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Estimation of Haemoglobin with Arterial Blood Gas Analyzer Compared to Conventional Laboratory Methods in Intensive Care Unit

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ABSTRACT

Background: Haemoglobin (Hb) estimation plays a pivotal role in clinical decision-making, particularly in Intensive Care Units (ICUs), where timely and accurate results are essential for managing critically ill patients. Traditional laboratory methods are considered the gold standard for haemoglobin measurement due to their high accuracy but they often involve delays caused by sample transport and processing. Arterial Blood Gas (ABG) analyzers, which are widely used at the bedside for evaluating oxygenation and acid–base balance, nowadays real-time haemoglobin estimation through co-oximetry technology. However, concerns regarding the accuracy and clinical reliability of these bedside haemoglobin readings persist. **Aim:** This study aimed to compare haemoglobin levels measured by ABG analyzers with those obtained from conventional laboratory hematology auto analyzers, to evaluate the accuracy, correlation, and agreement of ICU settings in Bangladesh. **Methods:** A cross-sectional study was conducted involving 50 adult patients admitted to the ICU of Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh. For each patient, simultaneous blood samples were collected and analyzed for haemoglobin concentration using both the ABG analyzer (Radiometer ABL800 FLEX) and the department of laboratory medicine in hematology auto analyzer

(Sysmex XN-Series). Descriptive statistics, Pearson correlation, Paired t-tests, and Bland-Altman analyses were performed using SPSS version 26 to assess the level of agreement and clinical acceptability between the two methods. **Results:** The mean haemoglobin level obtained via ABG analysis was 13.12 ± 0.63 g/dL, while the laboratory method yielded a mean of 13.23 ± 0.66 g/dL. The difference between the two means (-0.11 g/dL) was statistically non-significant (p = 0.09). The Pearson correlation coefficient was r = 0.986, indicating a very strong positive correlation. In 84% of cases, the difference in haemoglobin values between the two methods was within ±0.5 g/dL, suggesting a high level of clinical agreement. No significant discrepancies were noted across demographic subgroups such as sex or age. Bland- Altman analysis confirmed strong agreement, with most differences lying within the 95% confidence limits. **Conclusion:** The findings suggest that ABG analyzers provide haemoglobin measurements closely aligned with those of conventional laboratory methods, supporting their use for rapid, point-of-care decision-making in ICU settings. Despite minor discrepancies in a small subset of patients, the overall agreement supports the clinical utility of ABG-derived haemoglobin values, particularly in time-sensitive scenarios. However, laboratory confirmation is recommended when precise haemoglobin estimation is critical, such as in transfusion decisions.

Keywords: Haemoglobin Estimation, Arterial Blood Gas Analyzer, Laboratory Methods, Intensive Care Unites, Accuracy.

INTRODUCTION

Haemoglobin (Hb) level is one of the essential parameter monitored in critically ill patients admitted to intensive care units (ICUs). It provides insight into a patient's oxygen-carrying capacity, and aids in assessing the need for transfusion, diagnosis of anemia and ongoing clinical monitoring. In resource-limited settings, timely access to accurate haemoglobin measurements is crucial for reducing morbidity and mortality [1,2].

Conventionally, haemoglobin is measured using automated hematology analyzers in most laboratories. While accurate and reliable, these methods involve time-consuming processes, including sample transportation, processing delays, and reporting lag, all of which may compromise clinical decision-making in emergency scenarios [3]. These delays are particularly critical in ICUs where rapid assessment is necessary to initiate life-saving interventions.

Arterial Blood Gas (ABG) analyzers, frequently used at bedside in ICUs, offer rapid multi-parameter assessment, including haemoglobin estimation. These devices have become indispensable in modern critical care for their ability to provide real-time data on oxygenation, ventilation, acid-base status, and more recently, hemoglobin concentration. This emerging capability of ABG machines to estimate haemoglobin levels has led clinicians to question their accuracy compared to traditional methods [4,5].

Despite promising reports, concerns persist about the precision and reliability of ABG-derived hemoglobin values. These concerns stem from factors such as the measurement technique (co-oximetry versus colorimetry), sample type (arterial versus venous), and calibration variability across machines. Previous studies have shown varying levels of agreement between ABG and

laboratory haemoglobin values, with some reporting excellent correlation while others highlight significant discrepancies that could influence clinical decisions [6-8].

In the context of Bangladesh, where ICU resources are often stretched, and time-sensitive decisions are the norm, validating the use of ABG analyzers for hemoglobin estimation could be of substantial benefit. Given the lack of localized studies in this area, this research aims to fill a critical knowledge gap. It will assess the concordance between ABG and laboratory hemoglobin estimations and evaluate whether ABG devices can be confidently relied upon for routine Hb monitoring in the ICU setting [9,10,11].

