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Research Article

Role of Venous Blood Gases in the Diagnosis of Chronic Obstructive Pulmonary Disease Exacerbation; Systematic Review

Abdulrahman Bin Matar Al-Mughari[1]*, Walid Mishaal Madaj Al-Maghibi[2], Mohammad Nasser AL Qahtani[1], Ahmad Ali Al-Ghamdi[1] and Ahmed Abdulrahman Ibn Omayrah[1]

[1]Medical Laboratory Specialist, Prince Sultan Military Medical City, Riyadh, Saudi Arabia

[2]Laboratory Technician, Prince Sultan Military City, Riyadh, Saudi Arabia

***Corresponding Author:** Abdulrahman Bin Matar Al-Mughari, Medical Laboratory Specialist, Prince Sultan Military Medical City, Riyadh, Saudi Arabia.

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Abstract

Background: Arterial blood gas measurement is now the gold standard for assessing ventilatory dysfunction, metabolic abnormalities, and progress. There is ongoing discussion on the efficacy of venous blood gas in treating COPD patients. This study set out to systematically evaluate the clinical usefulness of venous blood gas in the diagnosis of COPD.

Method: The investigation was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. Keywords pertaining to blood gas analysis in COPD patients were used to search databases such as Medline, Google Scholar, and Scopus. Articles published between 2011 and 2024 were considered. Among the search terms are COPD, blood gas analysis, emergency, acute exacerbation, case-control study, cohort study, and risk factors.

Result and Conclusion: A total of 667 patients from 5 publications were included in this study. Although arterial and venous blood gases have a broad connection, there are slight differences in pH, pCO2, and HCO3. Four studies found a significant level of agreement between ABG and VBG values for pH and pCO2. One research emphasized how the importance to analyze samples promptly and how air pollution and sample delay affect these results, particularly pH and PO2. The ABG remains the gold standard of treatment in many clinical settings. However, VBG is increasingly being used to treat respiratory failure in patients with an acute exacerbation of COPD.

Keywords: Venous Blood Gases; Arterial Blood Gases; Chronic Obstructive Pulmonary Disease

Abbreviation

ABG: Arterial Blood Gas; CO2: Carbon Dioxide; COPD: Chronic Obstructive Pulmonary Disease; ED: Emergency Department; HCO3: Bicarbonate; LOA: Limits of Agreement; NIV: Non-Invasive Ventilation; pCO2: Partial Pressure of Carbon Dioxide; pH: Potential of Hydrogen; PO2: Partial Pressure of Oxygen; SaO2: Arterial Oxygen Saturation; SpO2: Peripheral Oxygen Saturation; VBG: Venous Blood Gas

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic progressive respiratory illness characterized by dyspnea caused

by the blockage of expiratory airflow. COPD is the sixth leading cause of mortality for women and the fourth leading cause for men worldwide. The main cause of COPD is cigarette smoking, but there are other reasons as well, including as environmental factors, genetics, chemicals, occupational dusts, and passive smoking [1].

Increased dyspnea, purulence, or amount of sputum are typical symptoms of acute exacerbations of COPD, which are frequently accompanied by worsening cough, wheezing, chest tightness, or exhaustion [2]. While more severe instances necessitate hospitalization, individuals with moderate COPD acute exacerbations can be treated as outpatients. Systemic corticosteroids, anticholinergic bronchodilators, short-acting inhaled beta-2 adrenergic agonists, and controlled oxygen +/- antibiotics are all part of the management [3]. Invasive or non-invasive ventilation (NIV) may be necessary for more severe exacerbations, particularly when type 2 (hypercapnic) respiratory failure is present. NIV has been demonstrated to quickly improve the respiratory rate and pH, minimize treatment failure, complications, duration of stay, and death as well as the necessity for intubation [4,5].

The current gold standard for measuring metabolic disturbances, ventilatory impairment, and progress is arterial blood gas (ABG) analysis. However, consequences from arterial sampling can include arteriospasm, infection, local hemorrhage, nerve damage, arterial thrombosis, vasovagal reaction, or embolization, which can lead to peripheral nerve trauma and ischemic injury to the fingers. Technically, the process itself can be challenging, and it could take many tries. Additionally, it is unpleasant, especially when done on the wrist's radial artery, and local anesthetic is not frequently utilized in clinical settings [6].

