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A Study to Find Out Any Difference Between Sodium and Potassium Values on Arterial Blood Gas Analysis and Those on Serum Electrolyte Measurement

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ABSTRACT

Background: Electrolyte abnormalities, particularly sodium and potassium disturbances, are common in critically ill patients and require rapid and accurate assessment for timely management. Although central laboratory auto-analysers are considered the standard method, their longer turnaround time may delay treatment, whereas arterial blood gas (ABG) analysers provide quick results. This study compared electrolyte values obtained by these two methods to determine whether ABG values could be used for rapid clinical decision-making in emergency settings.
Methodology: A hospital-based cross-sectional, observational study was conducted in the Department of Respiratory Medicine, Gouri Devi Institute of Medical Sciences and Hospital over a period of 3 months. A total of 102 patients admitted to the ICU or emergency and who fulfilled the inclusion and exclusion criteria were enrolled. Venous blood samples for sodium and potassium were collected before administration of any fluids or electrolyte correction and analysed using the Acculab Enlite Fully Automated Electrolyte Analyzer (Accurex Biomedical Pvt. Ltd., Mumbai, India). Simultaneously, arterial blood samples were analysed using the i-SmartCare 10 ABG analyser (i-SENS Inc., South Korea). Values obtained by both methods were recorded and tabulated in MS-Excel and analysed by IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA).
Results: A total of 102 patients (68 males, 34 females; with a mean age of 52.47 ± 18.12 years) were studied. The mean serum sodium concentration was significantly higher than the ABG sodium concentration (136.92 ± 5.61 mmol/L versus 131.96 ± 7.19 mmol/L; $p < 0.001$). Similarly, the mean serum potassium concentration was significantly higher than the ABG potassium concentration (4.06 ± 0.73 mmol/L versus 3.85 ± 0.76 mmol/L; $p < 0.001$). Sodium showed a moderate correlation ($r = 0.625$) with poor agreement, whereas potassium demonstrated a strong correlation ($r = 0.841$) and good agreement. Thus, ABG sodium cannot replace laboratory measurements, while ABG potassium may be usable for rapid bedside assessment.

Conclusion: ABG sodium measurements should not be considered interchangeable with conventional serum electrolyte measurements. Laboratory serum sodium estimation remains the preferred method for accurate clinical assessment. ABG potassium estimation is a reliable alternative for rapid assessment in emergency, life-threatening situations but should not replace laboratory testing.

Keywords: Arterial blood gas analyser, sodium, potassium, Laboratory Auto-analyser

INTRODUCTION

Electrolytes are electrically charged ions that play indispensable roles in numerous physiological processes. They are essential for the generation and maintenance of cell membrane potentials, regulation of hormonal and neural functions, cellular energy production, and preservation of acid–base homeostasis. Consequently, electrolytes influence virtually every physiological function within the human body. Alterations in electrolyte concentrations, ranging from mild to severe, may occur in a variety of pathological conditions and can significantly affect clinical outcomes. Among these, abnormalities in sodium and potassium levels are particularly common in emergency and critical care settings, where they may be life-threatening and substantially influence therapeutic decision-making as well as disease prognosis. Therefore, rapid and accurate assessment of electrolyte status is crucial for timely diagnosis and prompt initiation of appropriate corrective measures. [1,2]

Serum electrolyte concentrations are routinely measured using ion-selective electrode (ISE) technology, which can be performed by either direct or indirect ISE methods. [3] Central laboratory auto-analysers (AAs) predominantly employ the indirect ISE technique for electrolyte estimation. [3,5] However, this approach is associated with a relatively prolonged turnaround time, requiring approximately 4.5–5 hours for routine ward samples and 1–1.5 hours for emergency samples. The overall reporting time is influenced by several factors, including specimen transport, sample processing, and laboratory analytical procedures. [5] These delays may postpone clinical decision-making and the initiation of appropriate treatment, particularly in critically ill patients, where timely intervention is essential. [6,12]

Arterial blood gas (ABG) analysers are widely available and routinely used in emergency departments and intensive care units (ICUs), providing rapid point-of-care assessment that facilitates prompt clinical management in critically ill patients. [6,12]

