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International Journal of Clinical Biochemistry and Research

Journal homepage: https://www.ijcbr.in/

Original Research Article

Study on comparison of electrolytes in hospitalized patients of critical care medicine by automated biochemistry analyzer and arterial blood gas analyzer

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ARTICLE INFO

Article history:
Received 17-04-2024
Accepted 08-06-2024
Available online 19-06-2024

Keywords:
Arterial Blood Gas Analyzer
Automated Biochemistry Analyzer
Sodium
Potassium and Chloride

ABSTRACT

Background and Objectives: Critical care medicine department has to assess electrolytes accurately and quickly to initiate the treatment. Blood samples are analyzed in a matter of seconds by arterial blood gas analyzers (ABG), albeit their accuracy is still up for debate. The current study objectives were to estimate and compare the levels of electrolytes (sodium, potassium, and chloride) in hospitalized critical care patients as determined by automated biochemistry analysis and blood gas analyzer and to assess the degree of agreement between the two instruments and obtain information on whether these values can be interchanged.

Materials and Methods: A prospective hospital based observational study was undertaken after obtaining institutional ethical committee clearance. The study included a total of 195 paired venous and arterial samples from the patients admitted to Critical Care Medicine Unit of NIMS Hospital, Jaipur, India in whom electrolytes were analysed on Arterial Blood Gas (ABG) analyzer and Automated Biochemistry Analyzer (ABA). Analysis was done on ABL555 blood gas analyzer located in the critical care medicine unit and vitros 5600, located in Clinical Biochemistry. Statistical analysis was done using Student's t test and Pearson's correlation coefficient test.

Results : A total of 195 samples were analyzed. The mean levels of sodium, potassium and chloride were 136.64 ± 5.44 mmol/L, 3.87 ± 0.523 mmol/L and 100.79 ± 6.65 mmol/L respectively analyzed by ABG analyzer. The mean levels of sodium, potassium and chloride were 136.65 ± 5.81mmol/L, 88 ± 0.543 mmol/L and 100.47 ± 6.41 mmol/L respectively analyzed by ABA. Student's t test comparison p values for sodium, potassium and chloride were 0.458 (Not Significant), 0.1867 (Not Significant) and 0.0438 (Significant) between the two instruments. The strength of agreement between the two instruments for sodium, potassium and chloride were analyzed using pearsons correlation coefficient. There was strong agreement for all the three parameters between the two instruments and the p value was 0.00001 (highly significant) for all the three parameters.

Conclusion : The results of this investigation showed no discernible differences between the automated biochemistry analyzer and arterial blood gas analyzer measurements of sodium, potassium, and chloride. Clinicians can make critically important decisions by relying on the results of arterial blood gas analysis.

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1. Introduction

Electrolytes are charged substances that are necessary for many bodily processes. They are crucial for the production of cell membrane potentials, the regulation of neurohormonal pathways, the production of energy, and the maintenance of the body's acid-base balance, among other physiological, biochemical, and metabolic processes.[1]

The electrolytes directly coordinate nearly every physiological activity. Variations in electrolyte levels,

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https://doi.org/10.18231/j.ijcbr.2024.009
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ranging from minor to significant, can be caused by a multitude of illnesses or several consequences. They may be acute or chronic, and they may cause issues that are potentially fatal.[2,3] Reversing metabolic abnormalities always requires sufficient treatment, regardless of the underlying cause.[3] Precise measurement of sodium and potassium electrolyte levels is crucial in clinical practice, particularly for patients in intensive care units.[4]

There are often two methods used on a daily basis. On the one hand, central laboratory autoanalyzers (AAs) regularly assess electrolytes from serum, but the time it takes to obtain findings after drawing blood is dependent on a number of variables, including transit time after sample collection, sample processing, and laboratory sample analysis.[5] This kind of delay could jeopardize critically ill patients' care. However, on the other hand the arterial blood gas (ABG) analyzers are widely used in almost all emergency rooms and intensive care units (ICUs) because they allow fast data collection and therapeutic response,[6,7] as intensive care unit (ICU) patients may have nonspecific signs and symptoms of electrolyte abnormalities.[8,9]

