ONLINE FIRST

This is a provisional PDF only. Copyedited and fully formatted version will be made available soon.

DISASTER AND EMERGENCY MEDICINE JOURNAL

Are blood gas analyzers reliable in electrolytes and other parameters?

Authors: Zamir Kemal Erturk, Togay Evrin, Berkay Ekici, Bahadır Ertürk, Sinan Cem Uzunget, Tuğba Çandar

DOI: 10.5603/demj.97695

Article type: Research paper

Submitted: 2023-10-03

Accepted: 2023-11-27

Published online: 2023-12-20

ORIGINAL PAPER

ARE BLOOD GAS ANALYZERS RELIABLE IN ELECTROLYTES AND OTHER PARAMETERS?

Zamir Kemal Erturk[1], Togay Evrin[2], Berkay Ekici[3], Bahadır Ertürk[4], Sinan Cem Uzunget[5], Tuğba Çandar[6]

[1]Etimesgut Martyr Sait Erturk State Hospital, Istasyon Mah., Ankara, Türkiye
[2]Department of Emergency Medicine, UFuK University Medical Faculty, Ankara, Türkiye
[3]Department of Cardiology, UFuK University Faculty of Medicine, Ankara, Türkiye
[4]Kaman District Health Department, Türkiye
[5]Erkunt Health Unit, Ankara, Türkiye
[6]Ankara UFuK University Faculty of Medicine, Ankara, Türkiye

ABSTRACT

INTRODUCTION: Rapid diagnostic tests play an important role, especially for critical patients in emergency medicine. Blood gas analysis is one of these tests. The aim is to understand how reliable venous blood gas analyzers in electrolytes, haemoglobin haematocrits, and glucose are.

MATERIAL AND METHODS: This research is prospective clinical research that collected data within five months in the emergency department of a training and research hospital. 350 patients were included in the research. Venous blood gases and biochemical parameters were measured in these patients. Haemoglobin haematocrit, potassium, sodium, and glucose levels were measured by a central laboratory and blood gases analyzer.

RESULTS: The mean blood gas analyzer's results for haemoglobin were above 2 g/dL ($p < 0.001$) than central laboratory, likewise haematocrit, this difference was % 7.4 ($p < 0.001$). When considering US CLIA limits, results that were outside of USCLIA limits for haemoglobin and haematocrit were 78% and 92% respectively. Blood gas analyzers were more successful in electrolytes, potassium ($p < 0.001$), and sodium ($p < 0.001$). Despite statistical differences two analyzer methods, results that are outside of USCLIA limits were 20% for potassium and 12% for sodium. Blood gas analyzers were reliable for glucose when

compared with the central laboratory. There are no statistically significant results in the two measurement methods for glucose.
CONCLUSIONS: Venous blood gas cannot be used for biochemical tests other than glucose in emergency departments. Venous blood gas can guide the physician until the biochemistry results are finalized.
KEYWORDS: venous blood gas; electrolytes; haematocrits

ADDRESS FOR CORRESPONDENCE:
Zamir Kemal Erturk
Etimesgut Martyr Sait Erturk State Hospital, Istasyon Mah., 06790 Ankara, Türkiye
e-mail: dr.kemalerturk@gmail.com

INTRODUCTION

Electrolyte imbalance and acid-base disorders are frequently encountered in critical patients in the emergency department [1, 2]. Tests that give fast results play an important role, especially in the diagnosis and treatment of critical patients in emergency medicine. Blood gas analysis is one of these tests. In emergency department and intensive care services, blood gas tests are used widely. In addition, blood gas test results can be used as the early prognostic factor in some cases [3].

Electrolyte disorders can cause life-threatening arrhythmias. Rapid diagnosis tests point out preventing these arrhythmias [1, 4]. Blood gas analyzers and central laboratory analyzers, both of them can be used to measure the electrolyte values, however, the analysis times of these two measurement methods are very different [5]. Critical patients' treatment that must start quickly could be delayed if a blood gas analyzer is not available [6].

