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Brief Report

How to avoid analytical errors in blood gas analysis

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1. Introduction

Every laboratory should intend to obtain good quality results to meet the needs and satisfaction of both patients and clinicians. This becomes more crucial in critical care settings for timely and correct diagnosis and treatment. Blood gas analysis (BGA) is required in critically ill patients admitted to ICU/ICCU. Though the analytical phase in clinical laboratory testing is only a minor source of error as compared to preanalytical and post-analytical phases [1–3] yet it may affect the quality of the patient's test results if due care is not taken off. The International Organization for Standardization (ISO) has developed standards for medical laboratories (ISO 15189:2012)[4] and point-of-care testing (ISO 22870:2016)[5] and these are followed by most of the laboratories worldwide for good laboratory practices. Here are some important tips (based on clinically approved guidelines)[6–8] for how to avoid analytical errors to achieve good quality results for blood gas analysis:

2. Point-of-Care (POC) Analyzer (Handheld & Bench top)

1. Put on non-sterile gloves
2. Check the analyzer for:
   (a) It is ready to accept blood sample (calibration done)
   (b) Quality control check* done and it is "in control"
3. Collect the arterial blood with all precautions to avoid preanalytical errors.[9,10]
4. Analyze the sample-
   (a) Enter patient's data in the analyzer manually or using the barcode reader.
   (b) Enter the patient's body temperature** and oxygen supply***, if needed.
   (c) Mix the blood by gentle inversions and rolling between the palms of hands several times.
   (d) Introduce the blood sample into the analyzer (manufacturer's instructions should be carefully followed when introducing the blood sample into the analyzer). Overfilling and underfilling should not be done.
   (e) Check for any air bubble in the measuring path and at the sample/electrode interface, if measuring vessel is visible (if the bubble is present then wash the sample and repeat the measurement).

3. Laboratory Analyzer

1. Put on non-sterile gloves
2. Check the analyzer for-
   (a) Calibration is done
   (b) Quality control check* is "in control"
3. Check the sample for-

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(a) Proper sealing of syringe
(b) Leakage of blood
(c) Air bubbles
(d) Clots
(e) Correct filling of the syringe
(f) Improper transport and delay in transport
[These are sample rejection criteria]

4. Analyze the sample-

(a) Enter patient's data in the analyzer manually or using the bar code reader.
(b) Enter the patient's body temperature** and oxygen supply***, if needed.
(c) Mix the sample properly by -
i. Capillary blood - using a metal bar and magnet (remove the metal bar before introducing the sample into the analyzer).
ii. Syringe blood - mix the blood by gentle inversions several times followed by rolling the syringe between the palms of hands and expel 1-2 drops of blood from the syringe (to check the clots at the tip of the syringe and also to remove the blood present in hub of the syringe which can't be mixed well) before introducing the sample into the analyzer.
(d) Introduce the blood sample into the analyzer as per the equipment manufacturer's instructions).
(e) Check for any air bubble in the measuring path and at the sample /electrode interface, if the measuring vessel is visible (If the bubble is present then wash the sample and repeat the measurement).

4. Before Release of Report

In case of some erroneous values of patient's acid-base, oxygenation or ventilatory status -

1. Verify the values using a modified Handerson - Hasselbalch equation and alveolar gas equation to check if there is a discrepancy in the measurement or transcription. This would avoid the interpretation of confusing results.[11]
2. Check for type of blood (arterial/venous - due to a significant difference in pO2 and pCO2).[12]
3. Since the BGA results may be affected by some endogenous and exogenous substances, the analysts should be aware of these interfering substances.[6–8]

5. *Quality Control[4–8,13]

The purpose of QC is to maintain the accuracy and precision of test results so that the critical care of the patients is not compromised. It has been found that quality error rates are higher in POCT as compared to central laboratory testing.[14] Therefore, regular quality check should be done using electronic QC, built-in QC and liquid QC (however, the electronic QC checks only the device measurement signal and not the analytical pathway).

