RESEARCH ARTICLE

Difference in Sodium and Potassium Reading by Blood Gas Analyzer and Electrolyte Analyzer at Sanglah Hospital Denpasar, Bali, Indonesia

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Abstract

Introduction: Electrolytes measurement is a standard procedure in medical practice to diagnose diseases or disease-related complication. Recently, there is a various device used to analyze blood electrolytes, but the difference accuracy between devices is a problematic issue for clinicians. Thus, we evaluate the differences of sodium and potassium concentration reading by Blood Gas Analyzer (BGA) and Electrolyte Analyzer at Sanglah Hospital to assess whether the difference could be accepted according to Clinical Laboratories Improvement Amendments (CLIA). Methods: A cross-sectional analytic study was conducted in May 2017 at Clinical Pathology Laboratory of Sanglah Hospital, Denpasar. 30 subjects were enrolled consecutively during the study period and the blood samples were analyzed by both BGA and electrolyte analyzer. The data were analyzed using paired T-Test, Bland-Altman Plot, and Linear Regression. Result: The mean of sodium and potassium measured by BGA were 133.76 ± 5.68 mmol/L and 3.14 ± 0,86 mmol/L, respectively while electrolyte analyzer was 136,43 ± 6,48 mmol/L and 3,51 ± 0,9 mmol/L, respectively. Mean difference between sodium and potassium were 2.67 mmol/L (P=0,000) and 0.36 mmol/L (P=0,000), respectively. Bland-Altman plot analysis in sodium and potassium showed that the limit of the agreement was at -9.9 to 4.56 mmol/L and -1.28 to 0.56 mmol/L, respectively. Conclusion: There was a significant difference between BGA and electrolyte analyzer reading with BGA has higher acceptance level compared to electrolyte analyzer.

Keywords: *Natrium, Kalium, Blood Gas Analyzer, Electrolyte Analyzer*.

Introduction

Electrolytes are essential parameters that often be used to determine fluid balance due to underlying disease or treatment monitoring. According to The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), the reference method in electrolyte measurement is Ion Selective Electrode (ISE) method[1]. Currently, it is commonly used in electrolyte measurement and blood gas analysis. ISE method is divided into direct and indirect ISE which are differentiated according to whether the specimen is diluted or not.

The direct ISE method usually used in Blood Gas Analyzer (BGA) and point of care testing (POCT) whereas indirect ISE method is used in high throughput analyzers. The advantages of direct ISE method are shorter measurement time and not influenced by electrolyte exclusion effect that usually hampers the indirect ISE.[2] Direct ISE in BGA and indirect ISE in electrolyte analyzer are often used interchangeably by clinicians to monitor the electrolyte status of the patient. According to the Clinical Laboratories Improvement Amendment (CLIA) guidelines, the acceptable difference range of two measurements is up to 4 mol/L for sodium and up to 0.5 mmol /L for potassium[3]. Some studies have compared electrolyte measurement between direct ISE and indirect ISE.

These studies showed that electrolyte result from BGA was significantly different with electrolyte analyzer.[4,5] However, several others report insignificant findings.[6] Because of the discrepancy, the authors aimed to evaluate the difference in sodium and potassium levels between BGA and electrolyte analyzer and the percentages of

the differences that still acceptable to CLIA. These data are fundamental to conclude whether sodium and potassium in BGA with electrolyte analyzer can be used interchangeably or not.

Methods

A cross-sectional analytic study was conducted at Clinical Pathology Laboratory Sanglah Hospital throughout May 2017. A total of 30 patients who perform electrolyte examination on BGA and electrolyte analyzer were consecutively enrolled. The inclusion criteria were all of the patients who had BGA examination and patients with hemolysis were excluded. The arterial samples were taken using a dry heparinized BGA syringe and a 3 ml syringe which was inserted in a plain tube.

Whole blood samples were analyzed for an hour after collection and were analyzed by BGA Siemens Rapidlab 1348 using direct ISE method. Samples in plain tubes were allowed to clot for 30 or 60 minutes at $20-25^0C$ and then centrifuged at 1100-1300g for 15 minutes using a fixed angle centrifuge. These serum samples were analyzed by Cobas c601 device using the indirect ISE method. The internal quality control procedure was performed for both devices according to Westgard. The readings from both devices were compared and analyzed by paired T test, Bland-Altman plot, and linear regression using SPSS version 17 software with a P value < 0.05 was considered significant.

