ORIGINAL ARTICLE / ÖZGÜN ARAŞTIRMA MAKALESİ

Correlation of Hemoglobin, Hematocrit and Electrolyte Values with Venous Blood Gas Analyzer and Laboratory Autoanalyzers in Patients with Indications for Emergency Hemodialysis

Acil Hemodiyaliz Endikasyonu Olan Hastalarda Hemoglobin, Hematokrit Ve Elektrolit Değerlerinin Venöz Kan Gazı Analizörü Ve Laboratuvar Otoanalizörleri İle Korelasyonu

Mustafa Avcı[1], Nalan Kozacı[2]

ABSTRACT

Aim: The aim the study was to compare the hemoglobin (Hb), hematocrit (Hct) and electrolyte values measured in the venous blood by bedside blood gas analyzer and standard laboratory auto analyzers in patients with emergency hemodialysis indication, to determine the correlation between them and to investigate the accuracy of blood gas analyzer in K abnormalities.

Material and Methods: Patients aged 18 years and over who underwent emergency hemodialysis after being diagnosed in the ED between 01 January 2017 and 01 November 2019 were included in the study. Patients whose laboratory test results could not be reached, whose blood samples that analyzed by laboratory auto analyzer and venous blood gas analyzer were not collected simultaneously, whose venous gas results were reported more than 30 minutes after the blood sample was taken, showing hemolysis in laboratory tests and younger than 18-year-old were excluded from the study. The levels of Hb, Hct, sodium (Na), potassium (K) and chloride (Cl) measured by venous blood gas analyzer and laboratory auto analyzers were compared.

Results: Two hundred and thirteen patients enrolled in the study. There was a correlation between blood gas analyzer and laboratory auto analyzer results. The correlation coefficient was 0.608 for Na, 0.821 for K, 0.548 for Cl, 0.738 for Hb and 0.771 for Hct. The highest correlation was in K. The formulas were designed to calculate laboratory analyzer values from venous blood gas analyzer values. Each of these formulas designed was applied to the patients included in the study and the results were found reliable.

Conclusion: The values of Na, K, Cl, Hb and Hct measured by blood gas analyzer in venous blood sample are correlated with those measured in laboratory auto analyzers in patients with emergency hemodialysis indication in emergency department. Especially, K abnormalities have the highest correlation coefficient. The values of Na, K, Cl, Hb and Hct measured by blood gas analyzer in venous blood sample can be used in daily practice. Furthermore, formulas were able to be produced to calculate the value measured by a laboratory automatic analyzer from the value measured by a blood gas analyzer. These formulas can be useful in case of urgent decisions.

Keywords: Hemodialysis, blood gas, laboratory, potassium

ÖZ

Amaç: Bu çalışma ile, acil hemodiyaliz endikasyonu olan hastalarda venöz kanda ölçülen hemoglobin (Hb), hemotokrit (Hct) ve elektrolit değerlerini başucu kan gazı analizörü ve standart laboratuvar otoanalizörleri ile karşılaştırmayı, aralarındaki korelasyonu belirlemeyi ve özellikle de potasyum anormalliklerinde kan gazı cihazının etkinliğini araştırmayı amaçladık.

Gereç ve Yöntemler: 01 Ocak 2017 ve 01 Kasım 2019 tarihleri arasında 18 yaşında veya daha büyük ve acil servisten acil hemodiyalize alınan hastalar çalışmaya dahil edildi. Laboratuvar test sonuçlarına ulaşılamayan, laboratuvar otoanalizörü ve venöz kan gazı analizörü ile analiz edilen kan örnekleri aynı anda alınmayan, venöz gaz sonuçları kan örneği alındıktan sonraki 30 dakikadan daha uzun sürede rapor edilen, test sonuçları hemolizli olan ve 18 yaşından küçük hastalar çalışma dışı bırakıldı. Başucu venöz kan gazı analizörü ve laboratuvar oto analizörleri ile ölçülen Hb, Hct, sodyum (Na), potasyum (K) ve klor (Cl) seviyeleri karşılaştırıldı.

Bulgular: Çalışmaya 213 hasta dahil edildi. Başucu kan gazı analizörü ile laboratuvar otoanalizörü sonuçları arasında korelasyon tespit edildi. Korelasyon katsayısı Na için 0.608, K için 0.821, Cl için 0.548, Hb için 0.738 ve Hct için 0.771 idi. En yüksek korelasyon K'da bulundu. Venöz kan gazı analizörü değerlerinden laboratuvar analizörü değerlerini hesaplamak için formüller tasarlandı. Tasarlanan bu formüllerin her biri, çalışmaya dahil edilen hastalara uygulandı ve sonuçlar güvenilir bulundu.

