Received: 17 Dec 2021 | **Accepted:** 24 Feb 2022
DOI: 10.54005/geneltip.1038123

ORIGINAL ARTICLE

Comparison of the Results of Sodium, Potassium, and Chlorine Measured Through Ion Selective Electrode (ISE) Method in Different Devices

Farklı Cihazlarda İyon Seçici Elektrot (ISE) Yöntemi ile Ölçülen Sodyum, Potasyum ve Klor Sonuçlarının Kıyaslanması

[1]Turan Akdağ, [2]Saadet Kader, [3]Hüseyin Dost, [4]Ali Ünlü

[1]Meram Vocational School, Necmettin Erbakan University, Konya, Turkey

[2]Biochemistry Laboratory, Karapınar State Hospital, Konya, Turkey

[3]Medical Supervisor, Ankara, Turkey
[4]Department of Biochemistry, Faculty of Medicine, Selcuk University, Konya, Turkey

Correspondence

Turan Akdağ, Meram Vocational School, Necmettin Erbakan University, Konya, Turkey.

E-Mail: turanakdag570@gmail.com

How to cite ?

Akdağ T, Kader S, Dost H, Ünlü A. Comparison of the Results of Sodium, Potassium, and Chlorine Measured Through Ion Selective Electrode (ISE) Method in Different Devices. Genel Tıp Derg. 2022; 32(2): 198-202

ABSTRACT

Objective: The measurements of electrolytes are an indispensable part of the routine tests performed in clinical biochemistry laboratories. In the present study, we aimed to evaluate Na, K, and Cl electrolytes with the ISE method in the Mindray BS-800M and Beckman Coulter AU5800 devices.
Material and methods: The serum samples were obtained from the healthy volunteers admitted to the Karapınar State Hospital for control purposes between January and April 2021. The sample probe was conducted using the same indirect method in the Mindray BS-800M and Beckman Coulter AU5800 devices, which is an individual sample probe for the ISE method.
Results: While the comparative measurements were performed on different devices, the correlations between the electrolytes were found as follows: Na [r=0.964, 95% CI (0.52-0.90)], K [r=0.995, 95% CI (0.09-0.12)], and Cl [r=0.972, 95% CI (0.69-1.12)]. Moreover, a correlation was also found between these results.
Conclusion: A consistency between the measured Na, K, and Cl electrolytes was determined on the different analyzers. Also, a positive correlation was determined between those electrolytes. We consider that further and comprehensive studies are needed to elucidate these results.

Keywords: Chlorine, electrolyte, potassium, sodium

ÖZ

Amaç: Elektrolit ölçümleri, klinik biyokimya laboratuvarlarında yapılan rutin testlerin vazgeçilmez bir parçasıdır. Bu çalışmada Mindray BS-800M ve Beckman Coulter AU5800 cihazlarında Na, K ve Cl elektrolitlerini ISE yöntemi ile değerlendirmeyi amaçladık.
Gereç ve yöntem: Serum örnekleri, Ocak-Nisan 2021 tarihleri arasında Karapınar Devlet Hastanesi'ne kontrol amaçlı başvuran sağlıklı gönüllülerden alınmıştır. Örnek probu, ISE yöntemi için ayrı bir numune probu olup Mindray BS-800M ve Beckman Coulter AU5800 cihazlarında indirekt yöntem kullanılarak gerçekleştirilmiştir.
Bulgular: Karşılaştırmalı ölçümler farklı cihazlarda yapılırken elektrolitler arasındaki korelasyonlar Na [r=0,964, % 95 CI (0,52-0,90)], K [r=0,995, % 95 CI (0,09-0.12)] ve Cl [r=0.972, % 95 CI (0.69-1.12)] olarak bulundu. Ayrıca bu sonuçlar arasında da bir korelasyon belirlenmiştir.
Sonuç: Farklı analizörlerde ölçülen Na, K ve Cl elektrolitleri arasında bir tutarlılık belirlendi. Ayrıca, bu elektrolitler arasında pozitif bir korelasyon bulunmaktadır. Bu sonuçların açıklığa kavuşturulması için daha fazla ve kapsamlı çalışmalara ihtiyaç olduğu görülmektedir.

