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Original Research

Can the clinician trust blood gas for serum electrolyte levels?

Blood gas reliability

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Abstract

Aim: Electrolytes are charged elements that are required for proper cellular function in most tissues of the body. Almost all metabolic processes are dependent on or performed by electrolytes. Electrolyte abnormalities may represent significant risks for life. Routinely, all electrolytes are measured from the serum sample, using the automatic analysis devices at the central laboratories of the hospitals. However, this is time-consuming. In this study, our aim is to compare the results of venous blood gas electrolyte, glucose and hemoglobin values with serum laboratory results and to investigate whether venous blood gas can substitute serum. Material and Method: Our study was designed as a prospective cohort study. A total of 418 adult patients between 18-88 years old, who were admitted to the nephrology outpatient clinic were included in the study. The demographic data of the patients and accompanying comorbidities were recorded. In addition, blood gas electrolytes, glucose, and hemoglobin values of each patient were recorded. Results: The study included 174 female patients and 244 male patients. In terms of both serum and blood gas hemoglobin, there was a statistically significant difference between the genders ($p<0.001$). A strong positive correlation was detected between serum sodium, potassium, glucose and hemoglobin values and blood gas sodium, potassium, glucose and hemoglobin values ($p <0.001$, $r = 0.764$, $p <0.001$, $r = 0.867$, $p <0.001$, respectively, $r = 0.969$; $p <0.001$, $r = 0.846$). The highest correlation coefficient was between serum and blood gas glucose values, while the lowest correlation coefficient was between the sodium values. Discussion: In our study, we believe that in CKD patients with a prominent fluid-electrolyte imbalance, in emergency departments, where critically ill patients are common in intensive care patients with a life-threatening disease, the rapid blood gas tests may be considered for the treatment planning until the results of the biochemical examination are available.

Keywords

Blood Gas; Sodium; Potassium; Glucose; Hemoglobin

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Introduction

Electrolytes are charged elements that are required for proper cellular function in most tissues of the body. Almost all metabolic processes are dependent on or performed by electrolytes. Electrolyte abnormalities may represent significant risks for life [1]. Routinely, all electrolytes are measured from the serum sample, using the automatic analysis devices at the central laboratories of the hospitals; but this is time-consuming. Typically, in the acute care laboratories of most of the tertiary hospitals, a return time of approximately 15 minutes has been recorded [2]. Rapid, bedside tests such as blood gas help the clinician in the management of the appropriate treatment in emergencies [3]. Recent studies have shown that venous blood gas can be used instead of arterial blood gas to evaluate pH, pCO2, and bicarbonate [4]. In the blood-gas analysis, in addition to pH, bicarbonate, pCO2, and pO2, electrolyte levels such as sodium, potassium, calcium, and glucose and hemoglobin can be measured. However, traditionally, they are less trusted tests since there are not enough clinical trials on this subject [5].

A rapid bedside blood gas test allows clinicians to initiate the appropriate treatment for emergencies so that the patient can benefit both clinically and economically [6].

In this study, our aim is to compare the results of venous blood gas electrolyte, glucose and hemoglobin values with serum laboratory results and to investigate whether venous blood gas can substitute serum.

Material and Method

This study was ethically approved by the Ordu University Faculty of Medicine Clinical Research and Ethics Committee (Approval No: 2018/80, Date: 12/04/2018). Voluntary consent was obtained from the cases who participated in the study.

Our study was planned as a prospective cohort study. A total of 418 adult patients who were admitted to the nephrology outpatient clinic between April 2018 and September 2018 were included in the study. The demographic data of the patients and accompanying comorbidities were recorded. In addition, blood gas electrolytes, glucose, and hemoglobin values of each patient were recorded.

Our exclusion criteria were: patients under 18, and over 88 years of age, patients with malignancy, and patients with active infection were not included in the study.

In addition, when evaluating the results, samples in which the blood was not collected simultaneously or samples who did not reach the laboratory simultaneously were not included in the study.

For routine biochemical analyses, Cobas c 501 module device, for blood gas analyses, ABL90FLEX blood gas Analyzer, for hemogram, Sysmex® XN-1000 SA-01 device was used.