5.1. Internal quality control (IQC)

IQC is used to verify the intended quality of test results based on the laboratory's quality goal and acceptable error tolerance for the test results. The quality manager is responsible for the design, implementation and operations of quality control and its retrospective evaluation to ensure that the POCT and laboratory analyzers conform to the quality standards. This assures the operator that the reagents and the analyzer are operating correctly and thus gives confidence in reported test results. The frequency of running IQC varies depending upon the laboratory's quality goals. CLIA recommends testing one IQC every 8 hours using normal and abnormal controls. The commercial liquid QC samples should be handled and prepared for analysis as per manufacturer's recommendations to get correct results. The patient sample should be analyzed only if the QC results are 'in control'.

5.2. External quality control

As per clinically approved guidelines every laboratory should participate in proficiency testing (PT) program/external quality assessment (EQA) program conducted by external independent PT / EQA providers. This is done to evaluate the performance of the laboratory on specific analytes with regard to the testing quality of patient samples. Typically, PT/EQA occurs at regular intervals (monthly to six monthly). The laboratory analyzes the sample provided by the PT/EQA provider and sends the results to the PT/EQA provider who performs statistical analysis of all the results sent by the participating laboratories (peer group) and sends the report to the laboratory. This way the laboratory can evaluate its own results in comparison with other laboratories.

6. **Patient's Body Temperature

Hypothermia and hyperthermia may affect blood gas parameters due to the effect of heat on carbonic acid and oxyhemoglobin equilibria. Hypothermia may result in spuriously elevated pO2 and pCO2 whereas hyperthermia results in spuriously low pO2 and pCO2.[11] Since the analyzers measure at 37°C some analyzers do temperature corrections. It is better to report both temperature corrected and temperature uncorrected values as the topic of temperature correction is controversial.[9,15,16]

7. ***Abnormal or Misstated FiO2/barometric Pressure at the Time of Blood Draw

The results may suggest a spurious hyperoxemia or hypoxemia.[11]

8. Maintenance of Analyzer

1. For proper functioning of the analyzer it is important to keep its good maintenance as per manufacturer's instructions (for routine, preventive and corrective maintenance) given in the Instruction Manual.
2. The routine maintenance schedule depends on the workload on the analyzer and is performed by the analyst and it includes the cleaning the sample chamber and fluidic path with deproteinization protocol.
3. Preventive and corrective maintenance is generally done by the service engineer.
4. IQC should be run after the maintenance procedure to ensure that the analyzer is operating correctly and giving accurate test results.
5. The consumables such as sensors, cartridges, calibration solutions and QCs should be stored as per the manufacturer instructions.

Training of users: The personnel using the analyzer especially POC analyzer (nurses, technicians and resident doctors) should be given proper training for:

1. How to operate the analyzer
2. Routine maintenance
3. Understanding common error messages and how to correct them
4. Who to contact in case of serious troubleshooting.

Further, regular assessment of their competencies should be done by competent persons and should be documented.

9. Common Sources of Analytical Errors:[17]

Insufficient sample- smaller sample volume may have a risk of underfilling of the measuring vessel and fluidic path or erroneous test results due to dilution by liquid heparin or due to an increase in final heparin concentration.

Inadequate mixing of the blood sample before measurement may result in nonhomogeneous distribution of red blood cells across the electrode junction.

Presence of air bubbles in the measuring path/at the sample – electrode junction may give erroneous test results.

Calibration set points not accurate - the calibration materials should be traceable to certified reference materials and calibrators values should be entered correctly when entered manually.

Quality controls not run or out of desired range - QC results "in control" assure precision and accuracy of test results whereas "out of control" QC may result in erroneous test results.

Analyzer maintenance (routine, preventive and corrective maintenance) not performed.

Failure to run calibration regularly - the analyzer specific calibration procedures recommended by the manufacturer should strictly be followed for accurate analytical performance.

Analyzer's measuring chamber temperature (37°C) control errors (during calibration and sample measurement) which may be due to clogged or pinched tubing within the analyzer or from clogs or spaces in the sample stream).

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None.

11. Conflict of Interest

None.

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