Prospective Study to Determine Possible Correlation Between Arterial and Venous Blood Gas Values

Zahid Hussain Khan¹*, Shahram Samadi¹, Mostafa Sadeghi², Mahmoud Gholam Alemohammad¹, Amir Poya Zanjani¹, Shahin Adine-Hashtjin¹, Jalil Makarem¹

¹Department of Anaesthesiology, Imam Khomeini Medical Center, Tehran, Iran.
²Department of Anaesthesiology, Shariati Medical Center, Tehran, Iran.

Received: Mar 12, 2010
Revised: May 10, 2010
Accepted: May 13, 2010

KEY WORDS:
- blood gas analysis
- perioperative care

Objective: Arterial blood gas analysis is an intrinsic component factor in the clinical evaluation of patients, but arterial puncture has many complications. Our study aimed to determine a correlation between arterial and venous blood gas values.

Methods: A prospective comparison of 200 samples from 100 patients undergoing lumbar disc surgery was conducted. Arterial and venous samples were obtained simultaneously from each patient. The samples were analyzed and compared using SPSS version 16 software, with Pearson’s correlation and 95% confidence intervals (CIs) of the difference.

Results: Arterial and venous values for pH, bicarbonate (HCO₃⁻), base excess (BE), buffer base (BB) and partial pressure of carbon dioxide (PCO₂) showed close and direct correlation. The comparison showed the following: pH, \( r = 0.938, p < 0.001 \) (95% CI, 0.019 to 0.032); HCO₃⁻, \( r = 0.884, p < 0.001 \) (95% CI, −2.65 to −1.99); BE, \( r = 0.861, p < 0.001 \) (95% CI, −1.89 to −1.17); BB, \( r = 0.849, p < 0.001 \) (95% CI, −2.35 to −1.60); and PCO₂, \( r = 0.899, p < 0.001 \) (95% CI, −5.97 to −4.66). Pearson’s correlation coefficients for partial pressure of oxygen and oxygen saturation were 0.092 and 0.345, respectively. The mean difference between arterial and venous values for pH was 0.025 pH units, for HCO₃⁻ was 2.327 mmol/L, for PCO₂ was 5.32 mmHg, for BE was 1.533 mmol/L, and for BB was 1.983 mmol/L.

Conclusion: Venous blood gas values are an acceptable alternative to arterial blood gas values in patients undergoing lumbar disc surgery.

1. Introduction

Arterial blood gas (ABG) analysis gives important information about the clinical status and progress of diseases. But arterial puncture may cause complications such as local hematoma, infection, aneurysm formation, arterial thrombosis or embolization, which could lead to ischemic injury of tissues that the punctured artery perfuses. Arterial puncture can be technically difficult and multiple assays may be necessary. There is also the risk of needle stick damage to the health care provider. In contrast, venous
sampling can be easily performed for laboratory tests and causes fewer complications.

According to existing evidence, venous pH in most patients is a clinically admissible substitute for arterial pH. In recent years, much research has been conducted to find a suitable alternative to ABG sampling. Studies that compared ABG and venous blood gas (VBG) values showed a good correlation between arterial and venous samples. VBG measurements accurately demonstrated the degree of acidosis in adult patients with diabetic ketoacidosis. There is some evidence that venous and arterial bicarbonate (HCO₃⁻) agree closely in diabetic ketoacidosis, but this requires confirmation. Measurement of central venous oxygen saturation can be done easily in intensive care unit (ICU) patients, and offers a useful, indirect indicator of the adequacy of tissue oxygenation. Venous pH and partial pressure of carbon dioxide (PCO₂) levels show relatively good correlation with ABG values. This correlation is not necessarily close, for example, VBG cannot be a substitute for ABG in exacerbation of chronic obstructive pulmonary disease. Venous pH is an acceptable substitute for that by arterial measurement but there is not sufficient agreement for venous PCO₂ to be able to replace arterial PCO₂ in the clinical evaluation of ventilatory function. In tricyclic antidepressant poisoning, peripheral venous pH measurement is a valid and reliable substitute for arterial pH.

In patients undergoing lumbar disc surgery, we usually obtain an ABG analysis in the middle of the operation because of the long duration of the procedure. This prospective study aimed to determine if VBG analysis can serve as a surrogate for ABG analysis in this group of patients by comparing the ABG and VBG values.

2. Methods

This prospective study was conducted in Imam Khomeini Hospital in Tehran between January 2007 and December 2008. The teaching hospital has 1300 beds and is situated nearly 1160 meters above sea level; the barometric pressure of the region is 830–108 mmHg; partial pressure of oxygen (PO₂), 660 mmHg; HCO₃⁻, 21–28 mmol/L; base excess (BE), –2 to +3 mmol/L; buffer base (BB), 40–44 mmol/L; and oxygen saturation (SO₂), 95–98%.