Treatments meant to preserve essential organ functions have an impact on electrolyte balance. As a result, people who are critically ill are more likely than those who are not to experience electrolyte imbalances. In ICU patients, the frequency of electrolyte imbalances is close to 25%.[2] Serum potassium and sodium levels have been demonstrated in recent studies[10,11] to be important predictors of death in ICU patients. For this reason, it is crucial that electrolyte imbalances in ICU patients be corrected completely and promptly. In these conditions, it is clear how important it is to have the serum electrolyte level findings as soon as possible. The autoanalyzers (AA) at hospital central laboratories are used to assess serum electrolytes using the indirect ion sensing (ISE) approach.[12,13]

Blood gas analysis (BGA) is a useful test for determining blood pH, bicarbonate content, oxygen saturation, oxygen content, and partial pressures of carbon dioxide and oxygen.[14] This enables medical professionals to assess the patient's hypoxia and acid-base imbalances; as a result, BGA is crucial to the treatment of acute respiratory failure, carrying out surgery, and tending to the severely ill. Furthermore, some manufacturers offer further tests, such as lactate and electrolyte assessments, which can provide doctors with more precise information about a patient's status and aid in patient management.[15] Whole blood is utilized in arterial blood gas analyzer technology to measure the electrolytes using ISE technology. Serum samples are utilized in auto analyzers to assess the electrolyte value using ISE technology.[1] Therefore, the estimated values of sodium and potassium in the serum sample and whole blood sample ought to be the same. As a result, we believe it to be interchangeable. Comparing these two approaches results in the publication of massive research. The findings of these studies' statistical analyses demonstrated the highly substantial distinction between these two approaches.[6–14]

Water homeostasis primarily controls serum sodium concentration, and any disruption to this balance is the primary cause of salt disorder. Drinking water and having arginine vasopressin in circulation are the two main defense mechanisms for serum osmolality. Most cases of sodium problems are caused by deficiencies in one or both of these two defense mechanisms.[2] On the other hand, imbalances in the body's sodium content, which is a crucial factor in determining the volume of extracellular fluid and the integrity of the circulatory system, result from anomalies in salt homeostasis. The posterior pituitary's secretion of arginine vasopressin is also influenced by volume status.[16] At every serum osmolality level, hypovolemia is linked to greater circulating levels of the hormone. Heart failure and cirrhosis are among the conditions caused by hypervolemia that result in arterial underfilling. The neurohormonal activation that goes along with this condition includes an increase in circulating arginine vasopressin, which causes water retention and hypernatremia.

Despite significant variations in dietary potassium intake, the homeostatic system maintains plasma potassium concentrations between 3.5 mmol/L and 5.3 mmol/L. Of the entire daily food intake, 90% of the potassium is eliminated by urine and 10% through feces. An essential mechanism for maintaining potassium homeostasis is the kidney. Up to 98% of total body potassium is mostly found in the intracellular compartment.[17] The huge intracellular pool, which is crucial for maintaining the homeostasis of plasma potassium concentration, primarily determines the extracellular potassium value. Significant hypokalaemia and hyperkalaemia are brought on by variations in the influx and efflux of intracellular and extracellular potassium. Severe hyperkalaemia can result from massive necrosis that releases intracellular potassium; acute renal damage and decreased potassium excretion exacerbate this disease.

