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Original Article

Comparison of the sodium, potassium, chloride and glucose levels measured by a blood gas analyzer and an autoanalyzer

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Abstract

Aim: A blood gas analyzers (BGA) are vital equipment frequently used in emergency departments and intensive care units. It is clinically important that the measurements of a BGA and an autoanalyzer (AA) provide equivalent results, which is confirmed by their proximitiy to the absolute value. This study aimed to compare the sodium (Na^+), potassium (K^+), chloride (Cl^-) and glucose values in venous blood samples measured with a BGA and a standard AA with external quality control values.

Material and Methods: The results of patients that presented to our emergency department between April 1, 2019 and July 1, 2019 and underwent the measurements of Na^+ (n = 5,908), K^+ (n = 5,755), Cl^- (n = 5,101) and glucose (n = 5,871) simultaneously by BGA and AA were retrospectively compared.

Results: In the Spearman correlation analysis between the two measurements, the correlation coefficient (r) was found as 0.78, 0.88, 0.89 and 0.97 for Na^+, K^+, Cl^- and glucose, respectively. According to the Bland-Altman analysis, in the comparison of Na^+, K^+, Cl^- and glucose values, the average bias percentages at the 95% confidence interval were -0.8 (4.8 to -6.4), -9 (8.6 to -26.5), -0.2 (6.2 to -6.5), and 0.3 (21.8 to -21.3), respectively.

Conclusion: We concluded that the Na^+ and Cl^- results obtained from BGA can be used instead of those obtained from an AA; however, the blood gas K^+ and glucose results of the former cannot replace those of the latter.

Keywords: Acid-base balance; autoanalyzer; blood gas analysis; electrolytes; glucose

INTRODUCTION

Blood gas analyzer (BGA) is vital in emergency departments and intensive care units, especially in the rapid assessment of acid-base balance and many diseases (1-3). Blood gas analysis is one of the most valuable laboratory methods that provide reliable information concerning the metabolic and respiratory status of patients and needs to be evaluated together with clinical findings (2,4-6). Emergency physicians need laboratory and imaging methods that offer fast results in the management of critical patients, and in this respect, blood gas analysis is a guiding tool. A venous blood gas (VBG) sample can be taken through the same venipuncture as blood samples simultaneously collected for other laboratory studies. Therefore, using VBG instead of autoanalyzer (AA) samples can offer time efficiency, and provide the physician with general and rapid information until the laboratory results are ready (7-10).

Blood gas analysis offers an important advantage in terms of providing rapid results and early diagnosis. The use of tests offering fast and reliable results in emergency departments is an imperative for the management of critical patients. It is extremely important to establish an early diagnosis and treatment of electrolyte disorders, such as hyperpotassemia, hyponatremia, and hypercalcemia, especially in patients with trauma and severe gastrointestinal bleeding (6,11). Through necessary modifications and additions, in addition to blood gas analysis, BGAs can also perform the measurement of critical parameters for the emergency physician, such as sodium (Na^+), potassium (K^+), chloride (Cl^-), glucose, and lactate. In the evaluation of critical patients admitted to the emergency department, the results of electrolyte values can be obtained in 60 to 90 minutes in the venous blood sample in the biochemistry laboratory using the standard techniques. Therefore, rapid treatments, which should be performed depending on electrolyte values in

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emergency situations, are either undertaken by evaluating clinical findings or delayed (4,12,13). In blood gas analysis, all the measurements only take a short time of about two to five minutes.

In light of this information, in the current study, we aimed to compare the values of venous blood measured by both BGA and AA in patients that presented to our emergency department. There are previous studies comparing Na^+, K^+, Cl^- levels, but in the current study, glucose values were also compared.

MATERIAL and METHODS

This is a retrospective cross-sectional study conducted in Konya Training and Research Hospital. The study included all patients aged 18 years or over who underwent VBG and serum electrolyte tests simultaneously in the emergency department between April 1, 2019 and July 1, 2019. Samples which were found to have hemolysis and those with missing results of either analysis equipment were excluded from the study. In addition, only the VBG analysis measurement results were used, and arterial blood gas measurements were excluded from the study. Age, gender, and BGA and AA values were screened from the hospital automation system and recorded. Blood gas analysis was performed using a Siemens Rapid Point 500 device and the serum Na+, K+, Cl- and glucose values were assayed by a Beckman Coulter AU5800 AA. The calibration of BGAs is automatically performed every hour, and that of AAs routinely once a week and more frequently if deemed necessary. The Blood samples taken into biochemistry tubes were centrifuged at 2,000 g for 10 minutes immediately after being transferred to the laboratory, and the serum samples obtained were loaded into AA. For this study, approval was obtained from the Pharmaceuticals and Non-Medical Devices Ethics Committee of KTO Karatay University Faculty of Medicine (Number: 2019/0012, Date: 20.03.2019).