The effectiveness of venous blood gas (VBG) in treating these individuals is still up for debate. In patients with COPD, Ahmet., *et al*. [7] showed that peripheral VBG sampling could predict the ABG values of pH, pCO2, and bicarbonate (HCO3). Chu., *et al*. showed the same findings in patients with COPD who were on mechanical ventilation [8]. The readings of pCO2 were deemed too erratic to be of therapeutic utility, despite meta-analyses confirming the value of VBG and ABG values of pH, HCO3, and base excess [9,10]. The purpose of this study was to methodically assess the clinical utility of VBG in the diagnosis of COPD.

Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was followed in the conduct of the study. Databases including Medline, Google Scholar, and Scopus were searched using keywords related to COPD patients' blood gas analysis. The search was conducted from 2011 and 2024. Blood gas analysis, case-control study, emergency, acute exacerbation, cohort study, risk factors, and COPD are some of the search phrases. The references in the publications that were searched were also examined by hand to ensure that no important papers were missed.

To be qualified for inclusion, the publications had to include patients with COPD, examine the pH, PaCO2, and HCO3 measurement data, and use the inspection methodologies of ABG and VBG studies. The articles were reviewed independently by two authors, who then extracted the data and cross-checked it. To settle any disputes about the data selection procedure, experts were consulted.

Two researchers evaluated the papers independently in order to classify each study. They also assessed the completeness of the data. Based on these criteria, articles that did not meet the standards were removed from the research. A database was created to validate the data, and data extraction was done according to a preset format to ensure accuracy and consistency. To get the complete text of any study reports that were discovered to be deficient, the author was approached. A third author was consulted to settle any disputes between the two researchers. Essential information about the article, research methodology, study design, intervention measures, outcome evaluation indicators, and the outcome data were all included in the extracted data.

Results and Discussion

In this study we included 5 articles with a total of 667 patients, the studies were conducted in UK, Australia, and Ireland. All of the included studies follow prospective study design. There are minor variations in pH, pCO2, and HCO3, despite the broad correlation between arterial and venous blood gases. For pCO2 and pH, the research by Kelly, McCanny, and Wong revealed a reasonable degree of concordance between ABG and VBG readings. O'Connor's study underlined the significance of prompt sample analysis and the impact of air pollution and sample delay on these findings, specifically in PO2 and pH.

Based on Kelly., *et al*. The average pH difference between venous and arterial blood was 0.04 units. For pH, the 95% limits of agreement (LOA) ranged from -0.02 to 0.11, suggesting that the limits of agreement between ABG and VBG are small. The LOA was −22.63 to 6.58 mmHg, and the mean difference between arterial and venous pCO2 was −8.02 mmHg. Accordingly, venous pCO2 was probably always greater than arterial pCO2. As stated by McCanny., *et al*. Venous and arterial pH differed by an average of 0.039. Although the pH 95% LOA was not given, there was a substantial association between the two readings, as seen by the high correlation ($r = 0.826$, $p = 0.001$). Venous pCO2 was often higher than arterial pCO2, as seen by the mean difference in pCO2 between arterial and venous samples of -7.7 mmHg and LOA of -23.2 to 7.8 mmHg. Regression analysis revealed significant agreement between arterial and venous HCO3 and a high correlation between the two ($r = 0.972$, $p < 0.001$).

Strong relationships between ABG and VBG were seen by Kelly, McCanny, and Wong for pH, pCO2, and HCO3, with venous blood gas readings being comparable for pH and HCO3 and higher for pCO2. According to these research, VBG are a trustworthy substitute for arterial samples, particularly when circumstances are steady or when measuring certain parameters like pCO2 and HCO3.

O'Connor's study showed that sample processing (delay and contamination) had a major impact on ABG findings, especially PO2 and pH, even though it did not directly compare ABG with VBG. This implies that achieving reliable blood gas measurements, whether venous or arterial, depends on the prompt and appropriate treatment of samples.

