Original Research Article

A comparative study on ABG analyzer versus Laboratory analyzer for estimation of Electrolytes

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Abstract

Background: Electrolytes are very important for the continuation of the physiological functions of the human body. When dealing with sick patients admitted in ICU the speed and accuracy of tests to detect electrolyte derangements is very important. **Materials & Methods:** The present study was planned with the target to research whether electrolyte levels assessed using ABG analyzer and laboratory auto-analyzer (AA) were equivalent or not. 100 paired venous and arterial samples from patients admitted to the Medical Intensive Care Unit (ICU) were analyzed for electrolytes on the ABG analyzer and AA. Data were collected and analyzed with the help of Microsoft Excel version 2010. **Results:** The mean level of Na^+ in serum samples on AA was 139.5±7.9 mmol/L compared 135.8±9.8 mmol/L in ABG analyzer($P < 0.05$). The mean K^+ in serum sample on AA was 3.9 ± 0.9 mmol/L as compared to 3.6 ± 0.8 mmol/L in ABG analyzer ($P < 0.05$). The difference in sodium levels through the 2 analyzing methods was statistically significant in the hyponatremia group (($P < 0.05$). The difference in Potassium levels through the 2 analyzing methods was statistically significant in the normokalemic group (($P < 0.05$). **Conclusion**: So the physicians should be very cautious in using the electrolyte results of AA and ABG analyzer in inter exchangeable manner. The difference between the measured sodium and potassium was found to be significant. We conclude that critical decisions better to be made by trusting the potassium values obtained from the arterial blood gas analysis.

Keywords: Electrolytes, ABG, Auto-analyzer, POCT

Introduction

Electrolytes are charged elements that are essential for normal cellular functioning in most tissues of the body. They play vital roles in regulation of the membrane potential, steady process of neuro-hormonal pathways, energy transformation and the fluid, and acid-base balance with in the body. Electrolyte abnormalities can precipitate life-threatening events. The incidence of electrolyte disorders is nearly 25% in ICU patients[1]. In recent studies, it is shown that in ICU patients, serum sodium and potassium levels are significant predictors of mortality[2-4]. That's why, prompt and complete correction of electrolyte disorders in ICU patients is vitally important. Although the more common practice is to measure electrolytes in serum which takes relatively more time due to requirement of separation of serum. Emergency and critical care physicians prefer Point-of-care testing (POCT) for measurement of electrolytes along with blood gas analysis (ABG), which helps them in diagnosis and monitoring of electrolyte imbalance in a short turnaround time. The quicker diagnosis play vital role in timely patient management by saving precious minutes. Ion selective electrodes (ISEs) are so far commonly used method for electrolytes estimation in clinical laboratories.

Despite the advantage of a decreased turnaround time with POCT, which will translate to prompt deciding, concerns are raised regarding the accuracy and reliability of POCT devices. Conflicting results from various studies, probably due to the use of different devices, made it serious concerns. The difference between ABG analyzer and AA is given in table-1. The United States Clinical Laboratory Improvement Amendment (US CLIA) 2006 accepts a difference of 0.5 mmol/l in measured potassium, and 4 mmol/l in measured sodium, from the gold standard measure of standard calibration solutions[5]. Some studies concluded that results differed significantly for plasma sodium and chloride concentrations, others also found significant differences in potassium values[6,7]. Moreover, there is paucity of literature comparing the results of electrolytes in an arterial sample processed on ABG analyzer and serum sample processed on a bench top electrolyte analyzer both of which use direct ISE method without any need of predilution of sample. The present study was planned with target to research that whether electrolyte levels assessed using ABG analyzer and laboratory AA were equivalent or not.