Arterial blood gas (ABG) analysers provide immediate electrolyte measurements using the direct ion-selective electrode (ISE) method. [3,13]. Results are generally available within approximately two minutes, thereby reducing turnaround time and facilitating rapid clinical decision making. However, the reliability of ABG analysers for electrolyte measurement remains controversial. [9,12] Differences in analytical methods, sample types, and dilution effects may lead to variation in measured values. [4,5] Evaluating the agreement between these two methods is essential to ensure reliable clinical decision-making in critically ill patients. [6] Only a limited number of studies have compared electrolyte values obtained from arterial blood samples with those measured from serum samples. Since arterial blood gas (ABG) analysers and serum analysers use different methods for measurement, the results may vary between the two. Therefore, it is important to assess the reliability and agreement of electrolyte values obtained from these methods. Hence, the present study aimed to compare sodium and potassium measurements obtained using an intensive care unit-based ABG analyser with those obtained using a central laboratory auto-analyser, and to determine whether the two methods are interchangeable for clinical use.

MATERIALS AND METHODS

After obtaining approval from the Institutional Ethics Committee and Institutional Research Committee (Approval no. IEC Ref No: CREC/GIMSH/270326/09), a hospital-based cross-sectional observational study was conducted in the Department of Respiratory Medicine, Gouri Devi Institute of Medical Sciences and Hospital for a period of 3 months. Patients admitted to the ICU or emergency and fulfilling the inclusion and exclusion criteria were enrolled in the study. Informed consent was taken from all the patients.

This cross-sectional observational study was conducted with the primary objective of determining the level of agreement and difference between sodium and potassium values measured by arterial blood gas (ABG) analyser and those measured by serum electrolyte analyser in adult patients. The secondary objectives were (1) to assess the correlation between sodium values measured by the two methods; (2) to assess the correlation between potassium values measured by the two methods; and (3) to determine whether ABG electrolyte values can be reliably used for clinical decision-making in emergency and intensive care settings.

The inclusion criteria were patients aged ≥18 years, patients requiring simultaneous arterial blood gas analysis and serum electrolyte estimation, patients who gave informed consent. The exclusion criteria were paediatric and neonatal ICU patients, patients who already received fluid therapy or electrolyte correction before sample collection.

The sample size was calculated by using the formula for a paired t-test, assuming a 95% confidence level (α = 0.05), 80% power (β = 0.20), an expected mean difference of 0.20 mmol/L, and a standard deviation of the paired differences of 0.60 mmol/L based on previous studies. The minimum required sample size was estimated to be 71 participants. After accounting for approximately 10% possible incomplete or unusable paired samples, the final required sample size calculated was 80 participants. However, 102 paired blood samples were ultimately included in the study to improve the precision and reliability of the estimates.

Venous blood samples were collected before the administration of intravenous fluids or electrolyte replacement therapy. The serum sample was collected by withdrawing 5 ml of venous blood in BD plain vacutainer (Becton Dickinson and Company, Franklin Lakes, USA) under strict aseptic precautions. Samples were collected by trained personnel under aseptic conditions. The blood samples were then transported to the central laboratory in the hospital. It was ensured that the samples reached the laboratory without delay. The samples were allowed to clot to obtain serum.

Serum sodium and potassium levels were measured using the Acculab Enlite Fully Automated Electrolyte Analyzer (Accurex Biomedical Pvt. Ltd., Mumbai, India), based on indirect ion-selective electrode (ISE) technology. The analysis time was approximately 30 seconds per sample. The machine was calibrated before the analysis.

For the ABG analyser, 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) under aseptic conditions using a standard sampling protocol. ABG samples received in heparinized BD syringes, 5000 IU/ml, 12 ml were processed using the i-SmartCare 10 (i-SENS Inc South Korea). Quality control was maintained by trained ICU and emergency personnel using standardized sample collection procedures, and both analysers were operated under identical laboratory conditions.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). The normality of the data was assessed before analysis. A paired-samples t-test was used to compare sodium and potassium concentrations measured by the laboratory method and ABG analysis. Pearson correlation analysis was performed to assess the strength and direction of the linear relationship between electrolyte values obtained by the two methods. Bland–Altman analysis was performed to find out the agreement between the laboratory and ABG measurements. Bland–Altman analysis was used to estimate the mean bias and the 95% limits of agreement. A two-sided p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 102 patients were enrolled in the study. Among the participants, 68 (66.7%) were male and 34 (33.3%) were female. The mean age of the participants was 52.47 ± 18.12 years. The demographic characteristics of the study population are shown in Tables 1 and 2. Out of 102 paired samples, there were no missing values for sodium or potassium measurements.