Strong correlation between the VBG and ABG values of pH and HCO3 [10,11], have been documented in several investigations, including recent reviews, which are consistent with our findings. More debatable, though, is the predictability and connection of pCO2, with the majority of research indicating that ABG sampling is still required. The current study, on the other hand, indicates that pCO2 is somewhat associated. The variability of individuals included in earlier trials that were not restricted to COPD alone is most likely the cause of the discrepancy.

Some studies included ED patients [12,13] with metabolic abnormalities and severe cardiorespiratory impairment, both of which are known to impact pCO2 [11]. In actuality, the Pearson coefficient was higher at 0.855 [14] when evaluating only respiratory patients, and it increases to 0.908 when evaluating only COPD patients [7].

Limitations

Our study has some limitations as the included articles include patients with varying conditions, this heterogeneity in the study populations may influence the comparability of results. Inconsistent Criteria for Sample Inclusion for example; (Wong's study focused specifically on COPD exacerbations, while McCanny and Kelly included patients with a variety of respiratory conditions). The varied disease severity and management strategies could affect the outcomes, especially when comparing ABG to VBG in different clinical settings. The impact of sample delay and contamination (particularly in O'Connor's study) introduces additional sources of variability. Venous and arterial sample collection protocols may also differ between studies, impacting the reliability of comparisons.

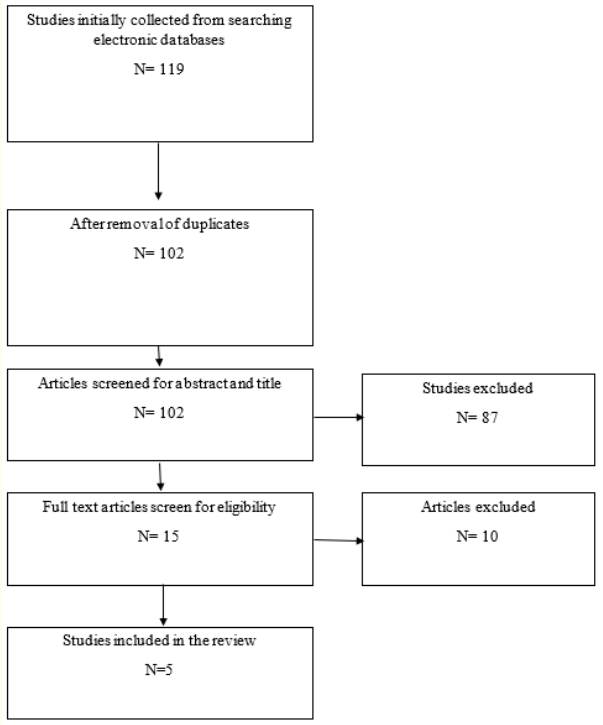

Figure 1: PRISMA consort chart of studies selection.

Citation	Study design	Country	Number of participants	Main findings
McKeever., *et al*. 2015 [15]	Prospective cohort study	UK	234	SaO2 and SpO2, as well as arterial and venous measurements of pH and HCO3-, agreed well. Compared to venous sampling, arterial sampling was more unpleasant and needed more tries.
Wong., *et al*. 2019 [16]	Prospective observational study	Australia	70	There is a strong correlation between VBG and ABG measurements for pH, pCO2, and HCO3, with the greatest agreement observed between pH and HCO3. In situations when arterial sampling is challenging, VBG may be a good substitute for ABG in the evaluation of blood gas parameters in patients with type 2 respiratory failure. Although venous samples are helpful, they might not be as accurate for pCO2 determinations as ABG, as seen by the lower agreement and broader Bland-Altman range for pCO2.
Kelly., *et al*. 2014 [13]	Prospective study	Australia	214	Acute pulmonary oedema (40%) and COPD (43%) were the main diagnosis. The average pH (a-v) difference was 0.04 pH units. The pCO2 (a-v) mean difference was -8.02 mmHg. Venous and arterial pH are clinically interchangeable for adult patients receiving NIV in ED because to the close and narrow arteriovenous pH agreement. Poor agreement with unacceptable large margins of agreement was found for pCO2.
McCanny., *et al*. 2011 [17]	Prospective study	Ireland	89	Using VBG sampling, all instances of arterial hypercarbia were identified when a 45 mm Hg screening criterion was used. With an average difference of 8.6 mm Hg and 95% limits of agreement ranging from -7.84 to 25.05 mm Hg, the bias plot showed a reasonable level of agreement between arterial and venous Pco(2). The average difference in pH across the groups was 0.039. With a regression coefficient of 0.955, linear regression analysis for pH indicated extremely close equivalency, and Spearman correlation revealed a significant correlation of 0.826.
O'Connor., *et al*. 2011 [18]	Prospective observational study	UK	60	The mean arterial pH was 7.4 and the mean venous pH was 7.3. The pH of the venous and arterial systems was correlated. The arterial pH was predicted using the regression equation arterial pH = 4.22 + 0.431 · venous pH. Analysis delay was not linked to any clinically relevant changes in arterial PO_2. At 30 minutes for patients experiencing a COPD exacerbation and 90 minutes for controls, a statistically significant drop in pH was seen. At 73 and 87 minutes, respectively, a clinically significant drop in pH was seen in individuals experiencing a COPD exacerbation. All samples, even those that were examined right after, showed a clinically significant rise in PO_2 in response to air pollution.