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Table 1: Differences between the blood gas analyzer and laboratory analyzer

S. No	Blood gas analyser	Electrolyte analyser
1	Whole blood analysed	Serum sample analysed
2	Arterial sample used	Venous sample used
3	Heparinized sample used	Serum sample used without anticoagulant
4	TAT is short – within 5 mins	TAT is long – within 30mins
5	Urine electrolytes cannot be measured	Urine electrolytes can be measured

Materials and Methods

This was a cross-sectional observational study conducted between February to May 2021 in the Biochemistry Laboratory of a tertiary care hospital. The prior approval from Institutional Ethical Committee was taken. The samples received from emergency and ICU were included in the study. Patients with positive informed consent and aged between 18 to 65 were included in this study. Only participants whose paired blood samples could simultaneously be collected from an arterial catheter were included in our study. Negative informed consent rendering, aged under 18 or more than 65, without an arterial catheter and the blood samples could not simultaneously be collected patients were excluded from our study. These sampleswere collected only when there was indication. Paired blood samples from 100 patients were collected. The serum sample was obtained by withdrawing 4 ml of venous blood in BD plain vacutainer (Becton Dickinson and Company, Franklin Lakes, USA) under aseptic conditions. For the ABG analyzer, 0.6 ml blood was collected in commercially available plastic ABG syringes (BD A-LINE ABG collection syringe of 1.0 ml volume, 0.6 ml recommended draw volume, coated with lithium-heparin) under sterile environment using standard sampling protocol. Quality control was ensured by collecting samples through trained staff of emergency and ICU in the hospital and analyzed on two analyzers located in the central laboratory under similar environmental conditions. ABG samples received in BD heparinized syringes were processed on Radiometer ABL 90 FLEX analyzer immediatelyfor electrolytes along with blood gases. The samples received in BD vacutainer for serumwere centrifuged within 20–30 min after clotting of blood. Electrolytes were measured on Cobas c 311 AA. Both these instruments AA as well as ABG, work on the principle of direct ISE technology. The internal quality control of BIORAD was run daily on both the instruments during the study period. The mean $Na^+$was 127.1 mmol/L and 142.8 mmol/L for the concentration of 127.3 mmol/L (124.24-130.36 mmol/L) and 143.1 mmol/L (140.74-145.45 mmol/L) respectively on electrolyte analyzer and 126.8 mmol/L and 142.5 mmol/L on ABG analyzer. The mean K^+ was 3.99 mmol/L and 6.1 mmol/L for concentrations of 3.93 mmol/L (3.83-4.03 mmol/L) and 6.06 (5.96-6.16) mmol/L, respectively, on electrolyte analyzer and 3.89 mmol/L and 5.98 mmol/L on ABG analyzer. Our laboratory also participates in the external quality assessment scheme (EQAS) for clinical chemistry (monthly) Program (BC50) Cycle 19 ran during the study interval.Z-score for electrolytes were between -1 to +1 in all three months when we did the present study.

Statistical Analysis

A total of 100 simultaneous ABG and serum samples were collected. The data were collected and arranged in tables using Microsoft Excel version 2010. The Mean, standard deviation and *P* value was calculated. *P* value < 0.05 was considered statistically significant.

Results

Table 2: Comparison of results in arterial and serum samples

Electrolyte	No. of samples	ABG value	Serum value	Mean difference	P value
Sodium level	100	135.8±9.8	139.5±7.9	3.7	< 0.05
Potassium level	100	3.6 ± 0.8	3.9 ± 0.9	0.36	< 0.05

The mean age of the participants was 51.2 years. There were 58 male and 42 female patients in the study. The mean level of Na^+ in serum samples was 139.5±7.9 mmol/L compared 135.8±9.8 mmol/L in ABG [Table 2]. We found significant difference when the mean (±SD) of sodium levels compared between ABG and AA ($p < 0.05$). The maximum difference in sodium level was 13 mmol/L and the minimum 0 mmol/L. The mean difference among the results was 3.7 mmol/L showing a negative bias in arterial sample. There were 67 samples with variation up to 4 mmol/L which is acceptablelimit for Na^+ as per Clinical Laboratories Improvement Amendment (CLIA) guidelines[5].

