Venous vs Arterial Blood Gases in Acute Exacerbation of COPD

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Abstract

Background: Arterial blood gases are necessary for management of respiratory failure in patients with acute exacerbation of COPD. Venous blood gas analysis may be a less invasive potential alternative. The objective of our study was to determine the accuracy of venous blood gases in the diagnosis of hypercapnic respiratory failure and to determine the correlation between arterial and venous PH, PCO₂, and HCO₃⁻.

Methodology: All adult patients presenting to Pulmonology department between November 2018 and March 2019 with COPD exacerbation having SPO₂ < 90% were included. Patients in shock, arrhythmia, diabetic ketoacidosis, renal failure, bleeding disorder or unwilling for blood sampling were excluded. Paired arterial and venous blood samples were obtained and analyzed on the spot via blood gas analyzer. The sensitivity, specificity and diagnostic accuracy of VBGs were calculated via spss-19, by taking PCO₂ >45mm of Hg as cut off value to diagnose hypercapnia using ABGs as the gold standard. Correlation between arterial and venous PH, PCO₂ and HCO₃⁻ were calculated via Pearson correlation.

Results: We enrolled 87 patients, with mean age of 51yrs (+ 8.89 SD) and male to female ratio of 1: 2.2. The mean venous minus arterial PH (7.39-7.40) was -0.13. The mean venous minus arterial PCO₂ (60-54) was 6mm of Hg. The sensitivity of venous PCO₂ in the diagnosis of hypercapnia was 97.95%, specificity 66.66%, PPV 80%, NPV 96% and diagnostic accuracy of 82.7%. There was a strong correlation between arterial and venous PH (r =0.83), HCO₃⁻ (r=0.63) and PCO₂(r=0.92).

Conclusion: VBGs instead of ABGs can be used as a screening test for detection of hypercapnia in hemodynamically stable patients presenting with acute exacerbation of COPD and VBGs indices (PH, PCO₂ and HCO₃⁻) can provide guidance about the severity of acid base disturbance.

Key Words: Arterial blood gases; Venous blood gases; Hypercapnia; COPD exacerbation

Introduction

Acute respiratory failure is a life threatening complication of acute exacerbation of COPD that results either from impaired gas exchange or dysfunction of respiratory muscle pump leading to hypoxemia and/or hypercapnia. The management is based on whether the patient has hypoxemic (type 1) or hypercapnic (type 2) respiratory failure. High flow oxygen is beneficial in former but associated with a worse outcome in the later by eliminating hypoxic drive of the respiratory centre leading to worsening of hypercapnia.

Analysis of arterial blood gases is the time tested investigation to confirm respiratory failure and...
categorize it by measuring oxygenation \( (P_{O_2}) \), ventilation \( (P_{CO_2}) \) and acid base disturbance \( (PH \) and \( HCO_3^-) \). However, arterial blood sampling is an invasive and painful procedure which may rarely be complicated by thrombosis, aneurysm, hematoma, infection or distal limb ischemia. Repeated arterial punctures may be required in those patients who don’t have a central arterial line particularly in respiratory failure secondary to chronic obstructive pulmonary disease. Using less invasive technique of measuring the ABGs indices could reduce the potential complications related to arterial punctures.

Venous blood sampling along with pulse oximetry is a possible alternative method which is easier, simpler and routinely used for hematological investigations. Many studies have found a good correlation between PH, PCO\(_2\) and HCO\(_3^-\) of arterial and venous bloods. However, some of these studies have a very small sample size, performed in ICU and a few have shown some contradictory results.

A meta-analysis has suggested a good agreement between venous and arterial blood gas indices but lack of validation studies preclude the widespread use of VBGs in clinical settings. In uncontrolled diabetes (diabetic ketoacidosis), venous sampling has replaced arterial sampling for the monitoring purposes of acid base disturbance. The use of VBGs in the management of respiratory failure in acute exacerbations of COPD has been limited, most probably because of a less stronger correlation between arterial and venous PCO\(_2\), although a partial pressure of venous Carbon dioxide (PvCO\(_2\)) of >45mm Hg has been shown to have 100% (95% CI 97% to 100%) sensitivity in predicting clinically significant hypercapnia.

Guidelines recommend arterial blood gases to manage respiratory failure in patients presenting to hospitals with COPD exacerbations. The aim of our study was to assess the utility of VBGs at least during the initial management of these patients in an effort to avoid or at least reduce the number of arterial punctures.