Anahtar Kelimeler: Klor, elektrolit, potasyum, sodyum

Introduction

Electrolytes are sine qua non for the human body to function and maintain the integrity of the cells. Therefore, electrolyte disorders may lead to serious and critical consequences (1) and are seen as the most common causes of morbidity and mortality in critically ill patients (2). Electrolytes affect many metabolic processes such as the regulation of osmotic pressure, hydration of various body fluid parts, stabilization of membrane potential, cell stimulation, maintenance of appropriate body pH, and regulation of heart and muscle functions in the human body.

Electrolytes are primarily involved in functioning in oxidation-reduction reactions and are found as the basic components and/or co-factors in enzymatic reactions (3). In routine clinical practice, sodium (Na) and potassium (K) are requested together and should be measured urgently in critical patients or emergent situations. As an extracellular cation, Na plays a critical role in the regulation of osmotic pressure and the regulation of acid-base balance in the human body. Potassium plays important role in the stimulation of muscles, muscle activity, and stimulation of the myocardium. Hypokalemia is defined as a serum K level of less than 3.5 mEq/L (3.5 mmol/L). Moreover, Cl plays an important role in many physiological processes such as maintaining electrical balance in the nervous system, intracellular and extracellular transport, water balance in the body, and formation of hydrogen chloride (HCl) from gastric mucosa (11, 14, 15).

Recently, various novel analyzers have been designed for the measurement of Na, K, and Cl electrolytes (4). The main principle of those devices is based on the electrode membrane compositions allowing the ion-selective electrode (ISE) transmission (5). With the advances in microprocessors, the ISE systems are shown as the new generation of electronics and potentiometric devices (6). In a previous study, it was reported that the success rates of the ISE method can differ in measuring different electrolytes (7). Additionally, the theory and application of ISE are quite complex due to many factors such as the temperature, selectivity of the membrane, and activity of other ions in the solution (8).

The analyses of electrolytes are measured with two different technologies as the direct ISE and indirect ISE methods. In those methods, the samples are diluted with a diluent before the concentrations, and then the electrolytes are measured, respectively. The direct ISE method is commonly used in blood gas analyzers and measures the electrolytes in undiluted sample types (9).

The most common causes of inaccurate results in clinical biochemistry are preanalytical sources that cause variation. Appropriate patient preparation and consistent sampling practices (time of day, fasting, position, tourniquet, and blood collection technique) with awareness of physiological variations are essential for many analytes to obtain reliable results and to accurately interpret observed changes. Although quality manufacturing techniques, the availability of reference standard materials, the use of quality control and proficiency tests have minimized errors and deviations from accuracy. The comparison of method experiments is based on the comparisons of the patients' samples with the new test methods through different devices. In the study, thus, we aimed to evaluate Na, K, and Cl electrolytes with the ISE method in the Mindray BS-800M and Beckman Coulter AU5800 devices.

Material and Method

The serum samples of Na (n=90), K (n=120), and Cl (n=90) were obtained from the healthy volunteers admitted to the Karapınar State Hospital for routine controls within the period between January and April 2021. The sample probe was carried out using the same indirect method in the Mindray BS-800M and Beckman Coulter AU5800 devices, which is an individual sample probe for the ISE method. The findings obtained from the devices were evaluated retrospectively. The study was approved by the Non-Invasive Clinical Research Ethics Committee of the Faculty of Medicine in Necmettin Erbakan University (Decision No: 2021/3321).

The Mindray BS-800M ISE analyser: The Mindray BS-800M (Mindray, Shenzhen, China) device is a fully automated modular analytical system designed for the analyses of general biochemistry, therapeutic drug monitoring, drug abuse parameters, urine biochemistry tests, specific protein tests, and serology assays. BS-800M system is also a modular platform from the BS-Series Biochemistry systems including the high-performance ISEs and uses spectrophotometry to perform kinetically endpoint and non-linear reactions. The Mindray BS-800M analyzer uses a indirect ISE method to measure Na, K, and Cl. MR Buffer solution applies to Mindray BS series auto chemistry analyzers. It is used to dilute samples before they are disposed to the electrodes flowcell.