When electrolytes are measured by blood gas analyzers, physicians rarely rely on these results to make their clinical decisions. Because the correlation of the results with the central laboratory is controversial, there are a limited number of studies [5]. Furthermore, the results of the research have different conclusions.

The research aimed to test the usability and reliability of venous blood gas analysis results according to central biochemistry laboratory results.

MATERIAL AND METHODS

This research is prospective clinical research. Prospectively collected data within five months between May 2016 and November 2016 at Ufuk University Medical Faculty Emergency Service was used in this clinical research. Informed consent was obtained from

patients who agreed to participate in the research. The ethical committee for the research was obtained from the Ufuk University Non-Interventional Scientific Research Assessment Commission in accordance with the "World Medical Association Declaration of Helsinki" which was complied with in the research.

Biochemistry analysis is a gold standard method for electrolyte parameters, glucose, and haemoglobin haematocrit. Acceptable differences between laboratory measurements have been identified by the United States Clinical Laboratory Improvement Amendments (US CLIA). According to US CLIA, acceptable limits for sodium, potassium, glucose, haemoglobin, and haematocrit are ± 4 mmole/L, ±0.5 mmole/L, ±6 mg/dL, 7% and 6% respectively.

This study was conducted on patients diagnosed with Chronic Obstructive Pulmonary Disease (COPD) between the ages of 18 and 65 who presented to the emergency department with complaints of dyspnea. Patients with Saturation < 80%, patients with Glasgow Coma Scale < 15 and trauma patients were excluded from the study.

A total of 378 patients who met the research criteria were included but 28 patients were excluded from the research because of different reasons. Twelve of these 28 patients' results had a warning sign that blood glucose was incorrectly measured. Haemolysis was detected in seven samples. In the other four patients, the blood gas was tested in a different device in the central laboratory. One patient wanted to leave the research. In addition, patients, who were inserted with thinner than 20 G peripheral IV catheter and younger than 18 were excluded from the research. As a result, 350 patients had vascular access from the antecubital region. Venous blood gas values and biochemical parameters were measured in these patients and the samples were taken at the same time.

CBC and biochemistry tubes were delivered to the central laboratory within five minutes. In the laboratory biochemical parameters were studied by an ion-selective electrode (ARCHITECT c8000 Clinical Chemistry Analyzer, Abbott) diluted by using a sodium and potassium ICT (Integrated Chip Technology) kit. Glucose was assessed using the Hexokinase/G-6-PDH (Glucose 6-Phosphate Dehydrogenase) methodology (ARCHITECT c8000 Clinical Chemistry Analyzer, Abbott). Twenty parameters were evaluated in a full blood count test (Cell-Dyn/Rubby, Abbott). The blood gas analyzer (Radiometer, ABL800 BASIC) was localized in the Emergency Department and all samples obtained from patients were analyzed immediately by this analyzer.

Statistical analysis

Statistical analyses were performed using IBM SPSS version 20 software. The variables were investigated using visual (Histogram and Probability Plot) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk Tests) to determine whether or not they are normally distributed. Descriptive analyses were presented using the median and interquartile ranges for non-normally distributed and mean ± standard deviation for normally distributed variables.

Comparing two different measurement methods, the paired T-test was used for the evaluations if the data showed normal distribution characteristics. The Wilcoxon test was used for the comparison of two measurement methods in non-normal distribution data.

A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS

Of the 350 patients, 173 (49.4%) were female and 177 (50.6%) were male. The average age of the patient was 58. The lowest age was 18 and the oldest age was 96. The average age of the male patients was 60 and the average age of the female patient was 56. For haemoglobin measurement, the mean of blood gas analyzers and biochemistry laboratory were 15.4 ± 2.6 g/dL and 13.4 ± 2.2 g/dL, respectively. Tests are not peer-to-peer tests and cannot be used interchangeably ($p < 0.001$). However, there was a high correlation between the two methods ($r = 0.917$, $p < 0.001$). When evaluated according to the US CLIA limits in terms of haemoglobin, 78% (n = 273) of blood gas analyzer results were outside the US CLIA limits.