Sonuç: Acil serviste acil hemodiyaliz endikasyonu olan hastalarda venöz kan örneğinde başucu kan gazı analizörü ile ölçülen Na, K, Cl, Hb ve Hct değerleri ile laboratuvar otoanalizörlerinde ölçülen değerler aralarında korelasyon göstermektedir. Özellikle potasyum anormallikleri en yüksek korelasyon değerine sahiptir. Venöz kan örneğinde başucu kan gazı analizörü ile ölçülen Na, K, Cl, Hb ve Hct değerleri günlük uygulamada kullanılabilir. Ayrıca, bir laboratuvar otomatik analizörü tarafından ölçülen değeri, bir kan gazı analizörü tarafından ölçülen değerden hesaplamak için formüller üretildi ve güvenliği test edildi. Bu formüller acil tedavi kararında fayda sağlayabilir.

Anahtar Kelimeler: Hemodiyaliz, kan gazı, laboratuvar, potasyum

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[1] Health Sciences University, Antalya Training and Research Hospital, Emergency Medicine Department, , Antalya, Turkey

[2] Alanya Alaaddin Keykubat University Alanya Training and Research Hospital, Department of Emergency Medicine, Antalya, Turkey.

Corresponding Author: Mustafa Avci, MD **Address:** Antalya Training and Research Hospital, Emergency Medicine Department, Antalya, Turkey **Phone:** +90 554 483 77 13 **e-mail**: dravcimustafa@gmail.com

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Introduction

Hemodialysis is the process of diffusion with the patient's blood and the dialysate fluid via a semipermeable membrane. In this way, substances accumulated in the blood are removed from the body. Hemodialysis reduces body fluid volume, regulates electrolyte abnormalities, removes uremic toxins / drugs from plasma which are the functions the patient's kidneys have lost (1). Acute renal failure, conditions requiring emergency hemodialysis secondary to chronic renal failure, electrolyte disorders (hyperkalemia, hypermagnesemia, hypo-hypernatremia, hypo-hypercalcemia, etc.), toxic causes (alcohol, drug addiction, salicylate, lithium, fungus, etc.), malignant hypertension, pulmonary edema, encephalopathy, acid-base balance disorders, rhabdomyolysis and metabolic disorders due to crush syndrome are the indications for emergency hemodialysis (1,2). Among these indications, the causes that may cause mortality and need urgent hemodialysis are hyperkalemia, severe uremic symptoms and pulmonary edema due to hypervolemia. (3-5). Rapid detection of electrolyte disturbances especially hyperkalaemia since it cause fatal cardiac arrhythmias are vital, in order to management of the patient and initiation of appropriate therapy (6). Indeed Wolfson et al. stated that a patient with cardiac arrest and a diagnosis of chronic kidney failure should be assumed to be hyperkalemic (3). In the studies conducted, the most common reasons for emergency hemodialysis of patients with chronic renal failure have been reported as hypervolemia and hyperkalaemia (4,5). Waiting for laboratory results or delaying results may endanger the treatment of critical patients in such emergency situations (7). For this reason; emergency physicians prefer to use blood gas measurement devices as bedside tests that provide rapid results in the management of treatment. Usually, these devices can produce results in as short as 90 seconds (6). These devices can measure pH, PO_2, PCO_2 and HCO_3, as well as glucose, Na, K, Cl, Hb and Hct (6-8). However, it is necessary to confirm the reliability of the measurement of these devices for accurate diagnosis and treatment.

In determining the indication for emergency dialysis, arterial blood gas analysis is the first step of laboratory studies. However, due to the painful arterial puncture, hemorrhage and other vascular risks, venous blood gas values have been used recently. In studies, it is shown that there is no significant difference between the values measured by arterial or venous blood gas analyzers in terms of pH, PCO2, bicarbonate (HCO3) and sodium (Na), potassium (K), and chloride (Cl) levels (9,10).

In the literature, there are studies comparing the levels of Hb, Hct and electrolytes measured in both arterial and venous blood gas analyzers with laboratory autoanalyzers (11,12). However, there are no studies investigating these values in venous blood gas analyzer in patients with indication for emergency hemodialysis.