The Beckman AU5800 ISE analyser: The Beckman Coulter AU5800 (Beckman Coulter Inc., Brea CA, USA) device is a new analytical platform designed for the analysis of general chemistry, esoteric, therapeutic drug monitoring, drug abuse, urine chemistry, special protein, and serology assays. The Beckman AU5800 ISE analyzer uses a direct ISE method to measure Na, K, and Cl. The ISE module for Na, K, and Cl employs peak ether membrane electrodes for sodium and potassium and a molecular oriented PVC membrane for chloride that are specific for each ion of interest in the sample. An electrical potential is developed according to the Nernst Equation for a specific ion. When compared to an internal reference, this electrical potential is translated into voltage and then into the ion concentration of the sample (10). Selected models in the AU5800 series are available in clinical chemistry module configurations as single or dual ISE flow cells (11).

Statistical analysis

The Statistical Package for Social Sciences (SPSS) for Windows 21.0 and analyses computer programs were used to perform the statistical analyses (SPSS Inc., Chicago, IL, USA). The Bland-Altman and Passing-Bablok plot graphs were utilized for the method comparisons.

Results

The correlations between the findings detected through the Mindray BS-800M and the Beckman Coulter AU5800 analysis devices were found as follows: Na [r=0.964, 95% CI (-1.41)-(-0.75) and (0.52-0.90) as respectively], K [r=0.995, 95% CI (-0.0319)-0.0070) and (0.09-0.12) as respectively] and Cl [r=0.972, 95% CI (-1.483)-(0.742) and (0.69-1.12) as respectively]. Also, there was a positive correlation between the findings, and the results (Table 1). Intercept/slope values and 95% confidence intervals after Passing-Bablok regression analysis for Na, K and Cl are given (Table 2). As shown in Table 1, pathological samples were included in the study. The study was carried out at the same time and under the same conditions on both devices. Also, the same serum sample was studied on both devices. Comparison and splots of serum Na, K and Cl in different devices are demonstrated in Figure 1-6.

Table 1: The comparisons between the findings of serum sodium (Na), potassium (K), and chlorine (Cl) detected via Mindray BS-800M and Beckman AU 5800 devices

Na	**Min mEq/L**	**Max mEq/L**	**n=90**	**Value**	**95% CI**	**Bias**
Beckman AU 5800	123.0	149.0	Mean difference	0.7	0.52-0.90	0.10
Mindray BS-800M	124.0	148.0	95% LoA	-1.1	(-1.41)-(-0.75)	0.17
Beckman AU 5800 + Mindray BS-800M/2	123.5	148.5	95% LoA	2.5	2.18-2.83	0.17
Correlation (r)	0.964		SD	0.9		
K			**n=120**			
Beckman AU 5800	1.910	5.320	Mean difference	0.111	0.0993-0.1220	0.00
Mindray BS-800M	1.930	5.530	95% LoA	-0.012	(-0.0319)-0.0070	0.01
Beckman AU 5800 + Mindray BS-800M/2	1.920	5.425	95% LoA	0.234	0.2143-0.2533	0.01
Correlation (r)	0.995		SD	0.063		
Cl			**n=90**			
Beckman AU 5800	90	124	Mean difference	0.91	0.693-1.125	0.11
Mindray BS-800M	93	127	95% LoA	-1.11	(-1.483)-(0.742)	0.18
Beckman AU5800+Mindray BS-800M/2	91.5	125.5	95% LoA	2.93	2.560-3.301	0.18
Correlation (r)	0.972		SD	1.03		

CI: Confidence interval, Cl: Chlorine, K: Potassium, LoA: Limits of agreement, Na: Sodium, SD: Standard deviation