Along with sodium and potassium, chloride is one of the main electrolytes in extracellular fluid and is essential for preserving appropriate fluid balance. Preventing problems including electrolyte imbalances, edema, and dehydration in critical care settings requires careful attention to electrolyte balance. Renal blood flow, glomerular filtration rate, and tubular function are among the processes that are impacted by chloride ions.[18] Metabolic acidosis is frequently observed in patients receiving critical care due to a variety of conditions, including organ malfunction, infection, and tissue hypoperfusion. Since chloride ions are involved in acid-base balance, they also have an indirect impact on respiratory function. For instance, acidosis can impair respiratory drive and function, which may put critically ill patients' breathing at risk.[6]

It is widely accepted that electrolyte homeostasis is crucial to the normal operation of various metabolic

processes and organ functions in the human body. As a result, electrolyte imbalances can occur in a variety of medical illnesses, including chronic renal failure[18] and diabetes mellitus.[19] as well as in some cancer patients undergoing platinum-based chemotherapy.[20]

The introduction of such blood gas analysers has substantially improved the management of these patients, particularly those who are severely ill. The main advantage of these blood gas analyzers is that they do not require centrifugation. Furthermore, blood gas analysers often require only 2 or 3 minutes to complete the entire testing process.[21]

In contrast, autoanalyzers used for biochemical studies require that samples be centrifuged prior to testing. This process would take at least ten minutes. In addition to the pre-analytical process, electrolyte measurements in autoanalyzers take time since they use advanced methodologies. In clinical laboratories, the turnaround time for tests in autoanalyzers is frequently set at 90 minutes, which accounts for centrifugation, test methods, and sample amount. Although most doctors and laboratory technologists believe that autoanalyzer results are more exact and reliable, their relatively high turnaround time restricts their usefulness in the management of critically ill patients.[22]

2. Aim and Objectives

2.1. Aim

To compare the levels of electrolytes estimated using ABG analyser and automated analyzer of admitted patients in critical care medicine unit.

2.2. Objectives

1. To estimate and compare the levels of electrolytes (sodium, potassium and chloride) estimated using ABG analyser and automated analyzer of admitted patients in critical care medicine unit.
2. To determine the correlation of serum electrolytes between ABG analyzer and automated analyzer, and find out to what extent these values are similar.

3. Materials and Methods

3.1. Study area

This research was carried out in Clinical Biochemistry Laboratory at National Institute of Medical Sciences & Research, Jaipur, Rajasthan in association with Department of Critical Care Medicine Unit after obtaining informed consent and institutional ethical committee clearance, NIMS University, Jaipur.

3.2. Study design

Prospective hospital based observational study.

3.3. Sample size

A total of 195 patients was be selected for the study.

3.4. Formula

$n = Z\alpha/_2{}^2 * \hat{S}e * (1 - \hat{S}e)$
$d^2 * (1-P)$
$n = 1.96^2 * 0.974 * (1-0.974)$
$(0.05)^2 * (1-0.8)$
$n = 194.57 \cong 195$ samples.
Total samples were 195.
$Z\alpha/_2$ = inverse probability of normal distribution at 95% Confidence of interval.
Se: sensitivity of RAPIDROLNT 500 of potassium.
d: margin of error (5% considered)
P: expected prevalence rate.

3.5. Inclusion criteria

Patients admitted in Department of Critical Care Medicine whose ABG analysis and venous blood sample analysis for electrolytes testing done at same time and patients willing to provide voluntary informed consent.

3.6. Exclusion criteria

1. Improper timing of samples.
2. Insufficient sample volume.

3.7. Data collection

In all the patients included in the study weight (Kgs) and height (metre) was measured and body mass index (BMI) was calculated[23] by dividing weight (Kgs) with height (meter^2). Blood pressure was measured using sphygmomanometer as per the standard protocols.[23]

4. Sample Collection and Electrolyte Analysis

2 ml arterial blood was collected for ABG analysis based on principle ion-selective electrode for electrolytes estimation in hospitalized patients and at the same time 2 ml venous blood sample was collected for electrolyte determination by automated biochemistry analyser vitros 5600 based on the principle ion-selective electrode.

5. Results

The present study included a total of 195 hospitalized patients of Critical Care Medicine Unit according to the inclusion and exclusion criteria.