Table 1. Descriptive Statistics of Age

	Total number	Minimum	Maximum	Mean	Std. Deviation
AGE	102	18	87	52.47	18.122
Valid N (listwise)	102				

Table 2. Descriptive Statistics of Gender distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	F	34	33.3	33.3	33.3
	M	68	66.7	66.7	100.0
	Total	102	100.0	100.0	

The mean serum sodium concentration measured by the laboratory method was 136.92 ± 5.61 mmol/L, whereas the mean sodium concentration measured by ABG analysis was 131.96 ± 7.19 mmol/L. The serum sodium values ranged from 123 to 152 mmol/L, while ABG sodium values ranged from 116 to 150 mmol/L. These findings indicate that serum sodium measurements were higher than ABG sodium measurements by approximately 4.96 mmol/L.

The mean serum potassium concentration measured by the laboratory method was 4.06 ± 0.73 mmol/L, while the mean potassium concentration measured by ABG analysis was 3.85 ± 0.76 mmol/L. Serum potassium values ranged from 2.3 to 7.7 mmol/L, whereas ABG potassium values ranged from 2.3 to 7.2 mmol/L. These results suggest that serum potassium values were higher than ABG potassium values by 0.21 mmol/L.

The descriptive statistics for sodium and potassium measurements obtained by both methods are presented in Table 3.

Table 3. Descriptive Statistics of Sodium and Potassium Measurements

Variables	Minimum	Maximum	Mean	Std. Error Mean	Std. Deviation	P value
Sodium measured by ABG analyzer	116.00	150.00	131.9608	0.71182	7.18899	<0.001
Sodium measured by laboratory	123.00	152.00	136.9216	0.55518	5.60708	
Potassium measured by laboratory	2.30	7.70	4.0577	0.07201	0.72728	<0.001
Potassium measured by ABG analyser	2.30	7.20	3.8461	0.07493	0.75671	

A paired sample t-test was performed to determine whether there was a significant difference in the two methods of estimation of sodium. The test demonstrated a statistically significant difference between serum sodium and ABG sodium measurements, with serum sodium values being higher by a mean of 4.96 mmol/L (95% CI: 3.84–6.09 mmol/L; t = 8.752, df = 101, p < 0.001).

A Paired sample t-test was performed to find out any difference in the two methods of estimation of potassium. Paired sample t-test demonstrated a statistically significant difference between serum potassium and ABG potassium measurements, with serum potassium values being higher by a mean of 0.21 mmol/L (95% CI: 0.129–0.294 mmol/L; t = 5.099, df = 101, p < 0.001).

Pearson correlation analysis was performed and demonstrated a statistically significant positive correlation between serum sodium measured by the laboratory method and sodium measured by arterial blood gas analysis (r = 0.625, p < 0.001). This indicates that patients with higher serum sodium concentrations had higher ABG sodium concentrations. The correlation coefficient of 0.625 suggests a moderately strong positive linear relationship between the two methods. However, the strength of correlation was not sufficiently high. Bland–Altman analysis demonstrated poor agreement, indicating that the two methods are not interchangeable for sodium measurement. The correlation between serum sodium values and ABG sodium values is shown in Figure 1.