Statistical Analysis

The normal distribution of data was evaluated by the Shapiro-Wilk test and the variance homogeneity was evaluated by the Levene test. The independent samples t-test was used to compare the groups in terms of gender. To evaluate the correlation between the serum and blood gas, univariate linear regression analysis was used. A P-value less than or equal to 0.05 was considered statistically significant. All statistical analyses were performed using SPSS v25 (IBM Inc., Chicago, IL, USA) statistical software.

Results

A total of 244 (58.4%) male and 174 (41.6%) female patients were included in the study. The mean age of the cases was 61.69 ± 16.37.

In Table 1, descriptive statistics of the cases in terms of gender are presented. In terms of both serum and blood gas hemoglobin, there was a statistically significant difference between the genders (p<0.001). In terms of other biochemical parameters, no statistically significant differences were detected between the genders (p<0.001).

Table 1. Descriptive statistics and result of independent t-test for the variables

	Gender	n	Mean	Std. Deviation	Std. error	P-value
Serum Glucose	Male	174	123,48	63,50	4,81	0,830 NS (t=0,215)
	Female	241	124,66	48,65	3,13	
Serum Na	Male	174	140,02	3,39	0,26	0,349 NS (t=0,938)
	Female	242	139,72	3,17	0,20	
Serum K	Male	174	4,76	0,58	0,04	0,753 NS (t=0,315)
	Female	242	4,78	0,68	0,04	
Serum Ca	Male	173	9,89	6,39	0,49	0,135 NS (t=1,499)
	Female	242	9,27	0,60	0,04	
Serum Hgb	Male	174	12,09	1,69	0,13	0,000*** (t=4,853)
	Female	242	13,00	2,12	0,14	
Blood gas K	Male	174	4,50	0,55	0,04	0,734 NS (t=0,340)
	Female	242	4,52	0,66	0,04	
Blood gas Na	Male	174	140,60	3,40	0,26	0,069NS (t=1,823)
	Female	242	139,99	3,35	0,22	
Blood gas Ca	Male	174	1,22	0,08	0,01	0,396 NS (t=0,849)
	Female	242	1,21	0,07	0,00	
Blood gas Glucose	Male	174	126,25	64,77	4,91	0,894 NS (t=0,133)
	Female	242	126,99	48,64	3,13	
Blood gas Hgb	Male	174	12,50	1,94	0,15	0,000*** (t=4,455)
	Female	242	13,42	2,15	0,14	

NS: was not statistically significant (p> 0.05); ***, statistically significant (p <0.001)

The mean serum and blood gas values of all of the patients are presented in Figure 1.

According to the Pearson correlation test, a strong positive correlation was detected between the serum sodium, potassium, glucose and hemoglobin values and blood gas sodium, potassium, glucose and hemoglobin values (p values: p < 0.001, r = 0.764; p < 0.001, r = 0.867; p < 0.001, r = 0969; p < 0.001, r = 0.846, respectively). The highest correlation coefficient was between serum and blood gas glucose values, while the lowest correlation coefficient was between the sodium values. The second highest correlation coefficient was between the hemoglobin values. Results of the Pearson correlation analysis are shown in Table 2 and 3.

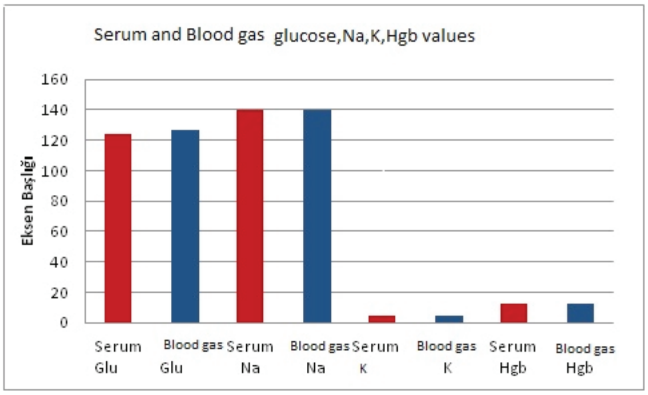

Figure 1. Serum and blood glucose, Na, K, Hgb values

The degree of accuracy for glucose according to the linear regression analysis was R2 96.4 (%). For sodium, it was R2 76.4(%), for potassium, it was R2 86.7(%), and for hemoglobin, it was R2 84.6 (%). The degree of accuracy for calcium according to the linear regression analysis was R2 07.1 (%). The low degree of accuracy for calcium is due to different units of serum and blood gas measurements. Serum calcium value is calculated as mg/dl and in blood gas, it is calculated as mmol/liter. Similarly, the low value of calcium in the correlation analysis can be attributed to the same cause. Regression equations established to estimate the serum electrolyte, glucose and Hgb amount of the patients from the blood gas electrolyte, glucose and Hgb are shown in Table 4, and the and p-values of the estimations performed using these equations are also presented in the same table.