**Objectives:**
1. To determine the accuracy of VBGs in the diagnosis of hypercapnic respiratory failure
2. To determine the correlation between arterial and venous PH, PCO\(_2\), and HCO\(_3^-\).

**Methodology**

All adult patients presenting to Pulmonology unit between Nov 2018 and March 2019 with COPD exacerbation having SPO\(_2\) < 90% measured via finger pulse oximeter were included in the study. Patients in shock, arrhythmia, renal failure, diabetic ketoacidosis, bleeding disorder or unwilling for blood sampling were excluded. Trained pulmonology technicians obtained paired arterial and venous blood samples. Arterial blood samples were taken from radial, brachial or femoral arteries. Venous samples were obtained within 5min of arterial samples from any peripheral veins usually during passing intravenous line or drawing blood for investigations. Blood gas analyses were performed on the spot with blood gas analyzer machine (Easy Blood Gas REF 6101-0000). Data were collected in a pre-designed proforma.

**Data Analysis:** We calculated the sensitivity, specificity and diagnostic accuracy of VBGs via SPSS 19, by taking PCO\(_2\) >45mm Hg as cut off value to diagnose hypercapnia using ABGs as the gold standard. Correlation between arterial and venous blood gas indices was determined using Pearson correlation coefficient. The data was analyzed using SPSS 19.
PH, PCO₂ and HCO₃ were calculated via Pearson correlation.

Results

We enrolled 87 patients, with mean age of 51 years (± 8.89 SD) and male to female ratio of 1:2.2. The frequency of type 2 respiratory failure was 62.35% as shown in graph 01. The sensitivity of venous blood gases for the detection of hypercapnia was 97.95%, specificity 66.66%, PPV 80%, NPV 96% and diagnostic accuracy of 82.7% as shown in table 01. The mean venous minus arterial PH (7.39-7.40) was 0.13. The mean venous minus arterial PCO₂ (60-54) was 6mm of Hg. There was a strong correlation (at the level of p=0.01) between arterial and venous PH (r =0.83), HCO₃ (r=0.63) and PCO₂ (r=0.92).

Table 1: Radiological pattern correlation with smear status

<table>
<thead>
<tr>
<th>Hypercapnia (PCO₂ &gt; 45) on VBGs</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
<tr>
<td>(a) 48</td>
<td>(b) 12</td>
<td></td>
</tr>
<tr>
<td>(c) 1</td>
<td>(d) 24</td>
<td></td>
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Sensitivity= 48/(48+1)x100=97.95%
Specificity= 24/(24+12)x100=66.66%
PPV = 48/(48+12)x100=80%
NPV = 24/(24+1)x100=96%
Diagnostic accuracy= (48+24)/87 =82.7%
a=True positive, b=False positive, c=False negative, d=True negative

agreement between venous and arterial PCO₂ to determine the degree of CO₂ retention. Another study conducted by Kelly AM, has also shown a sensitivity of 100% and specificity of 57% for the prediction of hypercapnia.

According to the results of a systemic review and meta-analysis of 2014 (12 articles relevant to PCO₂), normal venous PCO₂ (PvCO₂) has a high negative predictive value for normal arterial PCO₂ (PaCO₂), and a normal PcCO₂ can safely exclude clinically significant CO₂ retention, however the PcCO₂ cannot accurately represent PaCO₂.

The available literature suggests that VBGs (PvCO₂ > 45) can be utilized to screen for clinically significant hypercapnia in patients with COPD exacerbation, hence arterial blood sampling can be avoided if the venous blood PCO₂ falls below 45 mm of Hg.

The second part of our conclusion was a statistically significant correlation between venous and arterial blood indices (PH, HCO₃ and PCO₂). A quite similar result of strong agreement between arterial and venous blood gas parameters (pH and PCO₂) has been reported by Koul et al. Given this strong relationship between venous and arterial blood indices (PH and PCO₂), peripheral venous sampling instead of arterial has the potential for its utility to follow the trend of respiratory acidosis. These results can be explained by normal physiological mechanisms. Venous blood gas values depend on many factors like, cardiac output, local blood flow, arterial PO₂, arterial-tissue gas exchanges and kidney functions. Normally, venous-arterial PCO₂, pH and HCO₃ differ only in a narrow range because of effective buffering and regulatory mechanisms in contrast to PO₂.

