International Journal of Research in Medical Sciences
Chawang SK et al. Int J Res Med Sci. 2025 Dec;13(12):5238-5243
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20253753

Original Research Article

Agreement between arterial and venous electrolyte levels in patients admitted to intensive care unit: a retrospective study

Shelomith K. Chawang[1]*, Nito Yepthomi[2], Nokchur Imchen[3]

[1]Department of Clinical Biochemistry, Christian Institute of Health Sciences and Research, Dimapur, Nagaland, India
[2]Department of Laboratory Sciences, Christian Institute of Health Sciences and Research, Dimapur, Nagaland, India
[3]Department of Medicine, Christian Institute of Health Science and Research, Dimapur, Nagaland, India

Received: 20 October 2025
Revised: 06 November 2025
Accepted: 07 November 2025

***Correspondence:**
Shelomith K. Chawang,
E-mail: shelomithchawang@gmail.com

ABSTRACT

Background: Electrolyte disturbances are common in critically ill patients and can significantly influence morbidity and mortality. Prompt detection is essential; however, serum electrolyte estimation using automated analyzers (AA) in central laboratories often suffers from delayed turnaround times. Point-of-care (POC) arterial blood gas (ABG) analyzers provide rapid results; however, their reliability compared to that of conventional autoanalyzers remains uncertain. This study aimed to evaluate the agreement between sodium and potassium levels measured in arterial and venous samples using the GEM 3500 (ABG) and Vitros 5600 (AA) analyzer, respectively.
Methods: A retrospective study was conducted on 200 intensive care unit (ICU) patients in a secondary healthcare hospital between January and June 2024. The electrolytes were reported from both arterial and venous blood samples sent to the clinical biochemistry laboratory on the same day and at the same time. GEM 3500 and Vitros 5600 analyzers are used, respectively. Both methods use the direct ISE method. Statistical analyses included the Wilcoxon signed-rank test, Spearman's correlation, and Bland-Altman plots to assess correlation and agreement.
Results: The mean and standard deviation of sodium values (136.33±9.22 mmol/l in venous and 135.23±9.57 mmol/l in arterial blood) and potassium values (4.20±1.01 mmol/l and 4.01±0.97 mmol/l) were observed. The differences were statistically significant ($p<0.001$). Spearman's correlation showed strong positive relationships ($r=0.819$ for sodium; $r=0.844$ for potassium, $p<0.001$). Bland-Altman analysis demonstrated that 97.5% of the sodium and 93.5% of the potassium values fell within the limits of agreement, suggesting good concordance.
Conclusions: Sodium and potassium measurements obtained from arterial samples using the ABG analyzer can be used interchangeably with serum values derived from venous samples analyzed on an automated chemistry analyzer for the management of critically ill patients.

Keywords: Arterial blood gas analyzer, Auto-analyzer, Intensive care unit, Potassium, Sodium

INTRODUCTION

Electrolytes play a crucial role in maintaining physiological functions in the human body. They play vital roles in the regulation of cell membrane potential, the steady process of neurohormonal pathways, energy transformation, fluid and acid-base balance in the body. Signs and symptoms of electrolyte disorders may be nonspecific in intensive care unit (ICU) patients.[1-3] They are vital for normal growth, development, and maintenance of health.[4] Treatments aimed at supporting vital organ function can alter the electrolyte balance. As a result, electrolyte disturbances are observed more frequently in critically ill patients compared to those who are not critically ill, with an estimated occurrence of about 25% among ICU patients. Recent research further supports

this finding.[5-7] Serum sodium and potassium levels were significant predictors of mortality in ICU patients. Therefore, prompt and complete correction of electrolyte disorders in ICU patients is vitally important. Under these circumstances, the importance of obtaining serum electrolyte levels as early as possible is obvious. In routine applications, serum electrolytes are measured using the indirect ion-sensing (ISE) method with auto-analyzers (AA) located in the central laboratories of hospitals. In this method of analysis, the turnaround time is prolonged because of delays in transporting samples to the central laboratory for various reasons. Therefore, point-of-care (POCT) testing tools, such as arterial blood gas (ABG) analyzers, are now widely used in the routine evaluation of ICU patients. These analyzers utilize the direct ISE method and deliver results quickly, enabling physicians to make faster treatment decisions.[8,9] The United States Clinical Laboratory Improvement Amendments (US CLIA) accepts a 0.5 mmol/l difference in the measured potassium levels and a 4 mmol/l difference in the measured sodium levels in the gold standard measure of the standard calibration solution.[10] In some recent studies, the data revealed the difference in the electrolyte levels between the ABG and AA results.[11,12]