Results and Discussion

Overall, 30 blood samples were enrolled in this study during the research period. The baseline characteristic and the mean reading of sodium and potassium from BGA and Electrolyte Analyzer is presented in **Table 1**. The mean age was 34.3±26.08 years with the youngest sample was one year old and the eldest one was 72 years old. More than half of the sample was male (63.3%).

The mean of sodium BGA reading was 133.76±5.68 mmol/L while the mean of potassium reading at 3.15±0.87 mmol/L. The result of electrolyte analyzer reading was a little bit higher compared to BGA with mean sodium at 136.43±6.48 mmol/L while the potassium was 3.51±0.90 mmol/L. The mean difference in sodium reading between those devices was recorded at 2.67±3.68 while the potassium was at 0.37±0.47. The comparative analysis between the readings of those devices reveals that the differences were statistically significant. These results support another similar study[4, 5, 7-12].

Table 1: The baseline characteristic and the differences between BGA and Electrolyte Analyzer reading

Variabels	Mean/Proportion
Age	34.3±26.08 years
Min	1 Year old
Max	72 Years old
Sex	
Male	19 (63.3%)
Female	11 (36.7%)
Blood Gas Analysis (BGA)	
Natrium	133.76±5.68 mmol/L
Kalium	3.15±0.87 mmol/L
Electrolyte Analyzer	
Natrium	136.43±6.48 mmol/L
Kalium	3.51±0.90 mmol/L
Mean Difference Na	2.67±3.68*
Mean Difference K	0.37±0.47*

