, but cost is a major deterrent for their utilization in developing countries.

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Results

The study involved a total of 110 patients (70 males (63.6%) and 40 females (36.4%), mean ± SD and age of 40.91 ± 16.21 years). A total of 110 paired blood samples were included in the study. The presenting diagnoses of the patients were: poisoning (27.2%), neurological (20.9%), postsurgical (13.6%), trauma (10.9%), respiratory (9.0%), cardiovascular (5.4%), and sepsis and other infectious diseases (6.3%) each. Arterial values were as follows: pH (6.99–7.58), PCO₂ (17–134 mm Hg), HCO₃⁻ (9.2–43.5 mEq/L), Na⁺ (113–173 mEq/L), K⁺ (1.7–7.3 mEq/L), and Cl⁻ (79–139 mEq/L). Corresponding venous values were: pH (6.96–7.55), PCO₂ (18–146 mm Hg), HCO₃⁻ (9.6–43.2 mEq/L), Na⁺ (116–172 mEq/L), K⁺ (2.0–7.6 mEq/L), and Cl⁻ (82–134 mEq/L).

Table 1: Summary of arterial and central venous blood gas values (n=220)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ABG (Mean ± SD)</th>
<th>VBG (Mean ± SD)</th>
<th>A-V difference (Mean ± SD)</th>
<th>Correlation coefficient (r value)</th>
<th>Bland-Altman 95% LOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.4±0.10</td>
<td>7.36±0.11</td>
<td>0.04±0.07</td>
<td>0.799</td>
<td>-0.09 to 0.19</td>
</tr>
<tr>
<td>PCO₂ (mm Hg)</td>
<td>38.7±15.71</td>
<td>44.58±17.35</td>
<td>-5.84±9.77</td>
<td>0.831</td>
<td>-25 to 13.1</td>
</tr>
<tr>
<td>HCO₃⁻ (mEq/L)</td>
<td>24.50±5.79</td>
<td>23.60±6.28</td>
<td>0.89±2.85</td>
<td>0.892</td>
<td>-4.7 to 6.5</td>
</tr>
<tr>
<td>Na⁺ (mEq/L)</td>
<td>144.09±10.85</td>
<td>145.89±10.55</td>
<td>-1.8±8.94</td>
<td>0.652</td>
<td>-19.3 to 15.7</td>
</tr>
<tr>
<td>K⁺ (mEq/L)</td>
<td>3.5±0.99</td>
<td>3.55±1.25</td>
<td>-0.04±1.03</td>
<td>0.599</td>
<td>-2.1 to 2.0</td>
</tr>
<tr>
<td>Cl⁻ (mEq/L)</td>
<td>108.1±12.4</td>
<td>108.99±12.02</td>
<td>-0.89±8.98</td>
<td>0.730</td>
<td>-18.5 to 16.7</td>
</tr>
</tbody>
</table>

ABG: arterial blood gas; VBG: venous blood gas; A-V: arterial minus venous difference; SD, standard deviation; LOA, limits of agreement.
and that frequently arterial blood gases are obtained to help assess a patient’s course, central venous PCO$_2$ largely should be able to replace arterial PCO$_2$ in the most clinical circumstances.

Arterial blood gas and cVBG values for HCO$_3^-$ showed good correlation ($r = 0.892$). The mean arterial minus central venous difference for HCO$_3^-$ was 0.89 mmol/L, which was within clinically acceptable limits according to Tregger et al.$^3$ and Rang et al.$^{11}$ In this study, LOA (-4.7–6.5) was wide which was close to LOA by Tregger et al.$^3$ (-4–2.4) who have concluded this limit as an excellent agreement between arterial and venous HCO$_3^-$. The venous pH is generally lower than arterial pH and venous PCO$_2$ was generally higher than arterial PCO$_2$, mean venous HCO$_3^-$ was unexpectedly higher than the mean arterial value. We conclude that value of HCO$_3^-$ was influenced more by CO$_2$ level on which the calculation is based rather by the pH.

Arterial and central venous values of electrolytes moderately correlated (Table 1). Mean arterial minus central venous difference were sodium: -1.8 (SD 8.94), potassium: -0.04 (SD 1.03), and chloride: -0.89 (SD 8.98), which is consistent with study by Awasthi et al.$^4$ which showed good correlation between both samples and low arterial minus venous differences for pH, bicarbonate, and electrolytes in group of ICU and critically ill patients. Johnston$^5$ studied agreement between arterial and venous blood potassium in patients with cardiac arrest. It was found that mean difference between each pair of arterial and venous potassium was 0.106 mmol/L. Our study revealed that a mean difference of 0.04 mmol/L is comparable to the author’s analysis. Nanda et al.$^{12}$ found the mean values of arterial sodium and potassium were lower than venous sodium and potassium, which is consistent with the findings of present study. Wongyingsinn et al. observed a good correlation between arterial and venous potassium and stated that arterial potassium can replace measurement of venous potassium.$^{13}$ Flegar Mestric et al. observed that electrolytes measured in whole blood by point of care analyzer were comparable to electrolytes measured in plasma or venous serum samples.$^{14}$ Jain et al. observed that there was no significant difference between potassium measured in ABG analyzer and potassium measured by routine chemistry auto analyzer.$^{15}$

In the present study, which showed excellent correlation for acid base status with moderate correlation for electrolytes, this could become promising to use VBG analysis electrolytes along with pH, PCO$_2$, and bicarbonate in the place of ABG and serum electrolytes in early stages of resuscitation in emergency department and ICU patients. This can reduce serious complications associated with long term arterial catheterization and time required for electrolyte analysis. Due to good correlation and acceptable mean differences, the present study can suggest that changes in venous values would
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Figs 2A to C: Bland-Altman plot of arterial and venous (average vs difference) (A) sodium; (B) potassium; and (C) chloride

reflect changes in the corresponding arterial values and therefore can be used for trending purposes.

Limitations of the study included patients with diverse pathological conditions with abnormal blood gas and electrolyte values. Further study of the differences in the clinical decision making based on VBG analysis for acid base status and electrolyte levels from a specific patient population with a likelihood of abnormal blood gases and electrolytes is necessary before recommending routine use of an abnormal VBG.

**Conclusion**

The study showed good correlation for pH, PCO₂, bicarbonate values with moderate correlation for electrolytes. These results suggest that venous values may be an acceptable substitute for arterial measurement in many clinical settings encountered in ICU obviating the need for repeated arterial sampling. However, caution should be exercised while applying electrolyte measurements though it reduces the electrolyte estimation time and is cost effective. Further research is required to establish their accuracy with respect to electrolyte values.

**References**