The limitation of electrolyte measurement in serum is the delayed turnaround time, which is approximately 20 to 30 minutes. To overcome the limitation of serum electrolyte measurement in electrolyte analyzers, point-of-care arterial blood gas analyzers can be used to measure electrolytes in arterial blood, where results are available within 5 min, thus decreasing the turnaround time.[11,13] Despite the advantage of a rapid turnaround time with point-of-care testing (POCT), which may translate to prompt decision-making, concerns have been raised regarding its accuracy.[14] Several studies have documented significant discrepancies in sodium and chloride concentrations when measured using POCT devices, and additional reports have highlighted notable variations in potassium levels. These inconsistencies suggest that the results obtained from different analyzers may not always be directly interchangeable. Furthermore, the absence of a clear consensus in the literature stems from the fact that studies conducted with different devices and methodologies have yielded different outcomes. This lack of uniformity underscores the importance of validating the concordance of electrolyte values measured by arterial blood gas (ABG) analyzers and conventional serum sample testing within each hospital setting. As factors such as analyzer type, calibration technique, and laboratory protocols can differ widely, local verification is essential to ensure reliability, accuracy, and clinical confidence in patient management. Physicians want to trust the veracity of ABG results for electrolytes such as sodium and potassium because, by this method, the delay in reaching the results is minimized, and the risks arising from this delay may be reduced. However, the results of these studies are confusing and still pose a diagnostic challenge for physicians. Because of the physicians' hesitation, we investigated whether the sodium and potassium levels measured using ABG and AA were equivalent.

This study was thus undertaken to assess the correlation of electrolytes between arterial and venous samples measured by the ABG analyzer (arterial blood) and the automated analyzer (venous blood) of patients in whom samples were collected simultaneously for both tests. In most studies, serum electrolytes are usually measured by indirect ISE, but the Vitros 5600 uses direct ISE for venous samples. This direct comparison (GEM 3500 is also a direct ISE) is a major strength, as it removes the "electrolyte exclusion effect" caused by indirect ISE. There are very few published data comparing arterial and venous electrolytes. In this study, we aimed to investigate the agreement between sodium and potassium measurements in arterial and venous samples.

Aim and objective

To analyze and compare electrolyte concentrations in arterial and venous samples using the GEM 3500 ABG analyzer and the Vitros 5600 automated analyzer. To determine the strength of correlation and the level of agreement between arterial and venous electrolyte measurements.

METHODS

This retrospective study was conducted in the clinical biochemistry department of the Christian Institute of Health Sciences and Research Hospital, Dimapur, Nagaland, India, from January 2024 to June 2024. A total of 200 samples obtained from patients admitted to the intensive care unit (ICU) were included. Patients were included if both arterial and venous electrolyte results were available. Electrolyte values were retrieved from laboratory records, and the time at which each sample was received in the laboratory was documented. Inclusion criteria required patients of any age or sex for whom both arterial and venous samples were requested for electrolyte analysis, with paired samples collected within a maximum interval of 20 minutes. Exclusion criteria included missing results, a sampling interval exceeding 20 minutes, or samples that were hemolyzed, clotted, incomplete, or duplicated.

For venous electrolyte measurement, 3 ml of blood was collected into a plain vacuum tube, centrifuged to obtain serum, and analyzed using the Vitros 5600 analyzer (Ortho Clinical Diagnostics), which utilizes the direct ion-selective electrode (ISE) method. For arterial blood gas (ABG) analysis, 2 ml of arterial blood was collected in a heparinized syringe, sealed, and immediately transported for analysis using the GEM 3500 analyzer (Agappe Diagnostics), which also operates on the direct ISE principle. Only paired results containing both sodium (Na^+) and potassium (K^+) values from the two analyzers were included. The time of sample receipt in the laboratory was recorded for all cases.