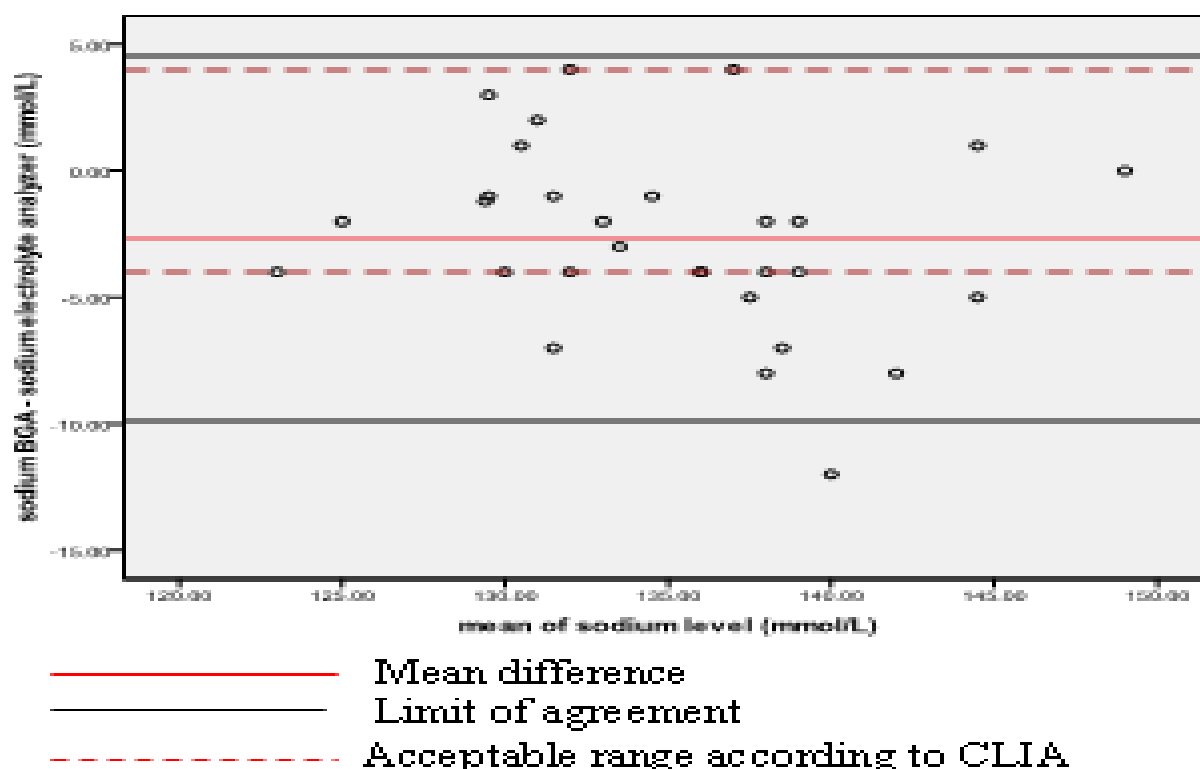*Statistically significant at P<0.001

Figure 1: Bland-Altman plot for sodium readings

The acceptable difference range according to CLIA for sodium parameters was up to 4 mmol/L. In this study, the limit of agreement was found at -9.9 - 4.56 mmol/L with 23 samples (76.6%) met the criteria of CLIA (**Figure 1**). Meanwhile, the acceptable difference range according to CLIA for potassium parameters was up to 0.5 mmol/L. In this study, the limit of agreement was found at -1.28 - 0.56 mmol/L with 17 samples (56.6%) met the criteria of CLIA (**Figure 2**).
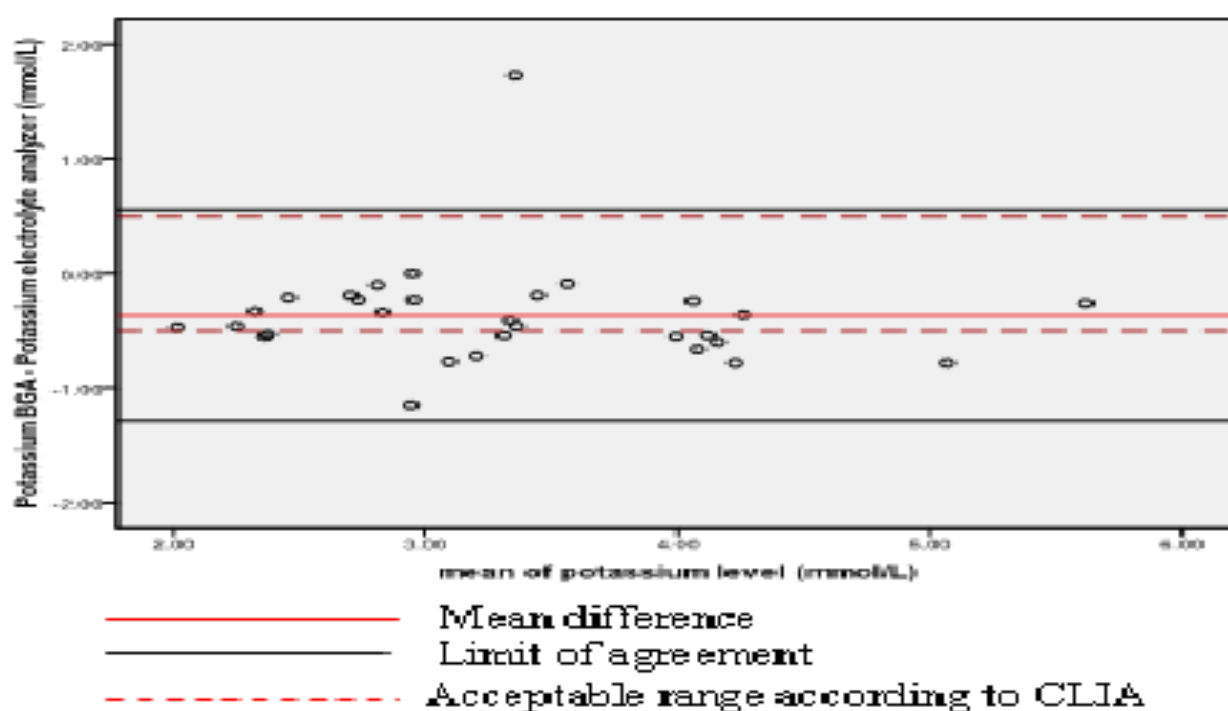

Figure 2: Bland-Altman plot for potassium reading

The linear regression analysis on sodium parameter showed that the R^2 value was found at 0.68 with the conversion formula for BGA sodium reading (x) to electrolyte

analyzer sodium reading (y) was y = 0.723(x) + 35.15. Meanwhile, the R^2 value for potassium parameter was 0.739 with the conversion formula for BGA potassium reading (x) to the electrolyte analyzer reading (y) was y = 0.824(x) + 0.252. Although the formulation could minimize the gap, this action is not recommended.[5] Many factors can affect the results of sodium and potassium measurement.

