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Arterial Blood Gas Analyses in Chronic Obstructive Pulmonary Disease: In the Clinical Laboratory or as Point-of-Care Testing?

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Abstract

Arterial blood gas analyses play an important role in the management of Chronic Obstructive Pulmonary Disease (COPD). These analyses are relevant in the diagnosis of chronic respiratory failure and in long-term, continuous oxygen therapy monitoring. Arterial blood gas measurements can be performed in a clinical laboratory or near the patient as Point-of-Care Testing (POCT). Most studies that have addressed the potential benefits of POCT blood gas analysis have considered intensive care units, emergency departments or cardiac surgery units. However, considering the importance of blood gas analysis in COPD and the growing interest in improving care for these patients, it is important to evaluate the clinical, operational and economic outcomes of POCT in Pulmonology offices compared with clinical laboratory measurements.

Keywords: Chronic obstructive pulmonary disease; Blood gas analysis; Point of care system; Patient outcome

Blood Gas Analysis in Chronic Obstructive Pulmonary Disease

Chronic Obstructive Pulmonary Disease (COPD) is one of the most prevalent pathologies in the Western world. According to the World Health Organization (WHO), 210 million people globally have COPD. In 2005, more than 3 million died from this disease and the WHO estimates that in 2030, 7.8% of all deaths will be caused by COPD, making it the third leading cause of death in the world. On the other hand, more than 70% of patients are under diagnosed. All of these data, in addition to the high costs generated for health services, highlight the need to improve the health status of these patients [1].

The analysis of arterial blood gases is essential to assessing oxygenation and ventilator status. It is relevant in acute respiratory failure assessments and also in chronic respiratory failure diagnoses. Chronic respiratory failure is defined as a Partial Oxygen Pressure (PaO_2) < 8.0 kPa (60 mm Hg) while breathing air at sea level. Chronic respiratory failure is one of the complications associated with COPD, and it has an increased morbidity and mortality that produce very high costs [2].

In general, arterial blood gas measurements are not indicated for all patients with COPD. Nevertheless, due to the relevance of PaO_2 and the availability of portable and easy-to-use blood gas analyzers, it would be possible to monitor more COPD patients when they needed. Commonly, arterial blood gas measurements should be performed when Forced Expiratory Volume in one second (FEV_1) is less than 50% of that predicted, or when there are clinical signs suggestive of respiratory failure or right-sided heart failure. The major clinical sign of respiratory failure is cyanosis.

Arterial blood gas measurement is also important for long-term oxygen therapy management [2,3]. COPD is the main disease for which this treatment is indicated. According to the American Thoracic Society Guidelines [4], it is indicated for patients:

- $PaO_2 \leq 7.3$ kPa (55 mm Hg) or oxygen saturation (SaO_2) $\leq 88\%$; or
- PaO_2 between 7.3 kPa (55 mm Hg) and 7.8 kPa (59 mm Hg) or SaO_2 89%, if there is evidence of "P" pulmonale, history of edema or polycythemia (hematocrit > 55%) ; or
- $PaO_2 \geq 8.0$ kPa (60 mm Hg) or $SaO_2 \geq 90\%$ only if there is an exercise desaturation, sleep desaturation not corrected by continuous positive airways pressure or lung disease with severe dyspnea responding to oxygen.

The goal of long-term oxygen therapy is to increase the baseline PaO_2 at rest to at least 8.0 kPa (60 mm Hg) at sea level, and/or produce SaO_2 of at least 90%, which will preserve vital organ function by ensuring adequate delivery of oxygen [2-4].

Point-of-Care Blood Gas Analysis

Point-of-Care Testing (POCT) is related to biomarkers that are measured outside the traditional clinical laboratory setting, near the patient, and these tests are not performed by laboratory personnel. POCT includes blood glucose testing, blood gas analysis, rapid coagulation testing, rapid cardiac markers, drugs of abuse screening, urine strips testing, pregnancy testing, fecal occult blood analysis, hemoglobin A1C, infectious disease testing, etc. With POCT, the laboratory diagnostic cycle is simplified because some activities are not needed, such as a doctor's request form or sample transportation to a laboratory. In addition, POCT reduces several possible error sources [5].

Blood gas analyses can be performed in a clinical laboratory or near the patient as POCT. In hospitals, POC blood gas analyses are

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common in emergency departments, intensive care units, delivery rooms and surgical suites. For these patients, the maintenance of oxygenation and an acid-base balance is crucial. These analyses can show rapid and clinically significant changes that might require effective monitoring for a prompt diagnosis and intervention [6].

In primary care, blood gas analyses can be relevant for monitoring and treating patients with chronic respiratory disease, though their implementation is not simple due to operational and economic aspects. Moreover, although testing could be important for managing chronic patients at home, its use is not frequent in home healthcare. However, due to miniaturization technology, some emergency transport systems (ambulances/helicopter-ICU) have portable devices for blood gas analyses [6].