Ethical approval for the study was obtained from the institutional ethics committee. Data were recorded and statistically analyzed using Microsoft Excel and SPSS software. Continuous variables were expressed as mean±standard deviation (SD), and a p value <0.05 was considered statistically significant. The Wilcoxon signed-rank test was employed to compare Na^+ and K^+ concentrations between the two analyzers. Correlation was assessed using Spearman's rank correlation coefficient, and agreement was evaluated using Bland-Altman analysis, with the limits of agreement calculated as bias ± 1.96 × SD.

RESULTS

The mean age of 200 subjects whose laboratory reports were analysed was 55.53 years. Of the 200, there were 57 females and 143 males. The mean value for serum sodium by AA was 136.33±9.22, and the ABG analyser was 135.23±9.57. The mean value for potassium by the AA analyser was 4.20±1.01, and in the ABG analyser was 4.01±0.97. In Table 1, we can observe a statistically significant difference between the values of the electrolytes analyzer on an AA and an ABG analyzer.

Table 1: Mean and standard deviation of the arterial and venous blood electrolytes.

Analyte (mmol/l)	Arterial blood	Venous blood	P value
	Mean±SD	Mean±SD	
Sodium	135.23±9.57	136.33±9.22	<0.001
Potassium	4.01±0.97	4.20±1.01	<0.001

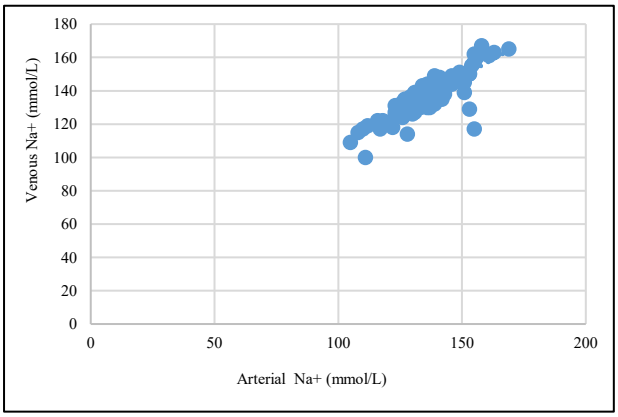

Figure 1: Spearman's correlation between arterial and venous sodium measurements.

Figure 1 shows a strong, positive, and statistically significant Spearman's correlation between sodium values measured in arterial and venous blood samples (r=0.819, p<0.001), indicating that sodium concentrations obtained from both methods increase proportionately.

Figure 2 demonstrate a strong and statistically significant positive Spearman correlation between arterial and venous potassium measurements (r=0.844, p<0.001), suggesting that potassium levels obtained by both sampling methods increase concurrently.

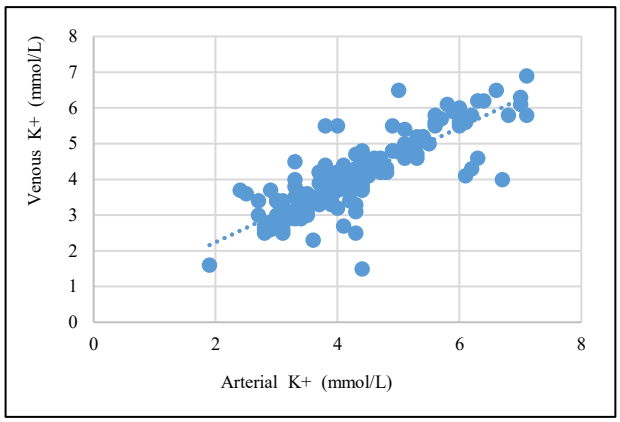

Figure 2: Spearman's correlation between arterial and venous potassium measurements.