Data were analyzed using SPSS version 16 (SPSS Inc., Chicago, IL, USA). The normality of distribution of all variables was evaluated with histogram and Kolmogorov-Smirnov Test. The strength of relationship between venous and arterial values of pH, PCO₂, HCO₃⁻, BE, BB, PO₂ and SO₂ were determined with Pearson’s test of correlation. Means and 95% confidence intervals (CIs) were computed for all variables and for the differences between ABG and VBG samples. Linear regression analysis was used for estimation of arterial values from venous values.

3. Results

A total of 200 sets of blood gas values were analyzed from 100 patients who met the inclusion criteria. Mean age was 49.8±11.3 years (range, 21–75 years). Of the 100 patients, 58 were male. Based on a normal pH range of 7.35–7.45 pH units, 28 arterial samples were acidotic and 36 were alkalotic. Data for the arterial and venous variables are shown in Table 1. Arterial and venous values for pH, HCO₃⁻, BE, BB, PO₂ and SO₂ were determined with Pearson’s test of correlation. Means and 95% confidence intervals (CIs) were computed for all variables and for the differences between ABG and VBG samples. Linear regression analysis was used for estimation of arterial values from venous values.

2. Methods

This prospective study was conducted in Imam Khomeini Hospital in Tehran between January 2007 and December 2008. The teaching hospital has 1300 beds and is situated nearly 1160 meters above sea level; the barometric pressure of the region is 830–108 mmHg; partial pressure of oxygen (PO₂), 660 mmHg; HCO₃⁻, 21–28 mmol/L; base excess (BE), –2 to +3 mmol/L; buffer base (BB), 40–44 mmol/L; and oxygen saturation (SO₂), 95–98%.

Data were analyzed using SPSS version 16 (SPSS Inc., Chicago, IL, USA). The normality of distribution of all variables was evaluated with histogram and Kolmogorov-Smirnov Test. The strength of relationship between venous and arterial values of pH, PCO₂, HCO₃⁻, BE, BB, PO₂ and SO₂ were determined with Pearson’s test of correlation. Means and 95% confidence intervals (CIs) were computed for all variables and for the differences between ABG and VBG samples. Linear regression analysis was used for estimation of arterial values from venous values.

3. Results

A total of 200 sets of blood gas values were analyzed from 100 patients who met the inclusion criteria. Mean age was 49.8±11.3 years (range, 21–75 years). Of the 100 patients, 58 were male. Based on a normal pH range of 7.35–7.45 pH units, 28 arterial samples were acidotic and 36 were alkalotic. Data for the arterial and venous variables are shown in Table 1. Arterial and venous values for pH, HCO₃⁻, BE, BB and PO₂ showed a close correlation, but there was poor correlation between arterial and venous PO₂ and SO₂ (Table 2).

Linear regression (Figure 1) equations for the estimation of arterial pH, PCO₂, HCO₃⁻, BE and BB were as follows: arterial pH = 0.138 + 0.9851 × venous pH (r² = 0.88, p < 0.001); arterial PCO₂ = 1.457 + 0.806 × venous PCO₂ (r² = 0.81, p < 0.001); arterial HCO₃⁻ = 0.207 + 0.882 × venous HCO₃⁻ (r² = 0.78, p < 0.001); arterial BE = 0.854 × venous BE − 1.882 (r² = 0.74, p < 0.001); arterial BB = 4.591 + 0.856 × venous BB (r² = 0.72, p < 0.001).
Table 1  Arterial and venous blood variables*

<table>
<thead>
<tr>
<th></th>
<th>Arterial</th>
<th>Venous</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.416±0.089</td>
<td>7.39±0.085</td>
</tr>
<tr>
<td>PCO₂ (mmHg)</td>
<td>29.6±6.72</td>
<td>34.9±7.5</td>
</tr>
<tr>
<td>HCO₃ (mmol/L)</td>
<td>19.19±3.42</td>
<td>21.52±3.43</td>
</tr>
<tr>
<td>BE (mmol/L)</td>
<td>−3.92±3.42</td>
<td>−2.39±3.45</td>
</tr>
<tr>
<td>BB (mmol/L)</td>
<td>43.55±3.44</td>
<td>45.5±3.42</td>
</tr>
<tr>
<td>PO₂ (mmHg)</td>
<td>131±60.56</td>
<td>60.35±21.3</td>
</tr>
<tr>
<td>SO₂ (%)</td>
<td>97.3±2.47</td>
<td>82.3±13.65</td>
</tr>
</tbody>
</table>

*Data presented as mean±standard deviation. PCO₂ = partial pressure of carbon dioxide; HCO₃ = bicarbonate; BE = base excess; BB = buffer base; PO₂ = partial pressure of oxygen; SO₂ = oxygen saturation.