A meta-analysis (2010) of five research studies conducted on COPD exacerbations in emergency department has shown a good agreement between peripheral venous and arterial blood gas indices (PH, HCO₃ and PCO₂). The weighted average difference for PCO₂, PH and HCO₃ was 0.79 kPa (n=440), 0.028 (n=239) and 1.34 mmol (n=239) respectively. The sensitivity of peripheral VBGs to detect arterial blood acidosis (PH<7.35) using Pco₂ cut off of 7.35 was 96%.

Discussion

COPD exacerbations are quite often accompanied by respiratory failure and its timely detection is of crucial importance, since it provides the opportunity to reduce its high mortality by earlier interventions. The Gold standard investigation to confirm and sub categorize respiratory failure is ABGs but due to its invasive nature and possible complications, VBGs is an alternative if used carefully.

One of the main conclusions of our study was the high sensitivity (97.95 %) of PpcO₂ to predict arterial hypercapnia. Using a previously validated screening cutoff of 45 mm Hg in patients with acute exacerbation of COPD, McCanny P et al have also reported that venous PpcO₂ has 100% sensitivity in predicting arterial hypercapnia, however there was insufficient
According to a systemic review and meta-analysis (2014) of undifferentiated seriously ill patients in HDU and ED, the arteriovenous pH and HCO$_3$ have a significant correlation at all values; the correlation being strongest at normal values. PvCO$_2$ (>45 mm of Hg) had a good negative predictive value to exclude hypercapnic respiratory failure in arterial blood. The combination of peripheral venous blood gas analysis (VBGs) plus finger pulse oximetry (SPO$_2$) provided accurate information about acid-base status, ventilation, and oxygenation in these critical patients.

On the other hand, a meta-analysis by Byrne et al. (2014) has reported some contradictory results. The authors have found a wide 95% prediction interval of bias for venous PCO$_2$ (−10.7 mmHg to +2.4 mmHg). They have also noted that in some cases, venous PCO$_2$ was lower than arterial PCO$_2$. They concluded that these differences are sufficiently large enough to be of clinical significance. However, there was a good agreement between venous and arterial blood pH estimations i.e arterial pH being higher (0.03) than the venous pH (0.029–0.038). The reliability of conclusions from this meta-analysis is limited because of considerable heterogeneity among its studies.

In order to verify the feasibility of replacing ABG with VBG in patients with COPD exacerbations, a more recent meta-analysis (2018) of seven studies comprising of 1234 patients in the final analysis was performed. In conclusion, VBG analysis compared well with ABG for pH, HCO$_3$ and PCO$_2$ estimations, but not for PO$_2$ in patients with acute exacerbation of COPD. An important limitation of this meta-analysis which needs to be highlighted is that all included cases had a normal blood pressure and stable hemodynamics.

According to some studies, the agreement between arterial and venous pH, PCO$_2$, and HCO$_3$ is poor in patients with circulatory failure or shock, which give rise to uncertainties about the use of VBGs in the subgroup of COPD patients who present with circulatory failure/shock and ABGs are frequently needed in this subgroup of patients. Although, normal venous blood indices (PH, PCO$_2$ and HCO$_3$) rule out at least the possibility of severe acid-base disturbances, there is insufficient evidence to conclude whether these relationships persist in patients with mixed acid-base disorders.

To summarize, venous blood PCO$_2$ might be useful to screen for arterial hypercapnia and arterial sampling can be avoided if PCO$_2$ falls below 45 mm of Hg in a subgroup of COPD patients who are not in circulatory failure/shock. According to our study results, more than half (n=54/87) of our patients fall in this category. Normal venous PH, PCO$_2$, and HCO$_3$ can provide sufficient information about acid base status of these critically ill patients. VBG may be used for pH and PCO2 estimations and VBGs combined with spO$_2$ needs to be studied further for its utility in replacing ABG for monitoring purposes of particularly those patients who need arterial blood sampling several times a day.

**Conclusion**

VBGs instead of ABGs can be used as a screening test for detection of hypercapnia in hemodynamically stable patients presenting with acute exacerbation of COPD and VBGs indices (PH, PCO$_2$ and HCO$_3$) can provide guidance about the severity of acid base disturbance.

**References**

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