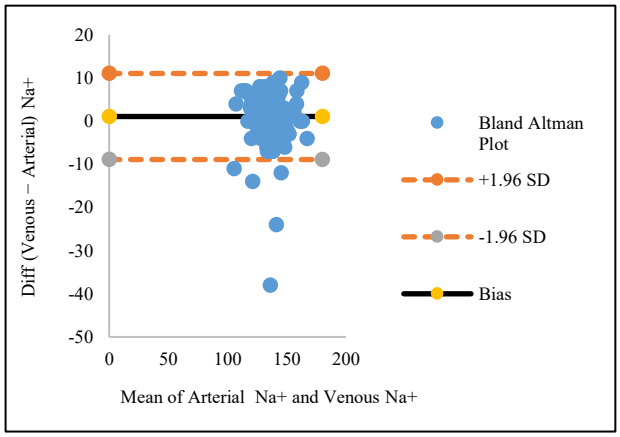

Figure 3: Bland-Altman plot of sodium in arterial and venous blood.

A Bland-Altman plot was used to evaluate the agreement between the two analyzers. The mean bias was 1.105, with a standard deviation (SD) of 5.0895. Using the formula bias ± 1.96×SD, the limits of agreement (LOA) were calculated as −8.87 to 11.08. The 95% confidence interval for the bias ranged from 0.482 to 1.728, and the p-value for bias different from zero was 0.0024, confirming statistical significance. Out of 200 paired measurements, 195 (97.5%) were within the LOA, indicating a generally acceptable agreement between the two analysers for sodium measurement.

A Bland-Altman plot was constructed to evaluate the agreement between two analyzers. The mean bias was −0.1974 with a standard deviation (SD) of 0.5628. Based on the formula bias ± 1.96×SD, the limits of agreement (LOA) were determined to range from −1.30 to 0.91. The 95% confidence interval for the bias was between −0.276 and −0.119, and the test for bias different from zero yielded a p value of <0.0001, confirming statistical significance. Out of 200 paired measurements, 187

(93.5%) fell within the LOA, indicating a moderate degree of agreement between the two analysers for potassium, though slightly below the commonly accepted 95% threshold.

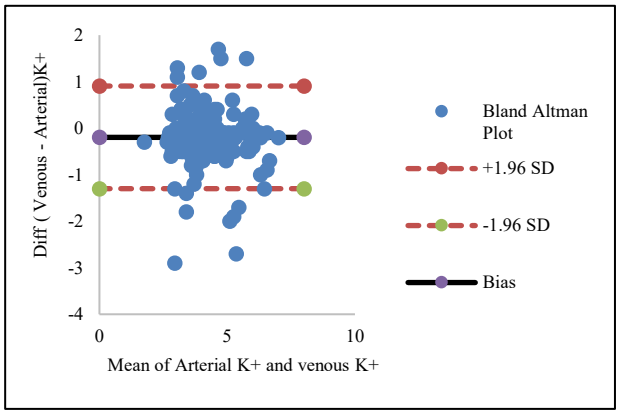

Figure 4: Bland-Altman plot of potassium in venous and arterial blood.

DISCUSSION

Critically ill patients require close and frequent monitoring of metabolic parameters, making turnaround time (TAT) highly important in emergency and intensive care unit (ICU) settings. Despite this, many hospitals still lack advanced facilities and equipment. To address this, point-of-care testing provides rapid bedside results, enabling quicker decisions and timely treatment initiation.[14] Therefore, timely and precise assessments of these parameters are essential in critical care. While the measurement of these electrolytes using a conventional autoanalyzer with venous serum samples is well standardized and reliable, the process requires centrifugation and serum separation, which is time-consuming. In contrast, arterial blood gas (ABG) analyzers provide immediate results for sodium, potassium, and chloride levels, but the presence of heparin in arterial samples may interfere with the accuracy of these assays**.**