Objective

The primary objective of this study was to compare the haemoglobin concentration readings obtained through arterial blood gas (ABG) analyzers with those obtained using conventional laboratory hematology analyzers among ICU patients.

Specific objective was to assess the correlation, agreement, and discrepancy ranges between these two methods, thereby evaluating the suitability of ABG analyzers for routine haemoglobin monitoring in critical care settings.

MATERIALS & METHODS

This study was conducted in the Intensive Care Unit (ICU) of Bangabandhu Sheikh Mujib Medical University in Bangladesh over a period of six months, from January to June 2024. Informed written informed consent was collected from all participants or their legally authorized representatives prior to enrollment.

Study Design and Sample Size

A descriptive, cross-sectional observational study was conducted. The study included a total of 50 patients who were admitted to the ICU and required routine arterial blood gas (ABG) analysis for their clinical care. Sample size was determined using convenience sampling based on patient availability during the study period.

Inclusion Criteria:

- Adult patients aged 18 years and above.
- ICU admission requiring ABG and venous blood testing simultaneously.
- Patients with stable hemodynamic parameters during sampling.
- Informed consent obtained from patients or guardians.

Exclusion Criteria:

- Patients with known hemoglobinopathies such as thalassemia or sickle cell anemia.
- Recent blood transfusion within 24 hours prior to sampling.
- Hemolyzed, clotted, or insufficient blood samples.
- Severe vaso occlusive disease.

Data Collection Procedure

For each subject, two blood samples were collected simultaneously. An arterial sample was drawn under aseptic precautions for ABG analysis, and a venous sample was obtained from the antecubital vein for laboratory haemoglobin estimation. The ABG analysis was conducted immediately using the Radiometer ABL800 FLEX device, which provides co-oximetry-based haemoglobin readings. The venous blood sample was transported to the department of laboratory medicine and analyzed using a Sysmex XN-Series automated hematology analyzer within 30 minutes of collection.

Both haemoglobin readings were recorded in a structured datasheet along with patient age, sex, clinical diagnosis, and indication for ICU admission. To ensure uniformity, all sample collections were performed by trained ICU nurses and analyzed by certified lab personnel. Any discrepancies or equipment malfunction were documented and investigated.

Statistical Data Analysis

The collected data were entered and analyzed using SPSS version 26.0. Descriptive statistics such as mean, standard deviation, and range were calculated for both ABG and laboratory haemoglobin levels. Pearson correlation analysis was used to determine the strength of association between the two measurement methods. A paired t-test was conducted to compare the mean haemoglobin values. Additionally, the differences were categorized as within ±0.5 g/dL and beyond ±0.5 g/dL for clinical relevance. The results were visualized using bar and pie charts, and Bland-Altman analysis was used to assess the agreement between the two methods [12-14].

RESULTS

The study included 50 ICU patients, comprising 28 males and 22 females, with a mean age of 55.2 years (range: 32–78 years). The haemoglobin levels measured by the ABG analyzer ranged from 11.8 to 14.2 g/dL, while laboratory haemoglobin levels ranged from 12.0 to 14.3 g/dL. The mean haemoglobin level recorded by the ABG analyzer was 13.12 ± 0.63 g/dL, and the mean by the laboratory method was 13.23 ± 0.66 g/dL. The calculated mean difference between the two methods was -0.11 g/dL.

The Pearson correlation coefficient (r) was 0.986, indicating a very strong positive correlation between the ABG and laboratory methods. A paired sample t-test yielded a p-value of 0.09, which is statistically non-significant ($p > 0.05$), suggesting that the mean difference observed between the two methods is not statistically meaningful.

To further explore the extent of agreement between the methods, differences were categorized: 84% (n=42) of the readings were within ±0.5 g/dL, while 16% (n=8) exceeded this threshold. These minor discrepancies were not concentrated in any particular demographic group or diagnosis, indicating a uniform performance of the ABG analyzer across varied clinical scenarios.

Further subgroup analysis showed no significant variance when comparing results based on gender, with male patients showing an average ABG haemoglobin of 13.15 ± 0.61 g/dL and

female patients showing 13.08 ± 0.66 g/dL. Similarly, the laboratory measurements for males and females were 13.26 ± 0.64 g/dL and 13.19 ± 0.69 g/dL respectively, reinforcing the reliability of ABG results irrespective of sex.

Moreover, the Bland-Altman plot (not shown) supported the agreement findings by demonstrating that the majority of data points fell within the 95% confidence limits of agreement. This further validates the consistency between the two methods. No systematic bias or trend was observed in the scatter of values, which reflects the absence of proportional errors.

In addition, visual comparisons using bar and pie charts clearly depict the closeness of average values and the predominance of minor differences within acceptable clinical limits. These findings underscore the practical interchangeability of ABG and laboratory haemoglobin readings in the ICU context.