At the preanalytic stage, hemolysis occurred within the blood sample could increase the serum potassium level. In this study, the samples with hemolysis were excluded to avoid confounding result. Nevertheless, there will always be a difference in serum potassium compared to plasma or whole blood in which the latter was 0.1-0.7 mmol/L lower than the serum samples. Excess potassium in the serum is mainly due to platelet degradation during the coagulation process.[2] A follow-up study of 10 whole blood samples and serum analyzed by BGA only showed a difference in the mean potassium at 0.386 (P = 0.000) in which the serum potassium was higher than the whole blood potassium level.

In this study, serum potassium reading was higher than the whole blood potassium which is in accordance with the theory. Another factor that potentially affects the result is storage temperature. At a temperature of 4^0C, potassium reading will falsely increase due to the inhibition of glycolysis.

In contrast, the uncentrifuged sample would also give falsely lower potassium reading if stored at 37^0 C.[2] In this study, the samples were analyzed at a maximum of 1 hour after collection for whole blood sample and were allowed to clot in 30-60 minutes at 20-25^0 C for serum samples before analysis. This practice would prevent falsely high potassium reading. Leucocytosis and glucose concentrations could also affect the potassium reading. Leukocytes count above 100×10^9 cells /L will induce glycolysis which results in intracellular diffusion of potassium ion and, thus, falsely lowers the reading value. In contrast, leukocytes count higher than 300×10^9 cells /L will results in falsely increased potassium reading due to leukocytes damage [2].

In this study, the sample was originated from one patient, so the effect of leucocytosis and glycolysis can be ignored. The falsely decreases and increases in sodium and potassium could also cause by electrolyte exclusion effects on indirect ISE methods in which hypoproteinemia or hypolipidemia will lead to a false increase in sodium and vice versa.[2,12] The follow up study to assess the correlation between total protein, cholesterol, and triglyceride with a difference of sodium reading from electrolyte analyzer and BGA was conducted in 10 serum samples.

The result showed a negative correlation for total protein (r=0.337, P> 0.05) and cholesterol (r=0.180, P> 0.05), but positive correlation for triglycerides (r=0.294, P> 0.05). The low and insignificant correlation was possibly caused by the fact that the level of total protein, cholesterol, and triglycerides was within the normal range in all samples. Based on previous studies, [2, 12] these factors could affect the result of indirect ISE methods. Although paired T-tests had shown significant differences, the Bland-Altman plot analysis was needed to explain in detail the limit of agreement in this study and the percentage of samples with acceptable differences according to CLIA[13] in order to draw a definitive conclusion about the interchanging use of either devices or method.

The limits of agreement of the research on both the sodium and potassium parameters were more extensive than the acceptable range of differences according to CLIA with only 76.6% of samples had acceptable sodium difference while only 56.6% of the samples had acceptable potassium differences. Therefore, it can be concluded that this two methods cannot be used interchangeably. A variety of reasons state the direct ISE is the method of choice for electrolyte analysis.[2,12] Major changes in plasma lipids or protein concentrations may occur in certain clinical conditions and therapy as well as in the administration of parenteral lipid emulsions.

This does not affect the electrolyte measurements reading using the direct ISE. The ion activity, which is the basis of direct ISE measurements, will still be converted to concentrations unit using the "flame mode" which is a recommendation of IFCC.[1] In addition, direct ISE method does not depend on coagulation processes that may affect the potassium value and shortening the turnaround time that suitable for the

emergency situation. Nevertheless, this study has some limitation such as not measuring the total proteins and lipids that play an important role in the electrolyte exclusion. Thus, it was not possible to evaluate the effect of these factors on sodium and potassium reading. Another limitation is, due to consecutive selection sample, the proportion of samples with low, normal, and high levels was not proportional in the study population which was dominated by samples with low potassium and sodium level.

Conclusion and Suggestion

The reading of sodium and potassium levels by BGA and electrolyte analyzer was found to be significantly different. 76.6% sample had an acceptable difference according to CLIA for sodium parameters and 56.6% for potassium parameters. According to the result, the clinicians are advised not to use the reading of sodium and potassium from BGA and electrolyte analyzer interchangeably.

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