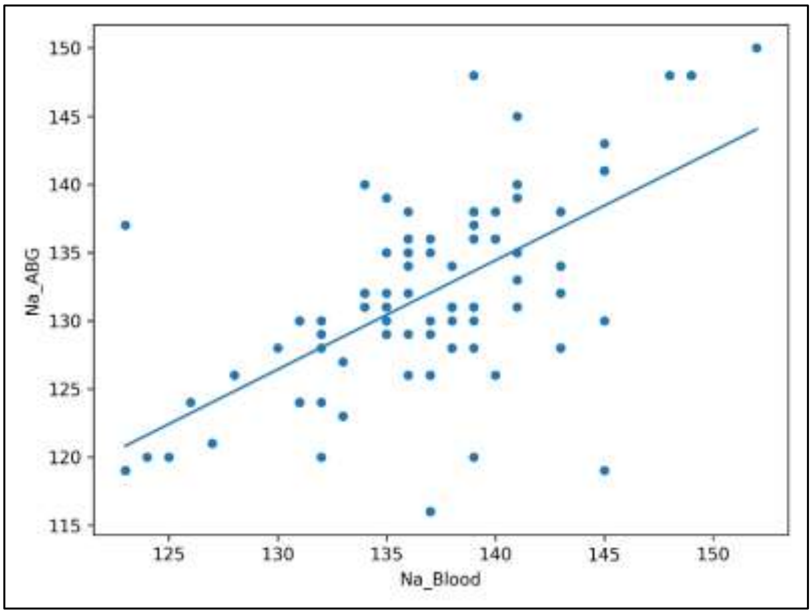

Figure 1. Scatter plot showing the correlation between laboratory serum sodium and arterial blood gas (ABG) sodium measurements

Pearson correlation analysis was performed and demonstrated a statistically significant positive correlation between serum potassium measured by the laboratory method and potassium measured by arterial blood gas analysis (r = 0.841, p < 0.001). This indicates that patients with higher serum potassium concentrations had higher potassium values on ABG analysis. The correlation between the two methods was statistically significant. The correlation coefficient of 0.841 suggests a strong linear relationship between the two methods. Therefore, ABG potassium measurements may provide an acceptable bedside estimate of serum potassium concentration, however, confirmatory laboratory testing remains advisable. The correlation between serum potassium values and ABG potassium values is shown in Figure 2.

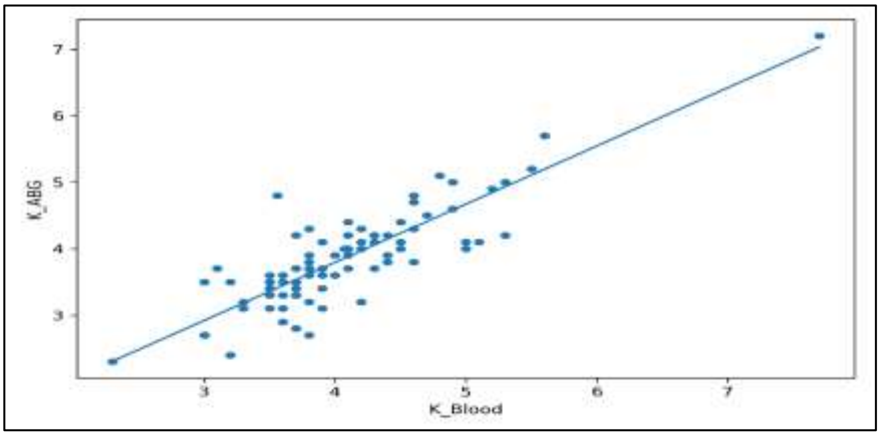

Figure 2. Scatter plot showing the correlation between laboratory serum potassium and arterial blood gas (ABG) potassium measurements.

Bland-Altman analysis demonstrated a mean bias of approximately +5 mmol/L between serum sodium and ABG sodium measurements, indicating that serum sodium values were systematically higher than ABG sodium values. The 95% limits of agreement ranged from approximately −6 to +16 mmol/L, suggesting considerable variability between the two methods. Although most observations were within the limits of agreement, the wide limits indicate poor agreement and suggest that the two methods cannot be used interchangeably for sodium estimation. The Bland–Altman plot illustrating the agreement between serum sodium and ABG sodium measurements is shown in Figure 3.