In Figure 1, age-wise distribution of patients enrolled in the study is shown. Out of 195 patients 1(0.51%),

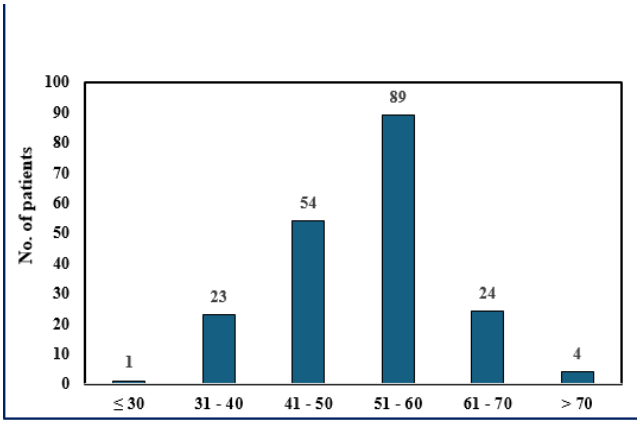

Figure 1: Age-wise distribution of patients

23(11.79%), 54(27.69%), 89(45.64%), 24(12.31%) and 4(2.05%) were in the age group of 30-40 years, 41-50 years, 51-60 years, 61-70 years and, more than 70 years respectively. Patients were majorly in the age group 51-60 years.

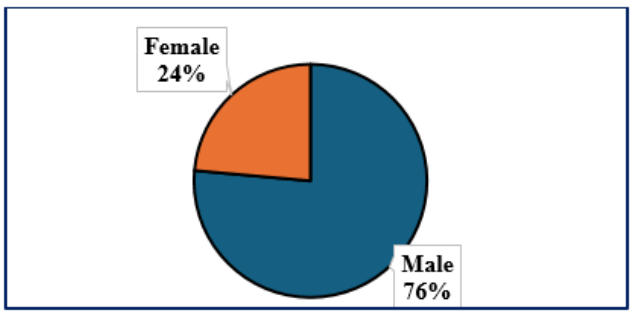

Figure 2: Gender distribution of patients

Figure 2 shows gender-wise distribution of the patients. Out of 195 patients 149 (76.41%) were males and 46(23.59(%) were females respectively.

Table 1 presents the comparison of sodium, potassium and chloride parameters between Automated Biochemistry Analyzer and Arterial blood Gas Analyzer groups. Any significant difference was not found in the levels of sodium (p = 0.4582) and potassium (p = 0.1867) using paired t test between the two instruments. There was significant increase in chloride levels estimated using ABG analyser as compared to automated biochemistry analyser (p=0.0438).

Table 2 presents the association of electrolytes parameters between Automated Biochemistry Analyzer and Arterial blood Gas Analyzer by using Pearson's correlation coefficient. A statistically strong and highly significant agreement existed among the two instruments for the measurement of electrolytes in critically ill patients (p=0.00001).

Figure 3: Correlation of serum sodium levels in patients with fully Automated Biochemistry Analyzer vs Arterial blood Gas Analyzer

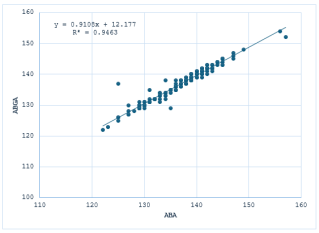

Figure 3: Scatter plot of sodium (Na+) (ABA vs. ABGA)

Figure 3 shows the correlation of serum sodium levels between the two instruments. It is seen that the strong positive correlation existed between the two instruments (r=0.9463) having a statistically highly significant value (p<0.001).