Haematocrit also had similar results to haemoglobin. The mean of venous blood gas and biochemistry laboratory for haematocrit were 47.4 ± 7.7% and 40.5 ± 6.0%, respectively ($p < 0.001$). However, there is a high correlation between the two measures ($r = 0.927$, $p < 0.001$). When assessed for haematocrit, 92% of blood gas analyzer results (n = 324) were outside the US CLIA limits

Venous blood gas and biochemistry laboratory potassium measurements were 3.99 ± 0.64 mmole/L and 4.06 ± 0.48 mmole/L, respectively ($p = 0.002$). They are not co-tests, but there is a high correlation ($r = 0,730$ $p < 0.001$). Additionally, only 20% of the values (n = 71) are outside the US CLIA limits.

The median values of sodium measurements in venous blood and biochemical laboratories are 137 (135–139) mmole/L and 138 (137–140) mmole/L, respectively ($p < 0.001$). Tests are not equivalent and cannot be used interchangeably. However, there is a high correlation between the tests ($r = 0.811$, $p < 0.001$). According to the biochemistry laboratory, 12% of the sodium values (n = 44) were outside the US CLIA limits.

Venous blood gas and biochemical laboratory glucose median values are 116 (100–143) mg/dL and 114 (100–141) mg/dL, respectively ($p = 0.165$). There is a high correlation between the two glucose measurement methods ($r = 0.960$, $p < 0.001$). According to the biochemistry laboratory, 26% of the results (n = 92) were outside the US CLIA limits. All results are shown in Table and Figure.

DISCUSSION

Blood gas analyzers and biochemistry laboratories use a similar methodology for haemoglobin and haematocrit measurements. Spectrophotometric evaluation after haemolysis is the basis of this measurement method. For this reason, no statistically significant difference is expected in the results of the two methods in theory but the reality is different. Similar research in the literature shows that these two methods' results are different from the following research.

According to Uysal et al. [8] research which is about the comparison of blood gas and central laboratory, they established differences in the mean of haemoglobin and haematocrit values (–0,06 ± 1.04 g/dL, 2.27% ± 3.41 respectively). For Zhang et al. [9], Ray et al. [10], and King et al. [11] this difference is 0.08 g/dL, 0.43 g/dL, and 0.19 g/dL respectively for haemoglobin. All these values were evaluated as statistically significant. Although the differences in outcomes are not as evident as in the present research, it is suggested that the tests are not co-tests.

Bland Altman and distribution point graphs for haemoglobin-hematocrit are shown in Figure 1. It can be easily seen that there is a good consistency with the laboratory measurements when considering the correlation coefficients. In the present research, however, there were significant differences between two different measurement methods like other studies in the literature. Most research does not analyze results separately for the USCLIA limits but results within limits according to US CLIA limits are important for the physician. Venous blood gas cannot be used in place of the central laboratory in terms of haemoglobin and haematocrit measurement.

When potassium in the venous blood gas was compared to the central laboratory, there was a statistically significant difference between the averages. When Bland Altman and distribution point graphs are examined, it is seen that the results are highly correlated with each other. When assessed according to US CLIA limits, the difference between the averages is within acceptable limits. However, if the potassium values in the venous blood gas are examined individually, 20% of the values are outside of the US CLIA limits.

According to Booth et al. [12] research, the difference means of the potassium results between venous blood gases and central laboratory was 0.56 mmole/L and the difference was statistically significant. Two tests are not interchangeable when evaluated according to US CLIA limits. The limitations of the research were retrospective and only 99 patients were included in it. The flushing of the injector with heparin may have caused different quantities of dilution effects. This situation could cause lower measurements of potassium values and lead to an increase in the difference with the laboratory. The present research was performed prospectively and negative pressure tubes containing lithium heparin for venous blood gas were used.