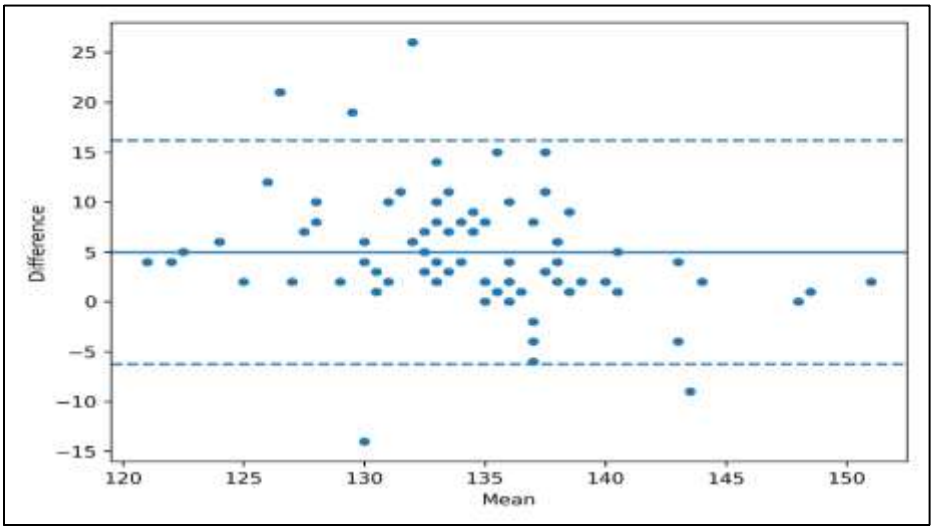

Figure 3. Bland–Altman plot comparing laboratory serum sodium and ABG sodium measurements.

Bland-Altman analysis demonstrated a mean bias of +0.21 mmol/L between serum potassium and ABG potassium measurements, indicating that serum potassium values were higher than ABG potassium values. The 95% limits of agreement ranged from −0.6 to +1.0 mmol/L. Most observations lay within the limits of agreement, and no significant proportional bias was observed. Bland–Altman analysis demonstrated that the difference between the two methods remained relatively constant across the range of potassium concentrations. These findings indicate good agreement between the laboratory and ABG methods. The Bland–Altman plot illustrating the agreement between serum potassium and ABG potassium measurements is shown in Figure 4.

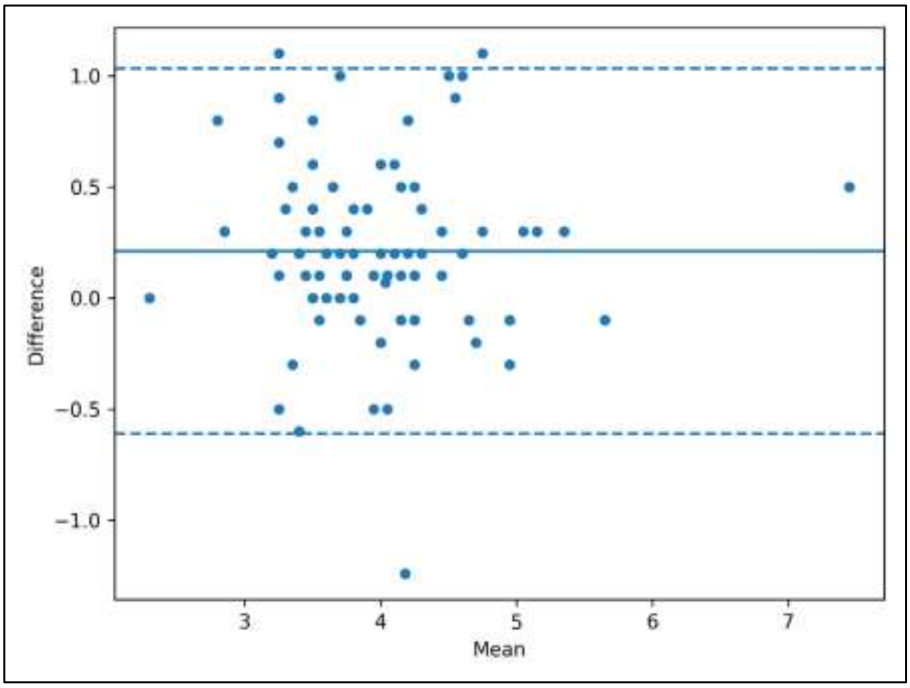

Figure 4. Bland–Altman plot comparing laboratory serum potassium and ABG potassium measurements.