Table 1: Characteristics of the included studies.

Citation	Participants and inclusion	Sample and measurement
McKeever., *et al*. 2015 [15]	Patients diagnosed with an exacerbation of COPD, admitted to Nottingham University Hospitals Trust. ABG and pulse oximetry performed by a junior doctor, with parallel VBG samples collected.	ABG Collected using a heparinised needle and syringe system. VBG Collected via a butterfly needle or other needle into a heparinised blood gas syringe. Both samples were processed on the same ward-based blood gas analyzer and calibrated according to standard procedures.
Wong., *et al*. 2019	Consecutive patients with an acute exacerbation of COPD presenting to the ED at St George Hospital, Sydney, Australia, who have type 2 respiratory failure (T2RF).	ABG and VBG samples were collected for each patient. VBG samples were obtained within 15 minutes of the ABG samples, using standard venepuncture techniques. Both ABG and VBG samples were processed by the Radiometer ABL800 FLEX analyser.
Kelly., *et al*. 2014 [13]	The study concentrated on patients who needed an ABG analysis as part of their clinical treatment and were having NIV for acute respiratory distress. Additionally, a venous blood sample had to be taken concurrently from these individuals.	The study employed two different analyzers; Radiopoint 405 for the first part. Radiometer ABL 825 for the second part.
McCanny., *et al.* 2011 [17]	Individuals with a history of acute exacerbation and documented COPD who were 16 years of age or older were eligible. Patients who needed an ABG analysis for clinical care were particularly included in the trial.	To minimize any possible timing inconsistencies, paired ABG and VBG samples were taken within 10 minutes of the patient's presentation, with less than 5 minutes separating the two samples. To ensure minimal travel delay, samples were tested immediately on-site using the Cobas b221 model blood gas analyzer. In order to guarantee stable respiratory condition throughout measurement, patients were kept on a consistent proportion of inspired oxygen for at least ten minutes prior to sample collection.
O'Connor., *et al*. 2011 [18]	Patients having a COPD exacerbation who were 16 years of age or older were included by the authors. The COPD group was matched by age and sex with control participants who had no prior history of respiratory illness.	Patients' arterial and venous blood were obtained one after the other, with arterial samples being taken first. No more than five minutes passed between the arterial and venous samples before the venous sample was taken. To study the impact of air contamination on ABG values, a fraction of arterial blood samples were purposefully air-contaminated to replicate standard clinical practice.

Table 2: Participants inclusion and measurements.

Conclusion

In many clinical situations, the ABG is still the gold standard of care. Nonetheless, VBG is becoming more and more useful in treating respiratory failure in individuals with acute Exacerbation of COPD. This patient group may be affected by the peripheral venous circulation's pH, pCO2, and HCO3. More investigation is required, especially on the clinical results of using VBG to guide NIV following the collection of a first paired ABG/VBG sample.

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