In research by Jain et al. [5] comparing arterial blood gas and laboratory potassium results, the mean difference was 0.46 mmole/L. When blood gas was evaluated separately in the hypokalemic normokalemic and hyperkalemic patient population, there was no significant increase in the differences and it was within the limits of US CLIA. This situation overlaps with the findings in the present research.

In research by King et al. [11] comparing arterial blood gas and central laboratory results for potassium results, the mean difference between the two tests was found to be 0.2 mmole/L. In this research, it was seen that, like the present research, had similar higher laboratory results. The cause of this difference may be the erroneous rise in potassium values due to the keeping of the blood sample in the laboratory.

In the research by Jose et al. [13] the difference in potassium values was found to be 0.03 mmole/L and only 5% of the results were outside the US CLIA limits. They concluded that, when making clinical decisions, blood gas analyzers were adequate and effective. In the following research, although the results are very close to each other, the authors do not participate in this interpretation. US CLIA out-of-limit results were higher in the present research. The authors think that this depends on the differences in the protocols. Each patient was included once in the evaluation and venous blood gas was used in comparison with the laboratory in the present research. In Jose et al. research, blood samples that belonged to the same patient were used multiple times for comparison.

Sezik et al. [14] performed retrospective research. Although it has shown a high correlation between the two methods, the results were observed outside the US CLIA limits. They concluded that these methods could not be used for each other. In the research blood gas analyses were performed using liquid heparin-washed injectors. This may have caused erroneous results as it may cause dilution.

In the research by Zhang et al. [9], the mean value of the difference between potassium is 0.43 mmole/L and it was observed that according to the US CLIA limit, the difference between the values is acceptable. However, in the research, involving 200 patients, 22% of patients (n = 44) were above the limit of US CLIA. The value of this research's superiorities over other research is that the values are examined individually by US CLIA limits and comments are made according to these parameters. The high rate of US CLIA in potassium makes clinically acceptable venous blood gases controversial.

There was a statistically significant difference between the average sodium value in the venous blood gas and central laboratory. When Bland Altman and distribution point graphs are examined, it is seen that the results are highly correlated with each other (Fig. 1). According to US CLIA limits, the difference between the averages is within acceptable limits. However, when sodium values in venous blood gases are examined individually, 12% of the values are outside the US CLIA limits.

Retrospective research by Sezik et al. [14] showed that the mean difference for the sodium value was 9.26 ± 6.54 mmole/L and a poor correlation was found between the values ($r = 0.407$ $p < 0.001$). Blood gas and biochemical sodium measurements could not be used interchangeably. The reason for these differences reason could be a lot of heparin used for bathing the syringe. In the present research, negative pressure tubes containing lithium heparin were used for venous blood gas. Sezik et al used sodium heparin for the bathing syringes. Compared to the present research, the mean difference between sodium results is higher than the present research. The type of heparin used in research may be the reason for these differences.

In research by Öner et al. [15], 1007 patients were included, and the mean difference between blood gas and biochemical laboratories for sodium was found to be 2.7 mmole/L, and a high correlation was found between the two measurements. The average of the differences is acceptable according to US CLIA limits. They have concluded that blood gas can be used in the management of the treatment of sodium until the central laboratory is concluded.

In research by Zhang et al. [9] The average difference between laboratory sodium and blood gas was 3.04 mmole/L. This difference is acceptable according to US CLIA limits. However, in the research for sodium value, 16% of venous blood gas results are out of the US CLIA limits. With these findings, blood gas sodium results are partially reliable for physicians