In the present study, we attempted to determine whether the venous and arterial samples analyzed on the automated analyzer (Vitros 5600) and the ABG Analyzer (GEM 3500) provide comparable results for sodium (Na^+) and potassium (K^+). If comparable, the ABG analyzer could serve as an alternative to the automated analyzer, offering advantages in terms of reduced turnaround time and cost. The results demonstrated that the differences between the arterial and venous sodium and potassium values were statistically significant. Pearson's correlation analysis indicated a strong positive relationship between the two analyzers (r = 0.819 for Na+ +; r = 0.844 for K+ +). Bland-Altman analysis further revealed that 97.5% of the sodium values fell within the limits of agreement, whereas potassium showed 93% agreement. Although slightly below the ideal 95% threshold, 93% is generally considered clinically acceptable and indicates a moderate level of agreement between the two analyzers for potassium measurements. Taken together, these findings suggest that the sodium values obtained from ABG and automated analyzers are highly comparable, whereas the potassium values show reasonable but slightly lower agreement. This supports the potential utility of ABG analyzers as a rapid and practical alternative for electrolyte estimation in certain clinical settings, provided that the limitations of potassium measurement are considered. In agreement with our study, Wongyingsinn et al observed a good correlation between arterial and venous potassium levels and stated that arterial potassium levels can replace the measurement of venous potassium levels.[15] Flegar-Mestric et al observed that electrolytes measured in whole blood by point-of-care analyzer were comparable to those measured in plasma or venous serum samples.[16] King et al observed that there was good agreement between the sodium and potassium values measured by ABG analyzer and chemistry autoanalyzer.[17] This is consistent with the findings of the present study. Awasthi et al observed that there was a strong correlation between the arterial sodium and potassium and venous sodium and potassium, which were similar to the findings of the present study.[18] Fu et al studied potassium levels in patients with diabetic ketoacidosis and concluded that arterial potassium cannot be used as a substitute for serum potassium in patients with diabetic ketoacidosis.[19] Although the agreement between whole blood and serum potassium was good and the average difference was small, the individual differences were clinically significant, particularly at lower potassium values.[20] Patients in ICUs are critically ill and tend to have low blood protein levels. The ABG results were not affected by serum protein levels, which made the ABG electrolyte results more accurate for critically ill patients.[21] Moreover, patients can have pseudohyponatremia if protein or cholesterol levels increase in ICU patients.

Although the use of ABG only for evaluating electrolytes can have a high operational cost, when we consider the total amount of information, we obtain from an ABG in a critically ill patient, such as oxygen requirement, lactate level, and acidosis per se, the use of ABG machines in critical areas of hospitals, such as emergency departments, operation theaters, and ICUs, is well justified. Furthermore, the direct cost of the machine to the hospital has been decreasing as the supply of such analyzers increases with time.[20] ABG provides rapid, reliable screening; however, systematic bias and wide limits of agreement necessitate instrument-specific correction factors for safe clinical substitution in the ICU.

Limitations of the study are

This was a retrospective study. Although ICU nurses are trained to collect arterial and venous samples, the possibility of preanalytical errors cannot be eliminated.

No data on treatment interventions, such as fluid infusions and blood transfusions, which can affect the results of both methods, were available

CONCLUSION

This study found that sodium and potassium values from arterial and venous samples, as tested on the ABG and automated chemistry analyzers showed a strong positive correlation and good agreement in Bland-Altman analysis. This suggests that results from venous samples on the chemistry analyzer can be used interchangeably with arterial samples on the ABG analyzer. However, further studies with clinical correlation are needed to confirm which instrument is more reliable. The ABG analyzer, using the direct ISE method, provides fast results, avoids the electrolyte exclusion effect, and helps in quick clinical decisions. For accurate results, proper sampling with dry or electrolyte-balanced heparin and regular quality control are essential. Each laboratory should also perform its own pilot study to establish correction factors, as equipment and calibration may vary.

ACKNOWLEDGEMENTS

Authors would like to thank Ms. Senjumroni Kikon, Biostatistician (NERMPI), for her support in data analysis.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee (CIHSR-IEC/2025-2026/Exp Rev/17)