The mean K^+ in serum sample was 3.9 ± 0.9 mmol/L as compared to 3.6 ± 0.8 mmol/L in ABG sample ($P < 0.05$) [Table 2]. A significant difference also found when the mean (±SD) of potassium levels compared between ABG and AA ($p < 0.05$). The maximum difference in measured potassium value was 0.8 mmol/L, and the minimum 0 mmol/L. The mean difference among the results was 0.36 mmol/L showing a positive bias in serum sample. There were 69 samples with variation up to 0.5 mmol/L which is acceptablelimit for K^+ as per Clinical Laboratories Improvement Amendment (CLIA) guidelines[5].

Table 3: Concordance between arterial blood gas and serum electrolyte values

Electrolyte	No. of samples	ABG value	Serum value	Mean difference
Sodium < 130 mmol/L	23	125.9±6.9	130.1±3.7	4.2
Sodium 130–145 mmol/L	59	137.1±7.1	139.2±3.5	2.1
Sodium > 145 mmol/L	18	148.7±7.6	151.2±6.5	2.5
Potassium < 3.5 mmol/L	29	3.0±0.4	3.1±0.6	0.13
Potassium 3.5–5.5 mmol/L	58	3.6±0.7	4.2±0.5	0.54
Potassium > 5.5 mmol/L	13	5.6±0.8	5.9±0.9	0.34

The sodium analysis results were stratified according to the standard laboratory values; <135 mmol/L was considered as hyponatremia, 135-145 mmol/L was considered as normonatremia, and values >145 mmol/L were considered as hypernatremia. The difference in sodium levels through the 2 analyzing methods was statistically significant in the hyponatremia group (($P < 0.05$) (Table 3). The difference of mean between AA and ABG was 4.2 mmol/L, which was not within the acceptable limit for sodium defined by CLIA. In normonatremia and hypernatremia group, difference between the 2 methods was within acceptable limits of CLIA.

The potassium values were stratified further. Patients with K^+ 3.5-5.0 mmol/l were normo-kalemic, values > 5.5 mmol/l were considered as hyperkalemia, and those < 3.5 mmol/l were considered as hypokalemia.The difference in Potassium levels through the 2

analyzing methods was statistically significant in the normokalemic group ($P < 0.05$) (Table 3). The mean difference between AA and ABG was 0.54 mmol/L, which was not within the acceptable limit for Potassium defined by CLIA. In hypokalemia and hyperkalemia group, difference between the 2 methods was within acceptable limits of CLIA.

Discussion

Electrolyte abnormalities are common reversible causes of morbidity and mortality in patients admitted in ICUs. The electrolyte level must be monitored regularly in these patients which are ordered in ABG or serum sample as per the convenience of sampling and requirement. The results of AA and ABG measurement are used in inter exchangeable manner and taken as they are equivalent. This study was planned to identify if the sodium and potassium levels measured by using AA and ABG instruments were equivalent and could be used interchangeably.

To ensure the accuracy of test results, our central laboratory (employing an AA) participates in an external quality assessment (EQA) program of BIORAD, both electrolytes were assayed with reasonable accuracy during the study period. The accuracy of ABG analyzer was not evaluated through any EQA program and this is limitation of our present study. But we used in-house trivalent quality control for ABG analyzer. For AA we also used internal quality control of BIORAD.

The differences amoung electrolyte levels measured using an ABG and AA may be explained by a combination of factors, including sample transport, dilution of serum samples prior to testing (in indirect ISE method), and variations in instrument calibration, preanalytical variables such as hemolysis (especially K^+ level), clots within the specimen, inproper mixing of the specimen with anticoagulant and varying ratio of blood sample to anticoagulant[8,9]. It is known that ISE-based instruments from different manufacturers yield Na^+/K^+ values that differ by 2-5%; calibration of an AA using a NIST standard lowers the differences[10]. Recently some authors reported that the use of different types of heparin in blood gas syringes can introduce a preanalytical bias. Heparin binds the positively charged ions and might introduce different negative biases when the levels of electrolytes are measured[12,15]. The extent of bias differs among syringe types[11,12]. Chhapola V et al. observed that ABG analyzers underestimate sodium and potassium levels if arterial samples are collected in liquid heparinized containers[13]. The underestimation of electrolytes due to liquid heparin can be avoided by use of lyophilized heparinized syringes. Jain A et al. observed negative bias in electrolytes values in arterial blood because of binding of heparin to electrolytes[14].