The aim of the study was to compare the hemoglobin (Hb), hematocrit (Hct) and electrolyte values measured in the venous blood by bedside blood gas analyzer and standard laboratory auto analyzers in patients with emergency hemodialysis indication, to determine the correlation between these and to investigate the accuracy of blood gas analyzer in K abnormalities.

Material and Methods

The study was conducted retrospectively after obtaining the Ethics Committee approval. The study was approved by the Clinical Research Ethics Committee of a tertiary hospital with the decision number 24/15 on 07 November 2019. Patients aged 18 years or over, who underwent emergency hemodialysis after being diagnosed in the ED of a tertiary hospital between 01 January 1, 2017 and November 1, 2019 and whose blood samples were collected at the same time and with the same protocol number for all three tests including complete blood count, venous blood gas analysis and serum electrolyte levels were included in the study. Patients who had results for complete blood count, venous blood gas analyzes and serum electrolyte levels taken at the same time and with the same protocol number for all three tests. Demographic dataset and laboratory test results of the patients were obtained by using hospital automation system database. Patients whose laboratory test results could not be reached, whose blood samples that analyzed by laboratory auto analyzer and venous blood gas analyzer were not collected simultaneously, whose venous gas results were reported more than 30 minutes after the blood sample was taken, showing hemolysis in tests' results and younger than 18-year-old were excluded from the study.

A standardized data recording form was created before starting the study. Cl, K, Na, HCO_3, Hct, Hb, PCO_2, pH, PO_2, and lactate levels measured by venous blood gas analyzer; Hb, Hct, blood urea nitrogen (BUN), creatinine, Na, K, and Cl values measured by laboratory auto analyzers; the age and sex of the patients were recorded in this form. The blood samples collected simultaneously were evaluated for laboratory auto analyzes and venous blood gas analyzer.

There is a bedside blood gas analyzer and a fully equipped laboratory in the emergency department in which conducted the study. Venous blood gas analyzes were performed with Radiometer ABL-800 flex brand blood gas analyzer at bedside and within 90 seconds after blood samples were taken from the patients and results were obtained. Complete blood count tests were performed by Sysmex XN-1000 brand standard auto analyzer and measurement of serum electrolyte levels were performed by Beckman Coulter AU 680 brand standard auto analyzer in

the laboratory of emergency department. Venous blood gas analyzes were performed by using Ayset brand 2 ml liquid lithium heparin containing blood gas injector. The samples taken for complete blood count and serum electrolyte levels were studied with standard tubes**.**

Statistical analysis

The statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS) 21.0 and MedCalc 18.9.1 statistical software. Firstly, the Kolmogorov-Smirnov test evaluated if the distribution of values was normal. Then, Pearson correlation and Spearman correlation analysis were performed. Linear regression equations were used to calculate the value measured with a laboratory auto analyzer from the value measured with a blood gas analyzer (Regression Equation (y) = bx + a) (y: blood gas analyzer value; x: laboratory auto analyzer value; a and b: constant coefficients). In addition to SPSS, to assess agreement Bland-Altman method was used. P value less than 0.05 was considered statistically significant.

Results

Two hundred and thirteen patients enrolled in the study. Eighty-eight (41%) of the patients were female and 125 (59%) were male. Blood gas analyzer results of the patients are given in table 1 and laboratory auto analyzer results are given in table 2.

Value	Median (min-max)
Na (mmol/L)	136 (118-163)
K (mmol/L)	4.60 (1.60-8.96)
Cl (mmol/L)	104 (82-141)
Hb (g/dL)	10.7 (2.1-22.3)
Hct (%)	33.9 (7.8-68.0)

Na: sodium, K: potassium, Cl: chloride, Hb: hemoglobin, Hct: hemotocrit

Table 1. Venous blood gas analyzer values of patients

There was a correlation between blood gas analyzer results and laboratory auto analyzer results.

Value	Mean ±SD (min-max)
Na (mmol/L)	134 (111-150)
K (mmol/L)	4.85 (2.39-11.51)
Cl (mmol/L)	103 (85-117)
Hb (g/dL)	10.8 (4.7-17.4)
Hct (%)	32.8 (8.1-55.0)

Na: sodium, K: potassium, Cl: chloride, Hb: hemoglobin, Hct: hemotocrit

Table 2. Laboratory autoanalyzer values of patients

The correlation coefficient was 0.608 for Na, 0.821 for K, 0.548 for Cl, 0.738 for Hb and 0.771 for Hct. The highest correlation was in K. (Table 3).