In research by Jain et al. [5] the mean value of the difference between the arterial blood gas and the central laboratory of sodium is 5.09 mmole/L. However, this difference was

not statistically significant. In the research, sodium values were divided into 4 groups. 145 mmole/L and higher, 135–145 mmole/L, 120–135 mmole/L and 120 mmole/L, respectively. The difference between the means increases in hyponatremia. The mean difference in the range of normal sodium values was 3.4 mmole/L. Statistically, this difference is significant but it is among the acceptable values according to US CLIA limits. This difference increases to 7.4 mmole/L in the 120–135 mmol/L group and to 12.8 mmole/L in the < 120 mmole/L group. In hyponatremic patients, the results are outside the acceptable limits for US CLIA limits. Clinically, venous blood gas cannot be used instead of biochemical measurement in cases of sodium balance disorders in which emergency diagnosis and treatment should be initiated, but it can give an idea to the physician as long as the results of the laboratory tests are over.

For glucose, the difference between means was not statistically significant. Bland Altman and distribution point graphs support this situation (Fig. 1). When assessed according to US CLIA limits, the difference between the averages is within acceptable limits. However, when the glucose values in the venous blood gas are examined individually, 26% of the values are outside the US CLIA limits

In the research by Uysal et al. [8], when the venous blood gas for glucose was compared with the biochemistry laboratory, the difference between means was –7.67 ± 25.17 mg/dL. The most reliable results were obtained in the glucose of other parameters. Similar results were found in the present research too.

In research by Öner et al. [15] the mean difference was found 17.3 mg/dL and there is a high correlation between the two measurement methods for glucose. When the distribution point graph for glucose is examined, it can be seen that the correspondence of the measurements decreases in hyperglycemic values.

Determining the acceptable differences for physicians is too difficult. Although 26% of patients' venous blood gas results were out of the US CLIA limits, the authors thought, this wouldn’t be important for physicians because US CLIA limits could cover clinically insignificant differences for glucose and this may cause this rate to be too high. According to the present findings, the authors think that venous blood gas gives reliable results on glucose.

CONCLUSIONS

The reliability of haemoglobin, haematocrit potassium, sodium and glucose values of venous blood gas should be discussed. The results show a high correlation with the laboratory results. However, when the results are examined individually, serious differences can be seen. Venous blood gas cannot replace biochemical and haematological examinations except for

glucose. It only allows the physician to have a prior opinion about the patient's clinic. Final decisions must be made according to central laboratory results.

As a result, venous blood gas cannot be used for biochemical tests other than glucose in emergency departments. Venous blood gas can guide the physician until the central laboratory results are finalized.

Article information and declarations

Data availability statement

Please contact author to request access to the data, and include a brief description of the intended use of the data. We are committed to supporting transparency and reproducibility in research.

Ethics statement

This research study was conducted with full adherence to ethical principles and guidelines.

Author contributions

Writing, Z.K.E.; conceptualization, Z.K.E.; methodology, Z.K.E., T.Ç.; formal analysis, Z.K.E.; data curation, T.E.; investigation, T.E., T.Ç.; supervision, T.E., B.E.; project administration T.E., B.E.; validation, B.E.; visualization, B.E.; review and editing, B.Er., S.C.U.

Funding

No funding.

Acknowledgments

We would like to express our gratitude to Prof. Atila Korkmaz who is working as the head of Emergency Department and contributed to the completion of this research.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