In our study, we tried to minimize these external contributing factors by considering other study limitations. For the standardization of sampling and to edge out all affecting factors, as mentioned above, we used BD A-LINE ABG syringes (coated with lithium-heparin) for sampling. To prevent sampling errors only trained and selected staff of the ICU performed the sampling. The simultaneously obtained arterial catheter samples were run for both analyses instead of different sampling areas. Moreover, we analyzed both the ABG and AA samples within a maximum of one hour after collection, to avoid hemolysis which might result from prolonged storage or a delay in analysis, use of alcohol for disinfection, and inappropriate sampling needles.Wongyingsinn M et al. concluded that arterial potassium can replace measurement of venous potassium[16]. Fu P et al. concluded that arterial potassium cannot be used as a substitute to serum potassium in patients with diabetic ketoacidosis[17]. Flegar Mestric Z et al. observed that electrolytes measured in whole blood by ABG analyzer were comparable to electrolytes measured in plasma or venous serum samples[18]. R King et al. observed that there was no significant difference between the sodium and potassium values measured by ABG analyzer and chemistry autoanalyser[19]. While Binila Chacko et al. concluded significant difference between arterial and venous sodium levels and also in arterial and venous potassium levels[20]. Jain et al. suggested that its better to make clinical decisions based on serum K^+ levels yielded by an ABG instrument[14]. The difference of electrolyte values in the paired samples is also due to the difference in the type of sample, serum or whole blood. The potassium is released from the platelets in the process of clotting that's why serum potassium values are higher than whole blood potassium values.

In the study conducted by Morimatsu et al. it was revealed that results with AA and ABG differed significantly for the plasma sodium and chloride levels[6]. They concluded that although the mean sodium level differences were not significant between AA and ABG, the Bland Altman's 95% limits of agreement or sodium were very wide, which was not clinically acceptable.

Story *et al*. have reported that indirect ISE leads to overestimation of Na^+ in hypoalbuminemia[21].They concluded that difference between direct and indirect ISE results was due to interference of serum albumin and total protein concentrations[22]. The use of different techniques was not a limitation in the our present study as we compared results of two instruments using direct ISE method.

King *et al*. compared two Radiometer ABG analyzers with laboratory auto analyzer for electrolytes[19]. The mean difference in Na^+ results was 1.7 mmol/L but the limit of agreement was -2.9 to 6.4 mmol/L. They concluded that though the mean difference is small, but the wide range indicate that the individual sample differences may be large[13].

The use of different analyzer and difference in use of calibrators could also be responsible for the observed difference in electrolytes[20]. It is known that ISEbased analyzer from different manufactures gave Na^+ and K^+ results that differ by 2-5%. Since we are unable to correlate the results with the clinical condition of patient and so we cannot comment that results of which analyzer represent better.

Study limitations

We performed test on only one AA and one ABG analyzer. Different types of analyzer might provide more information on variance and accuracy. But, these 2 analyzer and methods mentioned above were used by many hospitals in all over the world, making our study more relevant and generalizable. One more limitation that we didn't put emphasis on the serum protein levels. The serum protein levels, which might be low in critically ill patients, could directly affect the electrolyte results.

Conclusion

We conclude that the results of electrolytes on ABG and AA analyzer can't be utilized in inter-exchangeable manner and need to be interpreted with caution. Physicians must be aware of differences in electrolyte results between ABG and AA, to avoid potential misdiagnosis, investigation and unnecessary treatment. We would like to emphasize that the results obtained arespecific to the analyzer used. For better results of electrolyte the use of dried heparin syringes may be encouraged. The results for sodium differ between AA and ABG analyzer so we cannot advice the use of sodium results interchangeably. We advocate the use of ABG machines for accurate serum potassium measurement cause hemolysis can change values in serum.

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