Results	Mean difference ± SD (min-max)	P	R
LAB_Na/KG_Na	2.51±5.61 [(-8)-(+25)]	<0.001	0.608
LAB_K/ KG_K	-0.27±0.74 [(-3.41)-(+2.00)]	<0.001	0.821
LAB_Cl/KG_Cl	3.15±7.85 [(-6)-(+27)]	<0.001	0.548
LAB_Hb/KG_Hb	-0.19±2.06 [(-8.4)-(+11.3)]	<0.001	0.738
LAB_Hct/KG_Hct	1.79±5.64 [(-23.9)-(+34.5)]	<0.001	0.771

LAB: laboratory autoanalyzer value, KG: blood gas analyzer value, Na: sodium, K: potassium, Cl: chloride, Hb: hemoglobin, Hct: hemotocrit, R: correlation coefficient, P: statistical significance value.

Table 3. Correlation of blood gas analyzer values and laboratory autoanalyzer values

Since there was a significant positive correlation between laboratory analyzer values and venous blood gas analyzer values in 95% confidence interval, the formulas were designed to calculate laboratory analyzer values from venous blood gas analyzer values (Table 4).

Venous blood gas analyzer values	Regression Equation (y) = bx + a
Na (mmol/L)	(LAB_Na * 0,759) + (34,6)
K (mmol/L)	(LAB_K * 0,775) + (0,866)
Cl (mmol/L)	(LAB_Cl * 0,709) + (31,182)
Hb (g/dL)	(LAB_Hb * 0,891) + (1,773)
Hct (%)	(LAB_Hct * 0,911) + (4,723)

Na: sodium, K: potassium, Cl: chloride, Hb: hemoglobin, Hct: hemotocrit, LAB: laboratory autoanalyzer value, y: venous blood gas analyzer value (dependent group); x: laboratory autoanalyzer value (independent group); a and b: constant coefficients

Table 4. Formulas for calculating laboratory autoanalyzer values from venous blood gas analyzer values

Each of these formulas designed was applied to the patients included in the study and the results were found reliable. The results obtained in each test were collected in an average and near zero area as shown in the Bland-Altman plots and the values were found to be concordant with each other (Figures 1,2,3,4,5).

Discussion

Blood tests with standard laboratory auto analyzer can take more than half an hour (6). However, fast diagnosis and treatment is necessary in patients with indications for emergency hemodialysis. Bedside analyzers have been shown to yield results in a shorter time than laboratory auto analyzers and can be used clinically (6,8,13).

In a study involving 200 patients, a significant difference was found for Na values (r=0.68) and there was no significant difference between K values (r=0.72) (14). Peter et al.

conducted a study with 44 samples in the intensive care unit and found a significant difference with -4.07 (Lin's concordance correlation=0.71) between Na values.

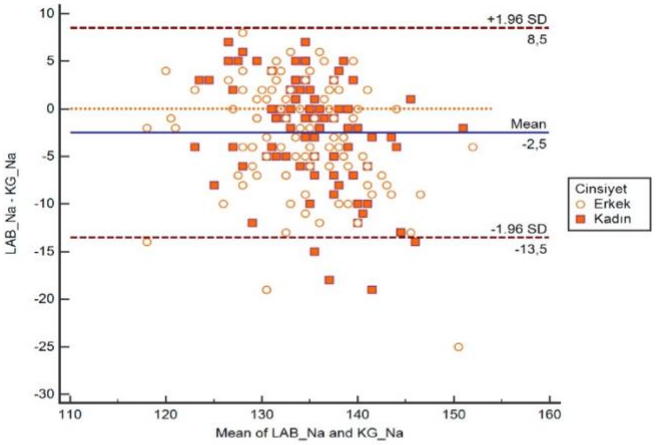

Figure 1. Bland Altman plot for sodium (Na) of laboratory autoanalyser and venous blood gas analyser (mean vs. difference).