Table 2  Simple linear regression of arterial variables using venous variables as the independent variable

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.938</td>
<td>&lt;0.001</td>
<td>0.019 to 0.032</td>
</tr>
<tr>
<td>PCO₂</td>
<td>0.899</td>
<td>&lt;0.001</td>
<td>−5.97 to −4.66</td>
</tr>
<tr>
<td>HCO₃</td>
<td>0.884</td>
<td>&lt;0.001</td>
<td>−2.65 to −1.99</td>
</tr>
<tr>
<td>BE</td>
<td>0.861</td>
<td>&lt;0.001</td>
<td>−1.89 to −1.17</td>
</tr>
<tr>
<td>BB</td>
<td>0.849</td>
<td>&lt;0.001</td>
<td>−2.35 to −1.60</td>
</tr>
<tr>
<td>PO₂</td>
<td>0.092</td>
<td>0.364</td>
<td></td>
</tr>
<tr>
<td>SO₂</td>
<td>0.345</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

CI = confidence interval; PCO₂ = partial pressure of carbon dioxide; HCO₃ = bicarbonate; BE = base excess; BB = buffer base; PO₂ = partial pressure of oxygen; SO₂ = oxygen saturation.

Figure 1  Regression figures for: (A) pH; (B) partial pressure of carbon dioxide (PCO₂); (C) bicarbonate (HCO₃); and (D) partial pressure of oxygen (PO₂).

4. Discussion

ABG is the mainstay and gold standard in the diagnosis and clinical management of oxygenation and acid base disturbances. ABG analysis provides useful information about the clinical status of critically ill patients, and is also utilized for ventilatory settings and assessing acid-base status. However, arterial puncture has its own complications, and physicians have long looked for alternatives.

In this study of patients undergoing lumbar disc surgery, there was good correlation between arterial...
and venous blood samples with regard to pH, PCO\textsubscript{2}, HCO\textsubscript{3}, BE and BB. It may thus be inferred that, for these variables under special conditions, peripheral venous blood samples could be used instead of arterial blood samples.

Middleton et al\textsuperscript{7} observed that pH, HCO\textsubscript{3}, BE and lactate estimations from central vein samples showed good correlation with arterial samples in ICU patients, with narrow 95% CIs. They concluded that venous samples in this group of patients could serve as an acceptable substitute for arterial samples. Malinoski et al\textsuperscript{8} reported that pH, PCO\textsubscript{2} and BE values obtained from central vein samples correlated well with those obtained from arterial blood samples in ICU patients on mechanical ventilation, but their 95% CIs were so wide that the substitution of arterial samples by venous samples could adversely affect patient management. Ak et al\textsuperscript{9} could predict the critical status of acute exacerbation in patients with chronic obstructive pulmonary disease from pH, PCO\textsubscript{2} and HCO\textsubscript{3} values obtained from venous samples, and concluded that VBG could serve as a reliable substitute for ABG. In our study, a different patient population from that in previous studies was enrolled so as to obtain more data to determine whether or not VBG can serve as a reliable surrogate for ABG. We analyzed the difference in BB between VBG and ABG and found out an acceptable correlation ($r=0.849$), concluding that VBG may be substituted for ABG. As some patients may not have a central venous line, at least initially, a blood sample from a peripheral vein could suffice. The 95% CIs in our study with respect to pH, PCO\textsubscript{2} and BE were narrow compared to those of Malinoski et al.\textsuperscript{8} The reason for this discrepancy is not clear, but could perhaps be attributed to the fact that they selected a venous sample from a central vein. While our linear regression equations are different from those of Ak et al,\textsuperscript{9} the 95% CIs for pH, PCO\textsubscript{2} and HCO\textsubscript{3} are similar to theirs.

Despite our promising results, our study has some limitations that should be taken into account when interpreting the results. Our sample size was not that large to provide us with concrete and highly statistically significant results. Moreover, there exist many other types of patients not included in our study in whom ABG analysis is of paramount importance. In some patients and in some metabolic disorders, ABG and VBG variables may not only not correlate with each other but be statistically significantly different from each other. Such patients and disorders need separate studies to find acceptable and plausible alternatives to ABG. It is suggested that large samples from other sets of patients be obtained and studied to match and correlate the findings and, if found to be meaningful, be transferred to a larger section of the population, which would help us to deduce new equations to predict arterial status from venous sampling in specific situations.

It is recommended that VBG should not substitute ABG with regard to PO\textsubscript{2} and SO\textsubscript{2} because there is a very poor correlation between the two. In limited similar situations to this study, VBG can serve as a surrogate for ABG, but it should be used cautiously and only in patients undergoing lumbar disc surgery. To conclude, in similar clinical conditions, a venous line may be set just for gas sample test, but only for selected parameters.

References