Figure 4: Correlation of serum potassium levels in patients with fully Automated Biochemistry Analyzer vs Arterial blood Gas Analyzer

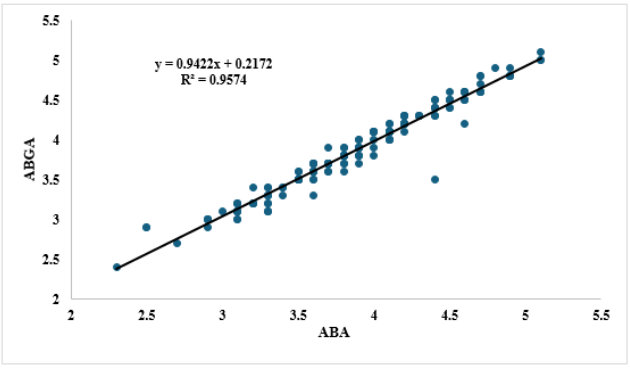

Figure 4: Scatter plot of potassium (K^+) (ABA vs. ABGA)

Figure 4 shows the correlation of serum potassium levels between the two instruments. It is seen that the strong positive correlation existed between the two instruments (r=0.954) and having a statistically highly significant value (p<0.001).

Figure 5: Correlation of serum chloride levels in patients with fully Automated Biochemistry Analyzer vs Arterial blood Gas Analyzer

Figure 5 shows the correlation of serum chloride levels between the two instruments. It is seen that the strong positive correlation existed between the two instruments (r=0.855) and statistically significant (p<0.001).

6. Discussion

This study was carried out in the Department of Biochemistry, along with the Department of Critical Care Medicine at National Institute of Medical Sciences & Research, Jaipur (Rajasthan). This research included an

Table 1: Comparison of serum electrolytes between fully automated biochemistry analyzer and arterial blood gas analyzer by using paired t-test

Variables	Automated Biochemistry Analyzer	Arterial blood Gas Analyzer	Paired t-test	P - Value	Significance
Sodium (Na^+)mmol/L	136.65 ± 5.81	136.64 ± 5.44	0.105	0.4582	Not Significant
Potassium (K^+) mmol/L	3.88 ± 0.543	3.87 ± 0.523	0.892	0.1867	
Chloride (Cl^{--}) mmol/L	100.47 ± 6.41	100.79 ± 6.65	-1.717	0.0438	Significant

Table 2: Association of serum electrolytes between fully automated biochemistry analyzer and arterial blood gas analyzer by using pearson's correlation coefficient

Electrolytes	Corr (r)	t-test	P - Value	Significance
Sodium (Na^+) mmol/L	0.973	58.34	0.00001	
Potassium (K^+) mmol/L	0.979	65.86	0.00001	All are significant
Chloride (Cl^{--}) mmol/L	0.925	33.73	0.00001	

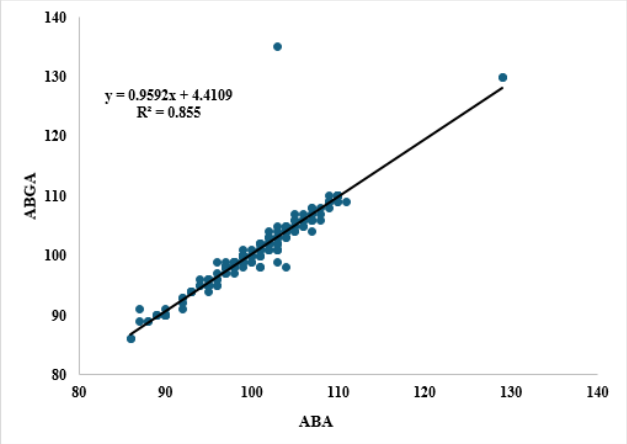

Figure 5: Scatter plot of chloride (Cl^-) (ABA vs. ABGA)

aggregate of 195 patients who were at National institute of medical sciences & research, Jaipur Rajasthan India

In this research, analysis of electrolytes in hospitalized patients revealed noteworthy patterns, shedding light on the association between electrolytes compared between blood gas analyser and Fully automated biochemical analyser.

The findings of our study showed that the mean ABG sodium, potassium and chloride were 136.64 ± 5.44 mmol/L, 3.87 ± 0.523 mmol/L and 100.79 ± 6.65 mmol/L respectively. The mean ABA sodium, potassium and chloride were 136.65 ± 5.81mmol/L, 88 ± 0.543 mmol/L and 100.47 ± 6.41 mmol/L respectively. Student's t test comparison p values for sodium, potassium and chloride were 0.458 (Not Significant), 0.1867 (Not Significant) and 0.0438 (Significant) between the two instruments.