Table 2: Intercept/slope values and 95% confidence intervals after Passing-Bablok regression analysis for Na, K and Cl

Parameter		**Estimate**	**95% CI**
Sodium (Na)	Intercept	1.0000	1.0000 - 1.0000
	Slope	1.0000	1.0000 - 1.0000
Potassium (K)	Intercept	-0.1431	-0.2358 - (-0.05651)
	Slope	1.063	1.042 – 1.083
Chlorine (Cl)	Intercept	1.0000	1.0000 - 1.0000
	Slope	1.0000	1.0000 - 1.0000

CI: confidence interval

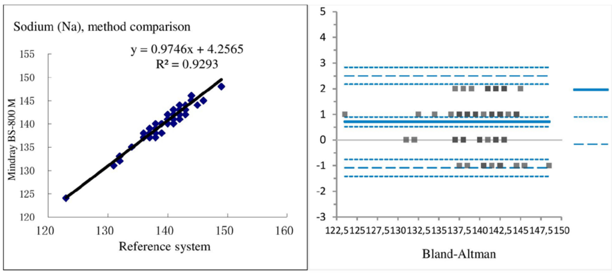
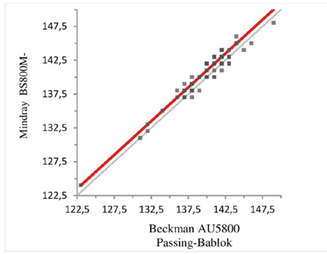


Figure 1: Comparison of Mindray BS-800M and reference system with sodium (Na)



	y=ax+b		r2
	a	b	
parameter	0.9<a<1.1	-	>0.90
value	0.9746	4.2565	0.9293

Figure 2: Plots of serum sodium (Na) in Mindray BS-800M and Beckman AU 5800

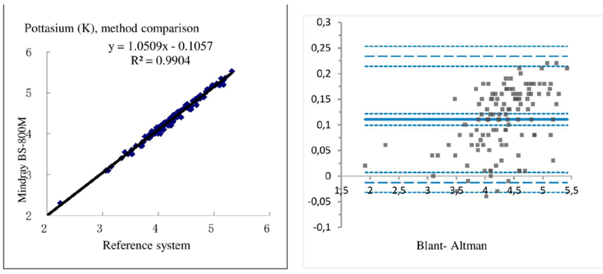
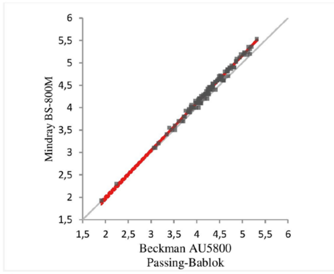


Figure 3: Comparison of Mindray BS-800M and reference system with pottasium (K)



	y=ax+b		r2
	a	b	
parameter	0.9<a<1.1	-	>0.90
value	1.0509	-0.1057	0.9994

Figure 4: Plots of serum potassium (K) in Mindray BS-800M and Beckman AU 5800

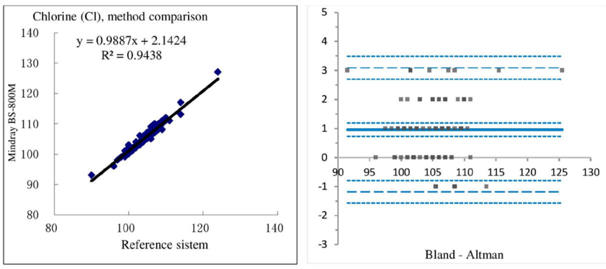
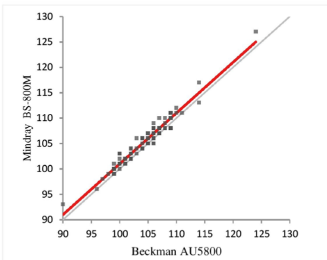