Significant differences were observed between electrolyte concentrations measured by the conventional laboratory method and those measured by ABG analysis. Serum sodium values were consistently higher than ABG sodium values and demonstrated only moderate correlation and poor agreement, indicating that the two methods should not be used interchangeably for sodium estimation.

Serum potassium measurements were statistically higher than ABG potassium measurements, the average difference was small (0.21 mmol/L) and the Bland–Altman analysis demonstrated acceptable agreement. Therefore, ABG potassium measurements can be considered a reliable alternative for emergency and life-threatening situations, but they are not interchangeable. However, confirmatory laboratory testing remains advisable whenever precise electrolyte assessment is required.

DISCUSSION

Several clinical studies have investigated whether electrolyte measurements (especially sodium and potassium) obtained from arterial blood gas (ABG) analysers agree with those obtained from laboratory analysers and whether they can be used interchangeably for clinical decisions.

Electrolytes are measured using ion-selective electrode (ISE) methods, namely direct ISE and indirect ISE techniques. In the direct ISE method, the electrode surface is directly in contact with an undiluted blood sample which is employed by the ABG analyser, while indirect ISE devices use diluted plasma samples. The indirect assay involves pre analytic dilution and is often used in many tertiary hospital laboratories.

Morimatsu et al**.** compared electrolyte measurements obtained from a point-of-care blood gas analyser with those from a central laboratory analyser in critically ill patients. They observed significant differences in sodium and chloride concentrations between the two methods, whereas potassium measurements showed better agreement. These differences resulted in clinically important variations in calculated anion gap and strong ion difference, leading the authors to conclude that point-of-care and central laboratory electrolyte measurements should not be considered directly interchangeable for clinical decision-making. [6]

Gupta et al. compared serum electrolyte measurements obtained using a central laboratory analyser with those obtained from an arterial blood gas (ABG) analyser. The authors reported that the mean serum sodium concentration was significantly higher in the laboratory serum samples (139.4 ± 8.2 mmol/L) than in the ABG samples (137.8 ± 10.5 mmol/L; $P < 0.05$). Similarly, the mean potassium concentration was marginally higher in the serum samples (3.8 mmol/L) compared with the ABG samples (3.7 mmol/L), and this difference was also statistically significant (P <0.05). Furthermore, statistically significant differences between the two analytical methods were observed in patients with hyponatraemia (serum sodium <135 mmol/L) and in those with potassium concentrations within the normal reference range (3.5–5.2 mmol/L), indicating that the degree of agreement between the two instruments may vary across different electrolyte concentration ranges. There were discrepancies observed between the methods. Their study suggested that, caution should be exercised when interpreting electrolyte values obtained from ABG analysers and laboratory analysers interchangeably.[7] This study also well corroborating with our current study.

Budak YU et al. reported that the mean sodium concentration measured using the arterial blood gas (ABG) analyser was 138.1 mmol/L, whereas the corresponding value obtained with the central laboratory auto-analyser was significantly higher at 143.0 mmol/L ($p < 0.001$). Similarly, the mean potassium concentration was significantly lower when measured using the ABG analyser (3.5 mmol/L) compared with the auto-analyser (3.7 mmol/L; $p < 0.001$). Based on these findings, the authors concluded that the level of agreement between the ABG analyser and the central laboratory auto-analyser was unacceptable, indicating that the two analytical methods should not be used interchangeably for electrolyte measurements without appropriate clinical consideration. They concluded that ABG analysers and laboratory auto-analysers were not equivalent for sodium and potassium measurements. They summarised multiple studies and highlighted that limits of agreement for sodium and potassium between ABG and laboratory measures were variable, and many studies concluded that the results are not strictly interchangeable in clinical practice. [11] These findings are in agreement with those of the present study.

Yi et al. conducted a study in 2020; They found that all parameters tested were significantly different between the two analysers using a t-test. It was observed that, blood gas analysers tend to underestimate the values, and the linear regression analysis revealed a strong correlation between the two analysers. They concluded that, statistically significant differences in sodium and potassium, and that might limit their direct substitution. [8] These findings are consistent with the present study.