Discussion

In this study, we investigated whether the sodium, potassium, glucose and hemoglobin levels in simultaneously collected samples measured by different methods and equipment such as blood gas analysis device and laboratory autoanalyzer are equivalent, and if so, whether they can be used interchangeably in the routine practice. In this study, it was concluded that Na, K, glucose and Hb values measured by the blood gas analysis device and laboratory autoanalyzer are positively correlated, and in cases where an emergency decision is required, blood gas analysis, in which the result is obtained within minutes, can be an important guide for the clinician.

Fluid and electrolyte balance disorders are common in clinical practice. The concentrations of electrolytes in the body are mainly mediated by renal functions; any functional impairment in these mechanisms, even including severe physiological stress conditions, can disrupt electrolyte balance and cause life-threatening emergencies [6].

Use of central laboratory tests at a hospital can lead to a long delay period between requesting this test and obtaining the results, and such delays can jeopardize the treatment of critically ill patients. In patients with CKD, rapid diagnosis and treatment are very important for the patient's life. Therefore, early detection of electrolyte, hemoglobin and glucose values in critically ill patients who need rapid intervention guides the physician when making a diagnosis and performing the appropriate treatment. Studying blood gas has been proven as beneficial to the clinical decision-making as it shortens the return time for routine biochemical tests [7].

Table 3. Correlation coefficients and their significance levels between serum and blood gas (n=415)

Variables	r	P
Glucose	0,969	0,000***
Na	0,764	0,000***
K	0,867	0,000***
Ca	0,071	0,149 AD
Hgb	0,846	0,000***

r: Pearson correlation coefficient
NS, Statistically not significant (p>0,05); ***, Statistically significant (p<0,001)

Table 2. Correlations coefficients and their significance levels among the variables (n=415)

		Serum Na	Serum K	Serum Ca	Serum HGB	Blood gas glukoz	Blood gas Na	Blood gas K	Blood gas Ca	Blood gas HGB
Serum Glucose	r	-0,228	0,134	-0,043	-0,027	0,969	-0,195	0,166	-0,015	-0,014
	P	0,000***	0,006**	0,386	0,581	0,000***	0,000***	0,001**	0,764	0,775
Serum Na	r		-0,098	-0,066	0,160	-0,229	0,764	-0,104	0,072	0,102
	P		0,045*	0,180	0,001**	0,000***	0,000***	0,035*	0,141	0,037*
Serum K	r			-0,038	-0,229	0,124	-0,160	0,867	0,011	-0,147
	P			0,444	0,000**	0,012*	0,001**	0,000***	0,826	0,003**
Serum Ca	r				0,037	-0,042	-0,033	-0,050	0,071	0,032
	P				0,457	0,388	0,506	0,306	0,149	0,517
Serum HGB	r					0,002	0,181	-0,243	0,108	0,846
	P					0,971	0,000***	0,000	0,027*	0,000***
Blood gas Glucose	r						-0,193	0,164	-0,003	0,012
	P						0,000***	0,001**	0,944	0,808
Blood gas Na	r							-0,116	0,243	0,110
	P							0,018*	0,000***	0,025*
Blood gas K	r								0,027	-0,136
	P								0,590	0,005**
Blood gas Ca	r									0,096
	P									0,051

r: Pearson correlation coefficient
*, Statistically significant (p<0,05); **, Statistically significant (p<0,01); ***, Statistically significant (p<0,001)

While the electrolyte levels in arterial blood gas, which is used for blood gas evaluation, are frequently used, there are recent studies on how venous blood gas can be used instead of ABG. In the study by Wongyingsinn, where rapid arterial blood gas potassium value can be substituted for venous potassium value, compatibility between arterial blood gas potassium value and venous potassium value and it was suggested that blood gas potassium level can be used instead of venous potassium value. Biochemical K, Na, Cl, glucose, and blood gas electrolyte and glucose values were compared and a significant positive correlation was detected between the values [8]. Similar to the study by Wongyingsinn et al., in our study, we found that there was a statistically significant, highly positive correlation between K, Na, glucose values.