Statistical analysis

For statistical analysis, data were evaluated using SPSS package program for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA). The mean, standard deviation, minimum and maximum values were used to summarize numerical data, and frequency distributions and percentages were used for categorical data. The Shapiro-Wilk test was conducted for the normality analysis to examine the distribution of numerical data. Non-parametric tests were used in cases where the results of the Shapiro-Wilk test were $p < 0.05$, and parametric tests when $p > 0.05$. The agreement between the results of BGA and AA analyses was evaluated by performing a correlation-regression analysis and plotting the Bland-Altman graph. The correlation analysis of numerical data was undertaken with the Spearman correlation test. Values less than $p < 0.05$ were considered statistically significant.

RESULTS

In this study, the measurements performed by both BGA and AA were screened from the patient files over a period of three months, and the data of 5,908 patients for Na^+, 5,755 patients for K^+, 5,101 patients for Cl^- and 5,871 patients for glucose were included in the statistical evaluation. Some of the patients were excluded due to the absence of VBG results or due to the hemolysis of blood samples in the system.

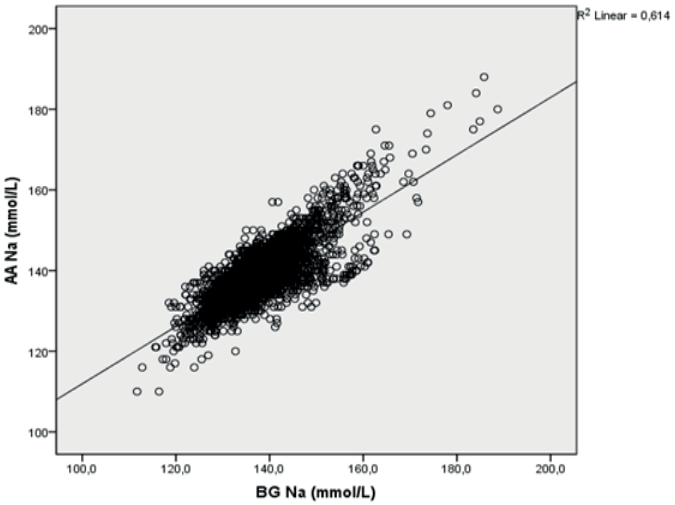

Figure 1. Correlation of the sodium (Na^+) values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

In the Spearman correlation analysis, the correlation coefficient was found to be $r = 0.78$ for Na^+, $r = 0.88$ for K^+, $r = 0.89$ for Cl^-, and $r = 0.97$ for glucose. Since there was a significant positive correlation between the VBG and AA measurements at the 95% confidence interval, all the results obtained from the correlation analysis were $p < 0.001$. The mean BGA and AA measurements are shown in Table 1. Figures 1 to 4 presents the correlation graphics of the results.

Table 1. Comparison of the Na^+, K^+, Cl^- and glucose values measured by BGA and AA

Variables	N	BGA (mean ± SD) (minimum-maximum)	AA (mean ± SD) (minimum-maximum)	p value	Correlation (r)
Sodium (mmol/L)	5908	137.4 ± 6.3 (111.7-188.7)	138 ± 5.7 (110-188)	0,000*	0.78
Potassium (mmol/L)	5755	3.8 ± 0.7 (1.2-7.9)	4.1 ± 0.7 (1.9-9)	0,000*	0.88
Chloride (mmol/L)	5101	105 ± 7.4 (74-144)	105 ± 6.7 (73-150)	0,000*	0.89
Glucose (mg/dL)	5871	131 ± 68.5 (12-653)	131 ± 69.5 (16-737)	0,000*	0.97

AA: Autoanalyzer; BGA: Blood Gas Analyzer; r: Spearman Correlation Coefficient; *Significant at $p < 0.05$

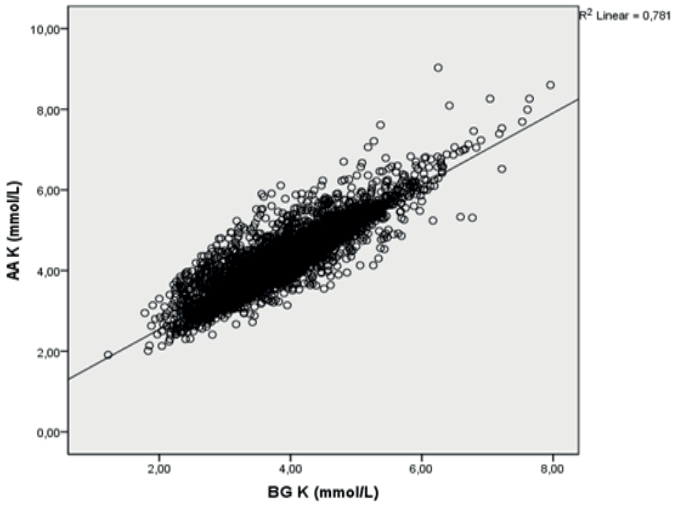

Figure 2. Correlation of the potassium (K^+) values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