Yilmaz et al. conducted a study in 2016; compared sodium and potassium values obtained from ABG analyser with auto-analyser. They observed that, serum sodium values were significantly higher than ABG sodium values, with only moderate correlation and poor agreement, suggesting that the two methods should not be used interchangeably for sodium estimation. In contrast, potassium measurements showed strong correlation and acceptable agreement between the two methods. The authors suggested that, although ABG potassium values can be used for rapid decision-making in emergency and critical care settings, laboratory confirmation is still essential. Their study highlights the need for cautious interpretation of electrolyte values obtained from ABG analysers, particularly for sodium measurement. [9] Similar observations were reported in our study.

Tatliparmak AC et al. conducted a retrospective study involving 414 emergency department patients to compare sodium and potassium measurements obtained by an arterial blood gas (ABG) analyser with those from a laboratory auto-analyser. The study found that agreement between the two methods was generally acceptable but was significantly poorer in elderly patients, particularly for sodium estimation. The authors concluded that although ABG analysers provide rapid electrolyte results, laboratory confirmation is advisable when precise electrolyte measurement is essential, especially in geriatric patients. [12]

Bisht SS et al. performed a prospective observational study in critically ill ICU patients comparing whole blood electrolyte measurements by ABG analyser (direct ion-selective electrode) with serum electrolyte measurements by laboratory auto-analyser (indirect ion-selective electrode). They observed good agreement for potassium values but clinically significant differences in sodium measurements. The authors suggested that ABG analysers are useful for rapid bedside decision-making; however, abnormal or borderline sodium values should be confirmed by laboratory analysis before major therapeutic interventions. [13]

Jain A et al. compared electrolyte measurements obtained from a point-of-care blood gas analyser with those from a central laboratory auto-analyser in emergency patients. The study demonstrated a strong correlation between the two methods for both sodium and potassium, with only minor clinically acceptable differences. The authors concluded that point-of-care blood gas analysers provide rapid and reliable electrolyte measurements that can facilitate timely management in emergency and critical care settings, while emphasizing that laboratory testing remains the reference standard. [14]

Zhang et al. did a study in 2015; compared sodium, potassium measurements obtained from an ABG with those from laboratory auto-analyser. The mean potassium concentration measured using the arterial blood gas (ABG) analyser was 3.77 mmol/L, whereas the corresponding mean value obtained from the central laboratory analyser was significantly higher at 4.20 mmol/L (P <0.0001). Similarly, the mean sodium concentration measured by the ABG analyser was 137.89 mmol/L compared with 140.93 mmol/L using the central laboratory analyser, with the difference also reaching statistical significance (P < 0.0001). These findings demonstrate significant differences in sodium and potassium measurements between the two analytical methods. They found that ABG sodium and potassium values were significantly lower than laboratory measurements. The authors concluded that, despite statistically significant differences in sodium and potassium values, the agreement was clinically acceptable, suggesting that ABG analysers can provide reliable electrolyte measurements for rapid clinical assessment when interpreted appropriately. [10] These findings differ from those of the present study. These differences may be attributable to variations in sampling protocols, analyser characteristics, turnaround time, and serum albumin concentration.

The present study demonstrated that electrolyte values obtained from arterial blood samples may be used for rapid potassium estimation; however, sodium estimation should continue to rely on conventional laboratory analysis.

Limitation

This was a single-centre study with a relatively small sample size, which may limit the generalizability of the findings to other healthcare settings. Additionally, sodium and potassium measurements were evaluated using one model each of the ABG analyser and laboratory auto-analyser; therefore, the results may not be directly applicable to other analyser systems or electrolyte parameters.

CONCLUSION

ABG sodium measurements should not be considered interchangeable with conventional serum electrolyte measurements. Laboratory serum sodium estimation remains the preferred method for accurate clinical assessment. ABG potassium measurement may serve as a reliable alternative for rapid bedside assessment in emergency and life-threatening situations; however, it should not replace conventional laboratory testing.

Declaration

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