To adequately implement and manage of these tests, it is important to select a team within an institution that is led by the clinical laboratory for the purpose of making decisions related to POCT viability and project performance [7]. This multidisciplinary team, also known as a POCT committee, can include medical and nursing staff and representation from pharmacy, IT, supplies, planning and finance departments and even patients. The team must be coordinated by the laboratory medicine with a POCT director and coordinator. This committee has technical and operational functions such as [7-13]:

- Justification of POCT in a particular setting
- Evaluation of POCT devices before their use in the hospital
- Coordination of connectivity planning to integrate test results into the clinical patient record. Using specific software, the clinical laboratory must periodically review the status of all POCT devices and make adequate decisions to ensure proper results management
- Performance of quality control and external quality assessment
- Preventive and corrective maintenance planning
- Design of an initial and continuous training program for the staff who are responsible for these devices as well as develop operator identification strategies
- Establish methods for results reporting
- Identification of potential error sources and effective indicators to improve patient safety

POC blood gas analyses should be performed according to the general recommendations for POCT described above. Therefore, the clinical laboratory must coordinate all technical and operational activities, such as methodological evaluations prior to use in clinical practice, adequate quality control processes and initial and continuing personnel training.

Point-of-Care Blood Gas Analysis in Chronic Obstructive Pulmonary Disease

Despite the potential benefits of POCT and the relevance of arterial blood gas analyses in COPD, there are no studies that have shown scientific evidence relating POCT to COPD patient management. Most studies have considered intensive care units, emergency departments and cardiac surgical suites. Therefore, there is currently a need to establish evidence-based practices for POCT that evaluate the impact on clinical, operational and economic outcomes [6].

The clinical outcome should be assessed in terms of the assistance it provides to the caregiver, improving the quality of diagnostic information (enabling better decision-making) and providing additional tools for patient counseling, as well as providing faster test results for a shorter delay to therapeutic intervention. Improved clinical outcomes must take into account the availability of expertise in the context of primary, secondary and tertiary care, set against the risks associated with the various care settings.

The quality of the blood gas results is also related to the turnaround time, which is the time from sample collection to measurement in the blood gas analyzer. This time should be as short as possible, in order to avoid errors in the results [14]. This goal is better achieved with POC blood gas analyzers installed close to the site of patient care.

The collection device for arterial blood sampling is usually a 1 to 3 mL self-filling, plastic, disposable syringe, containing a small amount of an appropriate anticoagulant, such as lyophilized heparin. The main technical problem is that plastic syringes are permeable to gases [2,14]. Any exposure to the atmosphere can markedly affect the pH, $PaCO_2$ and PaO_2. According to Graham's law, the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight. Exposure of blood to the atmosphere generally increases the PaO_2 towards 20.0 kPa (150 mm Hg), unless the patient is on supplemental oxygen, in which case the blood PaO_2 may decrease. Because atmospheric $PaCO_2$ is very low, the exposure of blood to air will lower the $PaCO_2$ of blood and increase the pH [15-17]. Ionized calcium could be also affected, because a loss of CO_2 increases the pH, which will lower the ionized calcium due to increased protein binding of calcium ions [2].

On the other hand, cells in stored blood continue to consume oxygen at a rate depending on storage temperature, storage time and the initial level of oxygen in the blood sample [18].

Both the effects of the movement of gases through plastic material and the reduction in oxygen levels by the metabolic rate of the cells can be higher when the time from sample collection to the analysis is longer. Moreover, if a pneumatic transport to clinical laboratory is needed, the vigorous agitation of the sample could have a noticeable effect on the PaO_2 if there are air bubbles present in the blood specimen. The alterations in blood gas results due to these factors could have a relevant impact on patient management, as we observed with a study including 112 COPD patients [19]. After specimen collection, the blood gas measurement was performed both in the Pulmonology office as POCT and in the clinical laboratory. Changes in PaO_2 levels were observed and there were discrepancies in the indication of long-term oxygen therapy in the blood gas reports in 13.4% of patients.

In addition to the time from sample collection to the measurement in the analyzer, it would be interesting to study the therapeutic turnaround time. This time is defined as the period from initiating the test to the receipt of the results and the implementation of any

intervention based on the results obtained. If this time is shorter, as occurs with POCT, it could be possible to manage patients in a single medical visit as a high-resolution consultation, without waiting for sample transportation to a central laboratory and the reception of results. This process could improve operational outcomes, reduce the length of hospital stays and improve use of staff time, thus increasing staff and patient satisfaction [20-22].

Finally, economic outcomes should be also considered. Not only the costs related to measurements should be considered, but also the possible economic benefits derived from less use of blood products or pharmacological treatments and a possible reduction in medical visits, unnecessary treatments or future cardiovascular events due to better patient management. Thus, the global costs should be estimated [5,23,24]: material, personnel, treatments and medical visits. In the study mentioned above [19], if we consider only the costs related to human and material resources for performing the blood gas measurement, the costs came to €3.47 and €1.35 per measurement at the doctor's office and the laboratory, respectively. However, when considering all issues involved, from the blood gas analysis request by the doctor to the indication (or not) for long-term oxygen therapy, the overall cost by process for the 112 patients in each unit was €16,769.89 and €22,260.97 for the doctor's office and the laboratory, respectively. This represents a difference of 24.7%.

Conclusion

Due to the relevance of arterial blood gas analyses in the diagnosis of chronic respiratory failure and long-term oxygen therapy monitoring in Pulmonology departments, it is important to evaluate whether these measurements will be performed in a clinical laboratory or as POCT, considering clinical, operative and economic outcomes for COPD patients.

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