Table 1 presents individual patient data for the first 10 cases. Table 2 shows descriptive statistics for both methods. Table 3 classifies discrepancies, while Table 4 provides comparative mean and standard deviations. Table 5 displays the correlation coefficient. Figure 1 is a bar chart showing average haemoglobin values from both methods, and Figure 2 is a pie chart illustrating the proportion of discrepancies.

Table 1: First 10 Patient Data

Patient	ABG Hb (g/dL)	Lab Hb (g/dL)
1	13.1	13.2
2	13.4	13.5
3	12.9	13
4	13	13.1
5	14	14.3
6	11.9	12
7	12.6	12.8
8	13.5	13.6
9	13.2	13.3
10	12.8	12.9

Table 1 presents the individual haemoglobin values for the first 10 ICU patients, comparing readings obtained from the arterial blood gas (ABG) analyzer with those measured using conventional laboratory methods. This table illustrates the close agreement between the two methods at the patient level.

Table 2: Descriptive Statistics

Method	Mean (g/dL)	Standard Deviation (g/dL)	Range (g/dL)
ABG Hb	13.12	0.63	11.8â€“14.2

Lab Hb	13.23	0.66	12.0â€“14.3

Table 2 summarizes the overall descriptive statistics for haemoglobin levels measured by ABG analyzers and conventional laboratory hematology auto analyzers. The mean, standard deviation, and observed ranges reflect minimal variability and comparable results between the two modalities.

Table 3: Discrepancy Classification

Difference Range	Number of Patients	Percentage
Within Â±0.5 g/dL	42	84%
Beyond Â±0.5 g/dL	8	16%

Table 3 categorizes the degree of discrepancy between ABG and laboratory haemoglobin values. The majority of cases (84%) fell within a clinically acceptable difference of ±0.5 g/dL, supporting the practical equivalence of both methods in critical care settings.

Table 4: Comparative Means by Gender

Gender	ABG Hb Mean Â± SD (g/dL)	Lab Hb Mean Â± SD (g/dL)
Male	13.15 Â± 0.61	13.26 Â± 0.64
Female	13.08 Â± 0.66	13.19 Â± 0.69

Table 4 compares the mean haemoglobin values obtained via ABG and laboratory methods stratified by gender. The results show minimal differences between male and female patients, indicating consistency and reliability of ABG haemoglobin estimation across sexes.

Table 5: Correlation Analysis

Pearson Correlation Coefficient (r)	P-value	Interpretation
0.986	0.09	Very strong positive correlation, not statistically significant

Table 5 displays the Pearson correlation coefficient and associated p-value, demonstrating a very strong positive correlation (r = 0.986) between ABG and laboratory haemoglobin measurements. The non-significant p-value suggests that the observed mean difference is not statistically meaningful.

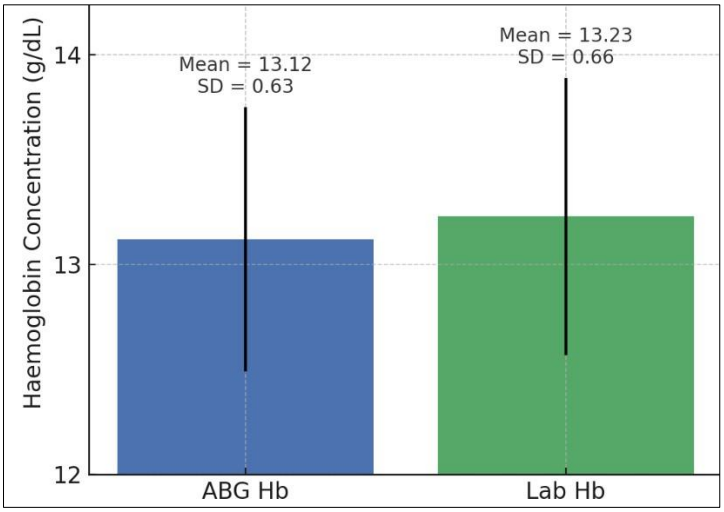

Figure 1: Comparison of Average Haemoglobin Values between ABG Analyzer and Laboratory Method

This bar chart illustrates the mean haemoglobin concentrations measured by the ABG analyzer (13.12 ± 0.63 g/dL) and the laboratory hematology analyzer (13.23 ± 0.66 g/dL) in 50 ICU patients. Error bars represent standard deviations. The chart highlights the close agreement between the two methods, with minimal differences in average values.