Figure 5: Comparison of Mindray BS-800M and reference system with chlorine (Cl)



	y=ax+b		r2
	a	b	
parameter	0.9<a<1.1	-	>0.90
value	0.9887	2.1424	0.9438

Figure 6: Plots of serum chlorine (Cl) in Mindray BS-800M and Beckman AU 5800

Discussion

The estimates of the prevalence of hyponatremia (serum Na concentration less than 135 mE/L) were reported to be as 1% in nursing home residents, 18% in the general acute care population, and 30% in the intensive care unit (ICU) patients (12). While hypernatremia (serum Na concentration above 150 mEq/L) was less frequent among the hospitalized patients, the incidence was reported to be 0.3-8.9% (13). From the reports, mild and chronic hyponatremia were observed as asymptomatic with neurological worsening and gastrointestinal symptoms. Hypernatremia may also be encountered as asymptomatic until the line of threshold (14).

The European Resuscitation Council (ERC) defines hyperkalemia as a plasma level>5.5 mmol/L and severe hyperkalemia as>6.5 mmol/L. Hyperkalemia may be witnessed with hypoxia, sepsis, cardiac, and/or renal failure in patients. The delays in the management of hyperkalemia may be potentially life-threatening and lead to serious outcomes. Based on the literature, several studies reported that the disturbances in the K mechanism may cause serious systemic and cardiac problems (15). While hypochloremia (<96 mEq/L) is observed in gastrointestinal and renal disorders, hyperchloremia (>106 mEq/L) may be seen in the conditions such as dehydration, Cushing's syndrome, hyperaldosteronism, severe diarrhea, and respiratory acidosis (16, 17).

The measurement of electrolytes is of vital importance in clinical diagnosis and the course of the disease in terms of providing valuable information. In our study, a positive correlation (r=0.964, 95% CI/0.52-0.90) was observed between the measurements of the devices in terms of serum Na. The minimum and maximum measurement ranges of sodium electrolyte in the Mindray BS-800M analyzer were 124.01-148.0 mEq/L and 123.0-149.0 mEq/L in the Beckman AU5800 analyzer [standard deviation (SD), 0.9; mean difference, 0.7] (Figure 1-2). In addition, it was observed that there was a correlation in the comparison of serum K measurements (r=0.995, 95% CI/0.09-0.12). The minimum and maximum measurement ranges of K electrolytes in the Mindray BS-800M analyzer were 1.930-5.530 mEq/L, and 1.910-5.320 mEq/L in the Beckman AU5800 analyzer (SD, 0.063; mean difference, 0.111) (Figure 3-4). In the present study, the correlation of serum Cl measurements was found to be as r=0.972, 95% CI (0.69-1.12). The minimum and maximum measurement ranges of potassium electrolyte were 93-127 mEq/L in the Mindray BS-800M analyzer and 90-124 mEq/L in the Beckman AU5800 analyzer (SD, 1.03; mean difference, 0.91) (Figure

5-6). Also, there is a concordance between the two different devices for the intercept/slope values and 95% confidence intervals for Na, K and Cl (Table 2).

In the study performed by Turkalp et al., a correlation was found between ISE and the flame photometry, and the researchers evaluated the measurements of Na and K electrolytes through the ISE method in terms of the precision, linearity, repeatability, accuracy, and compatibility with the flame photometry (r=0.908 for Na, r=0.921 for K) (6). In another study, however, Ustundag-Budak et al. determined the sigma metrics with two automated biochemistry analyzers and an arterial blood gas analyzer for the measurements of electrolytes. By using different technologies in the study, Ustundag-Budak et al. aimed to predict the best approach for electrolyte monitoring in the emergency settings and the context of routine services and proposed that increasing the calibration frequency for the electrolytes is necessary for quality assurance (18). In another study where Lippi et al. evaluated the analytical performance of the Beckman Coulter AU5800, good linearity was found for all tests, especially for the ISE module. In the study, the regression coefficients were determined as>1.000 (19).

In conclusion, a consistency was determined between the measurements of Na, K, and Cl electrolytes in the different analyzers. According to the Passing-Bablok results and the Bland-altman graphics, two different devices could be alternative to each other. Moreover, a positive correlation was also determined between those electrolytes. To the best of our knowledge, the number of studies where the optimization of different methods has been performed is very limited. So, we consider that comprehensive and further studies are needed to elucidate the entity.