In the study by Bozkurt et al., a significant difference was detected between laboratory potassium values and venous blood gas potassium values [9]. According to this result, it is not appropriate to use venous blood gas potassium value instead of laboratory potassium value. However, especially in critically ill patients for whom rapid treatment decisions must be made in emergency services, venous blood gas potassium value can be used to estimate the potassium value until the laboratory results are obtained. In our study, unlike the study by Bozkurt et al., we found that serum and blood gas K values were very compatible. In other words, blood gas K value can guide the treatment until serum K results are obtained.

In the study by Jain A. et al., where laboratory electrolyte values are compared with blood gas electrolyte values, a total of 200 samples were compared and no significant difference was detected between blood gas K values and laboratory K values. However, a significant difference was detected between the measured Na values. It has been concluded that critical treatments can be performed by relying on arterial blood gas potassium values [10]. In our study, both sodium and potassium levels were found to be compatible, and these results corroborated the study by Jain et al. in terms of K, while they did not in terms of Na. This can be attributed to the large patient number in our study.

In the study performed by Öner et al., biochemistry K, Na, Cl, glucose and blood gas electrolyte and glucose values were compared and a significant positive correlation was detected between the values [11]. In the study by Leino et al., where the interchangeability of blood gas and laboratory electrolyte and metabolic values was investigated, it was suggested that blood gas K, Na, Ca, glucose, lactate values can be used instead of the laboratory values in treatment management of critically ill patients [12]. In a study by Altunok et al., it was found that there was a moderate correlation between the two types of measurements in terms of sodium and potassium levels, but none of these levels had an acceptable compliance limit [13]. In the largest study published on this subject, Mirzazadeh et al. found a significant correlation between blood gas and laboratory in terms of sodium, potassium, and calcium, and concluded that blood gas can be accepted as a rapid bedside test for critically ill patients [14].

In our study, we found a strong correlation between VBG and routine laboratory measurement results in terms of Na and K values. Our study is similar in this respect to the studies by Wongyingsinn et al., Öner et al., Leino et al., Altunok et al., and Mirzazadeh et al. Our study is similar to the study by Jain et al. in terms of blood gas and serum K values, but different in terms of Na values. Similarly, in the study by Açıkgöz et al., K value was different [15]. This may be due to the fact that the number of cases of Jain et al. is less than the number of cases in our study and that they have studied Na values in a wide range such as normonatremic, hyponatremic, hypernatremic. Similarly, the number of cases in the study by Açıkgöz et al. on hyperkalemic patients was less than the number of cases in our study. The larger sample size in our study makes our study more valuable in terms of statistics and leads to more accurate results.

In the study by Jian Bo Zhang et al., they have suggested that there were no statistical differences between the blood gas analyzer and routine laboratory measurements in terms of hemoglobin [16]. Leina et al. also stated that the results from the blood gas analysis device and laboratory autoanalyzer are compatible in terms of hemoglobin [17]. Altunok et al. showed that hemoglobin values were strongly correlated in blood gas analyzer and laboratory autoanalyzer measurements [13]. In our study, we found that hemoglobin levels measured by blood gas analyzer and laboratory autoanalyzer were very close. Our results are concordant with the literature.

Altunok et al. have shown that blood gas analyzer and laboratory autoanalyzer results are highly compatible in terms of glucose levels [12]. In the literature review by Inoue et al., it was stated that the accuracy of the blood glucose measurements performed using arterial blood gas analyzers was significantly higher than the glucose measurements performed using the capillary blood from the fingertip [17]. In the study by Uysal et al., it was stated that among all other parameters, glucose value was the parameter by which the blood gas analyzer and laboratory autoanalyzer results were most compatible [18]. In our study, similar to the literature, we found that serum and blood gas glucose levels had the highest compatibility. Our study is concordant with the study by Uysal et al.

Conclusion

In conclusion , we believe that in CKD patients with a prominent fluid-electrolyte imbalance, in emergency departments, where critically ill patients are common in intensive care patients with a life-threatening disease, the rapid blood gas tests may be considered for the treatment planning until the results of the biochemical examination are available for the clinician. Clinician can rely on blood gas values.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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