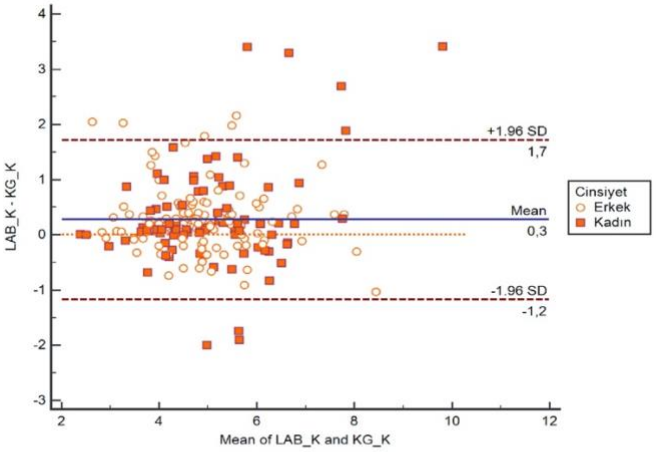

Figure 2. Bland Altman plot for potassium (K) of laboratory autoanalyser and venous blood gas analyser (mean vs. difference).

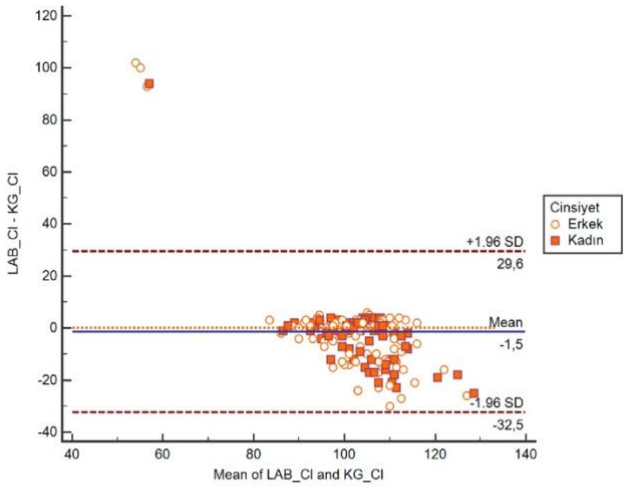

Figure 3. Bland Altman plot for chloride (Cl) of laboratory autoanalyser and venous blood gas analyser (mean vs. difference).

Again, in the same study, although the agreement between the two samples was strong (Lin's concordance correlation=0.96), they found a significant difference for the K value (15). Another study examined the blood gas values of 1105 patients; Na and K difference were found to be significantly different (7). In another study conducted with emergency department patients, there was no difference in central laboratory and blood gas values for Na and K within physiological limits. No significant differences were reported even in Na <130 mmol / L and Na> 150 mmol / L (8). In another emergency department study comparing laboratory and venous blood gas results, it has been suggested that the results for Na and K were correlated and could be used clinically (13). In a study comparing K values in venous blood gas and central laboratory results, it was determined a significant correlation ($p<0.001$) (16). In another study comparing bedside venous blood gas analyzer and laboratory auto analyzer of emergency department, correlation coefficients for Na, K and Cl were 0.720, 0.785 and 0.790, respectively, and the results were significantly positive correlated (6).

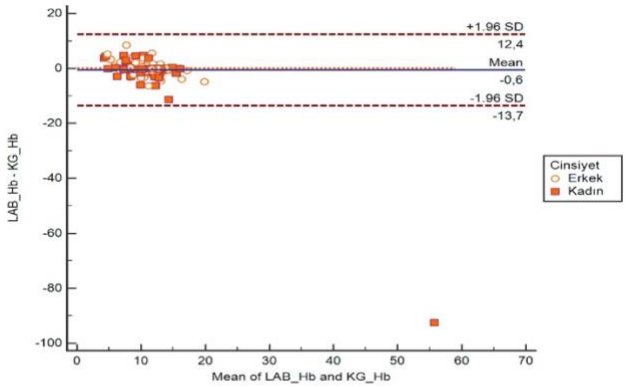

Figure 4. Bland Altman plot for hemoglobin (Hb) of laboratory autoanalyser and venous blood gas analyser (mean vs. difference).

The results of our study were similar to those of other studies. There was a significant correlation between blood gas analyzer and laboratory auto analyzer for Na, K and Cl. Unlike other studies, our study indicates that this correlation is preserved in patients with emergency hemodialysis indication. The correlation value for Na, K and Cl were 0.608, 0.821 and 0.548 respectively and Na difference between blood gas analyzer and laboratory auto analyzer was 2.51, K difference was -0.27 and Cl difference was 3.15. High correlation coefficient for K is important in terms of indicating that it is possible to make a treatment decision via blood gas analyzer result before laboratory auto analyzer tests are resulted in cases where rapid treatment is required such as cardiac arrhythmia.