Financial Disclosure

All authors declare no financial support.

Conflict of interests

The authors declare that they have no competing interests.

Acknowledgments

We would like to thank the staff of the Karapınar State Hospital. The authors also thank Numan Duran for assistance with language editing.

References

1.Arampatzis S, Funk GC, Leichtle AB, et al. Impact of diuretic therapy-associated electrolyte disorders present on admission to the emergency department: A cross-sectional analysis. BMC Med 2013;11:83.

2.Lee JW. Fluid and electrolyte disturbances in critically ill patients. Electrolyte Blood Press 2010;8(2):72-81.

3.Tietz NW. Fundamentals of clinical chemistry. 3nd ed. Philadelphia: WB Saunders Company, 1987;66-69.

4.Yilmaz S, Uysal HB, Avcil M, et al. Comparison of different methods for measurement of electrolytes in patients admitted to the intensive care unit. Saudi Med J 2016;37(3):262-267.

5.Morf WE, Pretsch E, de Rooij NF. Memory effects of ion-selective electrodes: theory and computer simulation of the time-dependent potential response to multiple sample changes. J Electroanal Chem (Lausanne) 2009;633(1):137-145.

6.Türkalp I, Erbiz E. İyon selektif elektrod ile serumda sodyum ve potasyum tayini-flame fotometrisi ile kıyaslanması, South Clin Ist Euras 1990;1(3):162-66.

7.Ustundağ Y, Huysal K, Ozgunay ŞE, et al. Interchangeability of sodium and potassium result values of arterial blood gas with laboratory analyzer: Narrative Review. Indian J Crit Care Med 2019;23(1):35-42.

8.Guenat OT, Generelli S, de Rooij NF, et al. Development of an array of ion-selective microelectrodes aimed for the monitoring of extracellular ionic activities. Anal Chem 2006;78(21):7453-7460.

9.Banerjee A, Mehrotra G. Role of correction factor in minimizing errors while calculating electrolyte values between blood-gas analyzer and laboratory autoanalyzer: a comparative study. Indian J Crit Care Med 2018;22(1):34-39.

10.Tietz NW, Pruden EL, Siggaard-Anderson O. Electrolytes. In: Teitz NW ed. Fundamentals of clinical chemistry. 3nd ed. Philadelphia: WB Saunders Company, 1987:614-624.

11.Jia KK, Zhang J. Evaluation of five routine glucose methods on an Olympus AU5400 analyzer using the CDC hexokinase reference method. Clin Chem Lab Med 2010;48:361-364.

12.Gross P. Correction of hyponatremia. Semin Nephrol 2001;21(3):269-272.

13.Adrogue HJ. Consequences of inadequate management of hyponatremia. Am J Nephrol 2005;25(3):240-249.

14.Adrogué HJ, Madias NE. Hypernatremia. N Engl J Med 2000;342(20):1493-1499.

15.Aygencel G. Potasyum Metabolizması Bozuklukları. J Turk Soc Intens Care 2018;12(1):31-42.

16.Morrison G. Serum Chloride. In: HK Walker (eds.) et al. Clinical methods: the history, physical, and laboratory examinations. 3.rd ed. Boston: Butterworths, 1990;197.

17.Hanberg JS, Rao V, Ter Maaten JM, et al. Hypochloremia and diuretic resistance in heart failure: mechanistic ınsights. Circ Heart Fail 2016;9(8):10.

18.Ustundag-Budak Y, Huysal K. Application of sigma metrics and performance comparison between two biochemistry analyser and a blood gas analyser for the determination of electrolytes. J Clin Diagn Res 2017;11(2):BC06-BC09.

19.Lippi G, Dipalo M, Musa R, et al. Evaluation of the analytical performances of the novel Beckman Coulter AU5800. Clin Biochem 2012;45(6):502-504.