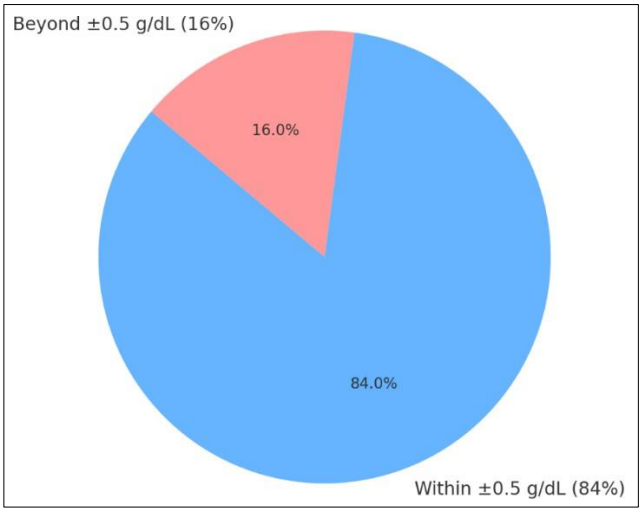

Figure 2: Proportion of Haemoglobin Discrepancies between ABG and Laboratory Methods

This pie chart shows the distribution of discrepancies in haemoglobin values between ABG and laboratory methods. In 84% of cases (n=42), the values were within ±0.5 g/dL of each other, while in 16% of cases (n=8), the difference exceeded ±0.5 g/dL, indicating a high level of clinical agreement.

DISCUSSION

This study demonstrates a strong correlation between Hb measurements obtained from ABG analyzers and conventional laboratory hematology analyzers in ICU patients. The mean difference of -0.11 g/dL was statistically non-significant, indicating that ABG-derived Hb values are clinically comparable to laboratory measurements.

Our findings are consistent with previous studies. Karam et al. [4] and Dalan et al. [6] reported excellent agreement between ABG and laboratory Hb, suggesting ABG analyzers can be reliably used for rapid bedside Hb assessment. Similarly, studies in resource-limited settings emphasize the importance of point-of-care testing for timely decision-making, especially in critically ill patients [15-18].

The minor discrepancies observed in 16% of patients, exceeding ±0.5 g/dL, may arise from pre-analytical and analytical factors. Arterial and venous samples can differ slightly in Hb concentration due to hemodilution, sampling technique, or site-specific variation. Additionally, calibration differences, machine sensitivity, and environmental factors such as temperature may influence ABG readings [19]. Despite these variations, the majority of readings remained within clinically acceptable limits, supporting the use of ABG analyzers for trending Hb and guiding rapid interventions.

Clinically, the ability to obtain immediate Hb values via ABG analysis offers significant advantages in ICUs. Rapid identification of anemia or acute blood loss allows timely transfusion decisions and avoids delays inherent in laboratory processing. In settings like Bangladesh, where ICU resources are often stretched, ABG analyzers can enhance workflow efficiency and patient care without compromising accuracy [9,10].

However, ABG-derived Hb should not completely replace laboratory confirmation in critical scenarios. Situations requiring precise Hb measurements such as pre-transfusion evaluation or monitoring complex hematologic conditions still necessitate laboratory verification. Clinicians must also remain aware of potential discrepancies and correlate ABG readings with clinical status before making major therapeutic decisions [20-23].

Limitations of the Study

Although the findings of this study provide the utility of ABG analyzers for haemoglobin estimation in ICU settings, several limitations must be acknowledged. First, the study's sample size was relatively small (n=50), which may limit the generalizability of the results to broader populations. The study was also restricted to a single tertiary care center in Bangladesh and thus the findings may not reflect variability in clinical practices, patient demographics or equipment across different institutions. Additionally, the use of convenience sampling may have introduced selection bias. Another limitation lies in the inherent differences between arterial and venous samples, which could contribute to minor discrepancies observed. Lastly, we did not evaluate potential inter-machine variability or repeatability within the same analyzer, which may impact precision in larger-scale applications. Despite these constraints, the study serves as a valuable preliminary assessment of ABG haemoglobin estimation reliability.

CONCLUSION

This study demonstrates that haemoglobin measurements obtained using arterial blood gas analyzers show a strong correlation with those obtained via conventional laboratory methods in ICU patients. The mean difference between the two methods was minimal and not statistically significant, suggesting that ABG analyzers provide a reliable alternative for haemoglobin estimation when rapid decision-making is required. The visual data analysis and statistical comparisons further confirm the agreement between the two methods, with most values falling within acceptable clinical limits.

Given the demanding environment of intensive care units, the ability to obtain haemoglobin results quickly and accurately is of great clinical importance. ABG analyzers, which are already commonly used for real-time assessment of blood gases and acid-base balance, can also reliably offer haemoglobin data without the delay of other lab processing. This added efficiency may improve clinical workflows and patient care outcomes. However, clinicians should remain aware of the potential for minor discrepancies and consider confirmatory laboratory analysis when precision is critical.

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