REFERENCES

1. Hoekstra M, Vogelzang M, Drost JT, Janse M, Loef BG, Van Der Horst IC, et al. Implementation and evaluation of a nurse-centred computerised potassium regulation protocol in the intensive care unit: a before-and-after analysis. BMC Med Inform Decis Mak. 2010;10(1):5.
2. Vincent JL, Abraham E, Moore FA, Kochanek P, Mitchell P. Textbook of Critical Care. 6th edn. Philadelphia (PA): Saunders; 2011.
3. Buckley MS, Leblanc JM, Cawley MJ. Electrolyte disturbances associated with commonly prescribed medications in the intensive care unit. Crit Care Med. 2010;38(6 Suppl):S253-64.
4. Shrimanker I, Bhattarai S. Electrolytes. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2024.
5. Whelan B, Bennett K, O'Riordan D, Silke B. Serum sodium as a risk factor for in-hospital mortality in acute unselected general medical patients. QJM. 2008;102(3):175-82.
6. Chawla A, Sterns RH, Nigwekar SU, Cappuccio JD. Mortality and serum sodium: do patients die from or with hyponatremia? Clin J Am Soc Nephrol. 2011;6(5):960-5.
7. Mousavi SAJ, Shahabi S, Mostafapour E, Purfakharan M, Fereshtehnejad SM, Amini J, et al. Comparison of the serum electrolyte levels among patients who died and survived in the intensive care unit. Tanaffos. 2012;11(4):36-42.
8. Dimeski G, Morgan TJ, Presneill JJ, Venkatesh B. Disagreement between ion-selective electrode direct and indirect sodium measurements: estimation of the problem in a tertiary referral hospital. J Crit Care. 2012;27(3):326.e9-16.
9. Scott MG, LeGrys VA, Klutts JS. Electrolytes and blood gases. In: Tietz Textbook of Clinical Chemistry and Molecular Diagnostics. 4th edn. Philadelphia (PA): Saunders; 2006:983-1018.
10. Ehrmeyer SS, Laessig RH, Leinweber JE, Oryall JJ. 1990 Medicare/CLIA final rules for proficiency testing: minimum intralaboratory performance characteristics (CV and bias) needed to pass. Clin Chem. 1990;36(10):1736-40.
11. Morimatsu H, Rocktäschel J, Bellomo R, Uchino S, Goldsmith D, Gutteridge G. Comparison of point-of-care versus central laboratory measurement of electrolyte concentrations on calculations of the anion gap and the strong ion difference. Anesthesiology. 2003;98(5):1077-84.
12. Chacko B, Peter JV, Patole S, Fleming JJ, Selvakumar R. Electrolytes assessed by point-of-care testing- are the values comparable with results obtained from the central laboratory? Indian J Crit Care Med. 2011;15(1):24-9.
13. Prichard JS, French JS, Alvar N. Clinical evaluation of the ABL-77 for point-of-care analysis in the cardiovascular operating room. J Extra Corpor Technol. 2006;38(2):128-33.
14. Burtis CA, Ashwood ER, Bruns DE. Tietz Fundamentals of Clinical Chemistry. 6th edn. W B Saunders Co Ltd; 2007.
15. Wongyingsinn M, Suksuriyayothin S. Use of rapid ABG analyser in measurement of potassium concentration: does it agree with venous potassium concentration? J Med Assoc Thail Chotmaihet Thangphaet. 2009;92(7):925-9.
16. Flegar-Mestrić Z, Perkov S. Comparability of point-of-care whole-blood electrolyte and substrate testing using a Stat Profile Critical Care Xpress analyser and standard laboratory methods. Clin Chem Lab Med. 2006;44(7):898-903.
17. King R, Campbell A. Performance of the radiometer OSM3 and ABL505 blood gas analysers for determination of sodium, potassium and hemoglobin concentrations. Anaesthesia. 2000;55(1):65-9.
18. Awasthi S, Rani R, Malviya D. Peripheral venous blood gas analysis: An alternative to arterial blood gas analysis for initial assessment and resuscitation in emergency and intensive care unit patients. Anesth Essays Res. 2013;7(3):355.
19. Fu P, Douros G, Kelly A. Does potassium concentration measured on blood gas analysis agree with serum potassium in patients with diabetic ketoacidosis? Emerg Med. 2004;16(4):280-3.
20. Magny E, Beaudeux JL, Launay JM. Point care testing in blood gas and electrolyte analysis: examples of implementation and cost analysis. Ann Biol Clin. 2003;61(3):344-51.

21. Budak YU, Huysal K, Polat M. Use of a blood gas analyser and a laboratory autoanalyser in routine practice to measure electrolytes in intensive care unit patients. BMC Anesthesiol. 2012;12(1):1.

Cite this article as: Chawang SK, Yepthomi N, Imchen N. Agreement between arterial and venous electrolyte levels in patients admitted to intensive care unit: a retrospective study. Int J Res Med Sci 2025;13:5238-43.