The strength of agreement between the two instruments for sodium, potassium and chloride were analyzed using pearsons correlation coefficient. There was strong agreement for all the three parameters between the two instruments, r values of sodium, potassium and chloride were 0.973, 0.979 and 0.925 respectively, and the p value was 0.00001 for all the three parameters.

The study conducted by Chacko et al,[24] found that the mean levels of sodium was 135.8 ± 5.7 mmol/L by ABG analyser as compared to 139.9 ± 5.4 mmol/L by automated biochemistry analyser and the differences were statistically highly significant ($P < 0.001$).

An another study done by Morimatsu H et al stated that the sodium levels estimated by the ABG machine are not completely reliable for making clinical decisions. Although there is a statistically significant difference in the measured sodium values in patients which are hypernatremic and normo-natremic, but it was within the guidelines recommended by US CLIA. This statistically significant difference in values also express clinical differences should be further studied.[17]

A cross-sectional study conducted by MN Zamanabadi[23] found that, in patients who have lung disease, mean sodium level estimated from gas and laboratory analyzer were 138.25 mEq/L and 137.57 mEq/L, respectively. This difference in values was not statistically significant, $p = 0.052$. In patients with heart disease, the estimated levels were 138.54 mEq/L and 137.23 mEq/L, respectively. This difference was statistically significant, $p = 0.015$.

Jain et al.[25] carried out an observational cohort study to compare the value of electrolytes estimated by a point-of-care blood gas analyzer and an automatic biochemistry analyzer in 200 patients admitted in intensive care unit. This study showed that levels of sodium estimated by point-of-care BGA were significantly less than automatic biochemistry analyzer, but the potassium levels which were estimated did not have any significant difference statistically. A study done by Solak[19] retrospectively

included 2557 samples to compare the levels of sodium estimated by BGA and auto analyzer. This study showed that levels of sodium estimated by BGA are higher than autoanalyzer which are statistically significant. The results of these studies are not in accordance with our study.

In a research study by Pouryahya, Tan[26] found that the values obtained by blood gas analyzer showed an significant variation for sodium, potassium and creatinine but they concluded that these variations were minor and can be fixed by precise calibration of the instrument. These differences are significantly large in preterm infants.

Rezaei Shahmirzadi, Mostafavi Toroghi[27] in his cross-sectional research study noted that the blood gas analyzer yielded significant high sodium values in comparison with autoanalyzer. Whereas Zhang, Lin[28] found that the potassium values obtained by blood gas analyzer were significantly lower as compared to autoanalyzer. But they accounted that the difference in sample size, sampling methods and making of BGA and autoanalyzer could be the reasons of these discrepancies.

The interesting finding in our study is that we did not find any such differences in the values of electrolytes measured by both ABG and ABA, probably our sampling methods, quality control runs and the calibration status of both the analyzsers were accurate and the precision was taken care well in each step of the analysis. Prior to this study, we had conducted one more study on pre-analytical errors accounting for errors in laboratory results, which showed highly negligible errors with a overall prevalence of 0.52% of the total samples 79592 of clinical biochemistry unit in a duration of 6 months. The critical clinical decision can be made based on the results obtained by ABG analyzer so that there will not be any delay in the initiation of treatment in critically ill patients.

7. Conclusion

Our research study showed no significant changes in the electrolytes measurements obatibed by ABG analyzer and ABA analyzer. Thus, critical decisions can be made by trusting the values obtained from arterial blood gas analysis.

8. Source of Funding

None.

9. Conflict of Interest

None.

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Cite this article: Jat NK, Sushma BJ, Roy M, Thakuriya R. Study on comparison of electrolytes in hospitalized patients of critical care medicine by automated biochemistry analyzer and arterial blood gas analyzer. *Int J Clin Biochem Res* 2024;10(1):52-58.