REFERENCES

1. Sterns RH, Cappuccio JD, Silver SM, et al. Neurologic sequelae after treatment of severe hyponatremia: a multicenter perspective. J Am Soc Nephrol. 1994; 4(8): 1522–1530, doi: 10.1681/ASN.V481522, indexed in Pubmed: 8025225.
2. Shiber JR, Mattu A. Serum phosphate abnormalities in the emergency department. J Emerg Med. 2002; 23(4): 395–400, doi: 10.1016/s0736-4679(02)00578-4, indexed in Pubmed: 12480022.
3. Kurowski A, Czyzewski L, Smereka J, et al. Blood lactate concentration after cardiac arrest resulting from myocardial infarction and outcome. Am J Emerg Med. 2016; 34(7): 1311–1313, doi: 10.1016/j.ajem.2016.04.044, indexed in Pubmed: 27182029.
4. Field JM, Hazinski MA, Sayre MR, et al. Part 1: Executive summary: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. JAMA: Circulation. 2010: S640–S656, doi: 10.1161/CIRCULATIONAHA.110.970889.
5. Jain A, Subhan I, Joshi M. Comparison of the point-of-care blood gas analyzer versus the laboratory auto-analyzer for the measurement of electrolytes. Int J Emerg Med. 2009; 2(2): 117–120, doi: 10.1007/s12245-009-0091-1, indexed in Pubmed: 20157454.
6. Flegar-Meštrić Z, Perkov S. Comparability of point-of-care whole-blood electrolyte and substrate testing using a Stat Profile Critical Care Xpress analyzer and standard laboratory methods. Clin Chem Lab Med. 2006; 44(7): 898–903, doi: 10.1515/CCLM.2006.148, indexed in Pubmed: 16776641.
7. United States Clinical Laboratory Improvement Amendment. **[??????]**
8. Uysal E, Acar YA, Kutur A, et al. How reliable are electrolyte and metabolite results measured by a blood gas analyzer in the ED? Am J Emerg Med. 2016; 34(3): 419–424, doi: 10.1016/j.ajem.2015.11.025, indexed in Pubmed: 26658635.
9. Zhang JBo, Lin Ji, Zhao XD. Analysis of bias in measurements of potassium, sodium and hemoglobin by an emergency department-based blood gas analyzer relative to hospital laboratory autoanalyzer results. PLoS One. 2015; 10(4): e0122383, doi: 10.1371/journal.pone.0122383, indexed in Pubmed: 25849375.
10. Ray, J.G., J.R. Post, and C. Hamielec, Use of a rapid arterial blood gas analyzer to estimate blood hemoglobin concentration among critically ill adults. Crit Care. 2002; 6(1): 72–75, doi: 10.1186/cc1456, indexed in Pubmed: 11940269.

11. King R, Campbell A. Performance of the radiometer OSM3 and ABL505 blood gas analysers for determination of sodium, potassium and haemoglobin concentrations. Anaesthesia. 2000; 55(1): 65–69, doi: 10.1046/j.1365-2044.2000.01166.x, indexed in Pubmed: 10594433.
12. Bozkurt S, Altunoren O, Kurutas E, et al. Comparison of the results of venous blood gas and laboratory measurement of potassium. Journal of Academic Emergency Medicine. 2012; 11(2): 73–76, doi: 10.5152/jaem.2012.02.
13. José RJP, Preller J. Near-patient testing of potassium levels using arterial blood gas analysers: can we trust these results? Emerg Med J. 2008; 25(8): 510–513, doi: 10.1136/emj.2007.053322, indexed in Pubmed: 18660404.
14. Sezik S, Kılıç T. Comparıson of the sodıum and potassıum results obtaıned by blood gas analysıs versus autoanalyzer. The Journal of Tepecik Education and Research Hospital. 2014; 24(1): 7–11, doi: 10.5222/terh.2014.95866.
15. Oner N, Kose A, Armagan E, et al. Utility of blood gas values in place of biochemical values in emergency department. Gaziantep Med J. 2012; 18(3): 155–159, doi: 10.5455/gmj-30-2012-105.