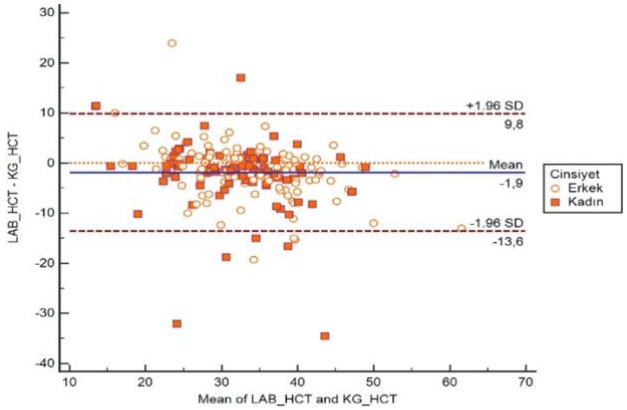

Figure 5. Bland Altman plot for hematocrit (Htc) of laboratory autoanalyser and venous blood gas analyser (mean vs. difference).

Anemia mostly occurs in patients with indication for emergency hemodialysis, as a consequence of renal failure. Renal failure may result in anemia due to erythropoietin deficiency, iron deficiency, folate or vitamin B_{12} deficiency. In addition, anemia may develop due to secondary hyperparathyroidism, acute and chronic inflammatory conditions and aluminum toxicity. Additionally, in hemodialysis patients, chronic blood loss due to the remaining blood in the dialysis membrane and sets at each dialysis session may lead to anemia (17). Therefore, Hb and Hct values are important in patients with hemodialysis indication. In the studies, central laboratory and blood gas hemoglobin values were compared and determined to be correlated (8,13,18). In another study evaluating venous blood gas samples and main laboratory results were identified that also Hct difference is correlated in addition to Hb (6). A study compared blood gas results and core laboratory results and found a strong correlation for Hb and Hct (19). In Turkey, Altunok et al. screened 59,221 patients retrospectively and found a strong correlation for Hb and Hct when compared arterial blood gas and venous blood samples (20). In our study, similar results were found with other studies. There was a significant correlation between the blood gas analyzer and the laboratory auto analyzer for Hb and Hct. The correlation coefficients for Hb and Hct were 0.738 and 0.771, respectively. The mean difference between blood gas analyzer and laboratory auto analyzer values were -0.19 g/dL for Hb and 1.79% for Hct.

The laboratory auto-analyzer test results are generally time consuming. In contrast, the blood gas measurement devices usually can produce results in as little as 90 seconds. So, the calculation of the value measured with a laboratory auto analyzer from the value measured with a blood gas analyzer can save time for the physicians. In a study comparing arterial blood gases and central laboratory measurements in critically ill patients, the researchers found the Na, Cl, Hb, bicarbonate and glucose values are correlated and calculated formulas for laboratory autoanalyzer values from venous blood gas analyzer values (21). In a similar study, Kozaci et al. calculated the laboratory blood sample values (measured by laboratory auto-analyzer) from venous blood gas sample values (measured by blood gas analyzer) by using linear regression equations (6). In our study, similar to the studies above, since there was a significant positive correlation between laboratory analyzer values and venous blood gas analyzer values in 95% confidence interval, we also calculated formulas to estimate the laboratory autoanalyzer values from venous blood gas analyzer values.

Conclusion

The values of Na, K, Cl, Hb and Hct measured by blood gas analyzer in venous blood sample are correlated with those measured in laboratory auto analyzers in patients with emergency hemodialysis indication in emergency department. Especially, K abnormalities that require rapid diagnosis and treatment have the highest correlation coefficient. The values of Na, K, Cl, Hb and Hct measured by blood gas analyzer in venous blood sample can be used in daily practice. Furthermore, formulas were able to be produced to calculate the value measured by a laboratory automatic analyzer from the value measured by a blood gas analyzer. These formulas can be used in case of urgent decisions.

Limitations

Our study was a single-center study with a relatively small number of samples and we examined the data retrospectively.

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Authors' Contribution: Conceptualization, Data curation, Project administration, Resources, Supervision, Roles/Writing - original draft, Writing - review & editing (MA, NK) Formal analysis, Methodology, Validation, Visualization (MA) Funding acquisition, Investigation, Methodology, Project administration, Software (NK)

Ethical Statement: The study was approved by the Clinical Research Ethics Committee of a tertiary hospital with the decision number 24/15 on 07 November 2019.
All authors declared that they follow the rules of Research and Publication Ethics.

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