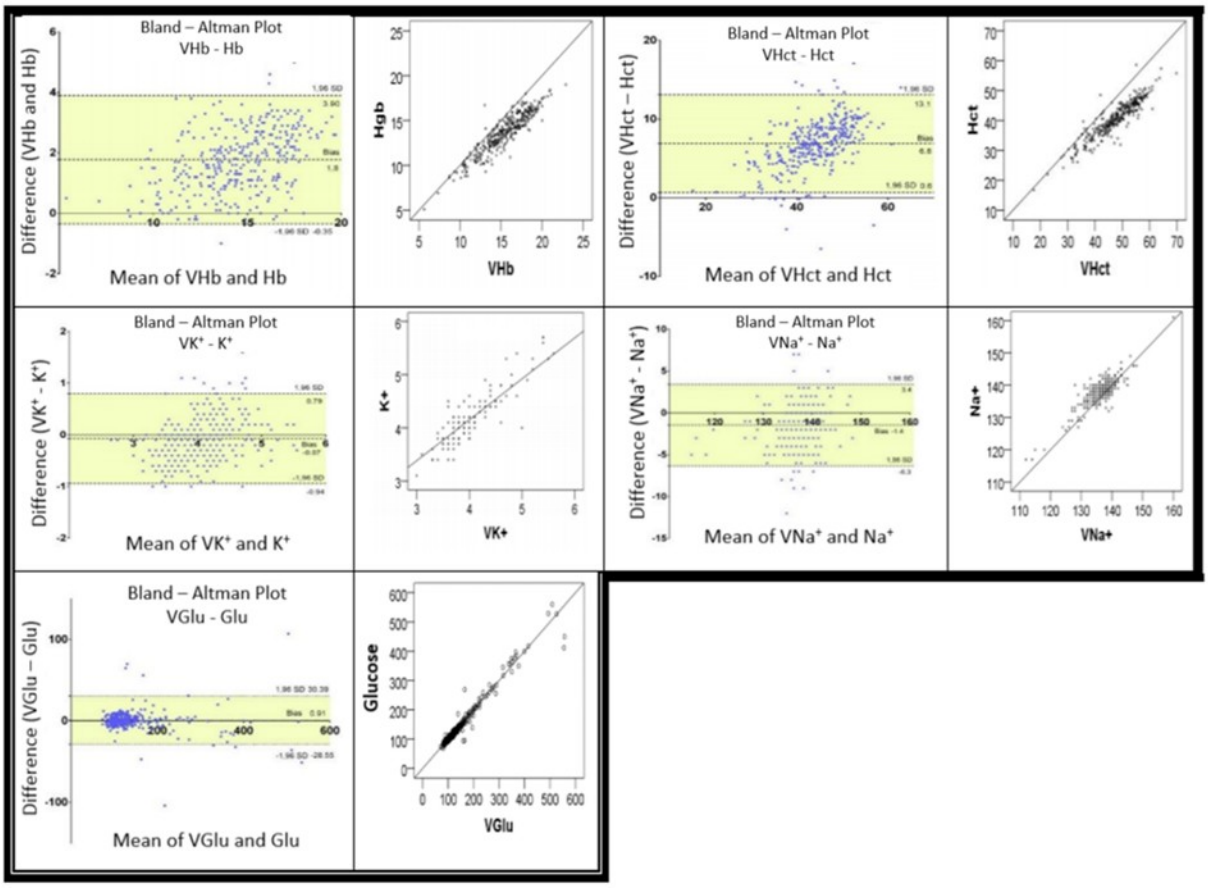

FIGURE 1. Bland — Altman Plots and Scatterplots

Table 1. Findings

Parameters	**Unit**	**Venous blood gases**	**Biochemistry laboratory**	**p-value**	**Out of US CLIA limits**
		Mean/SD	**Mean/SD**		
Haemoglobin	g/dL	15.4 ± 2.6	13.6 ± 2.2	**p < 0.001**	**78% (n = 273)**
Haematocrit	%	47.4 ± 7.7	40.5 ± 6.0	**p < 0.001**	**92% (n = 324)**
Potassium	mmole/L	3.99 ± 0.64	4.06 ± 0.48	**p = 0.002**	**20% (n = 71)**
Sodium	mmole/L	137 (135–139)*	138 (137–140)*	**p < 0.001****	**12% (n = 44)**
Glucose	mg/dL	116 (100–143)*	114 (100–141)*	**p = 0.165****	**26% (n = 92)**
***Median (25 Percentile — 75 Percentile)**			**Wilcoxon Test		

US CLIA — United States Clinical Laboratory Improvement Amendments; SD — **[???]**