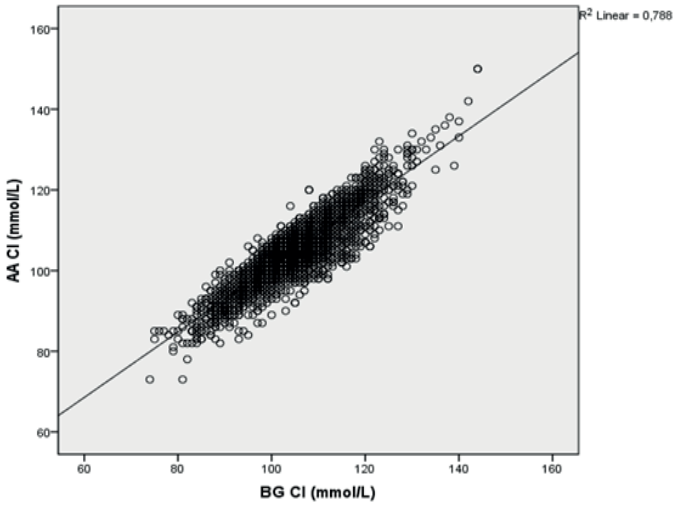

Figure 3. Correlation of the chloride (Cl^-)values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

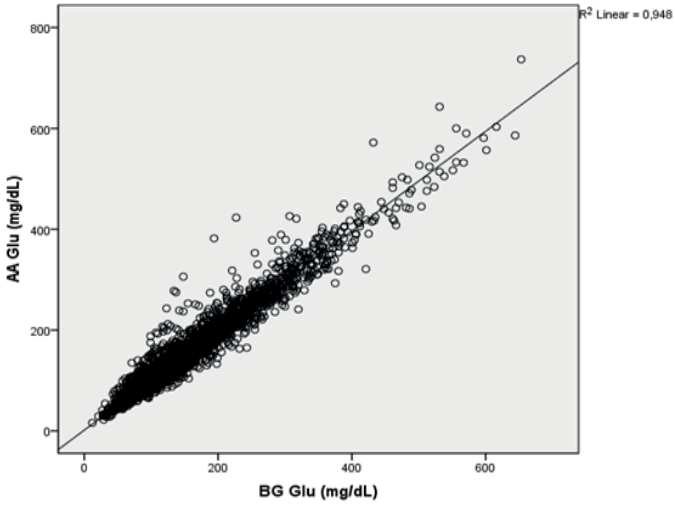

Figure 4. Correlation of the glucose values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

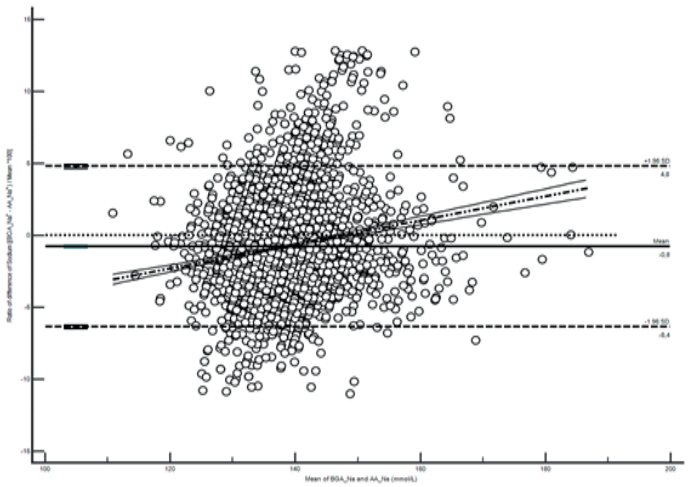

Figure 5. The Bland-Altman plot showing the comparison of the sodium (Na^+) values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

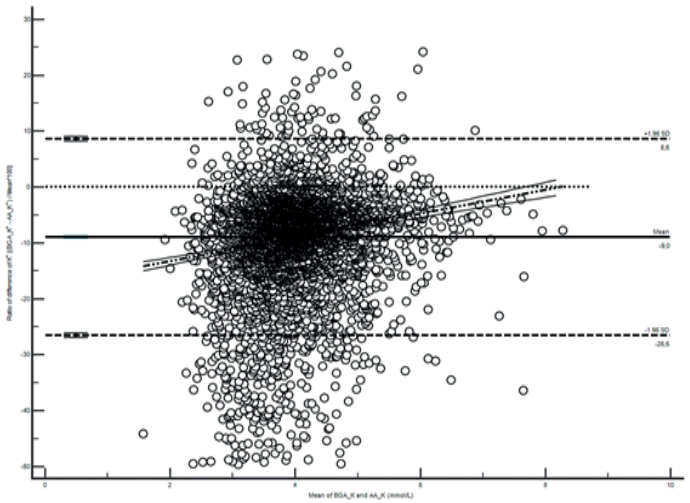

Figure 6. The Bland-Altman plot showing the comparison of the potassium (K+) values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

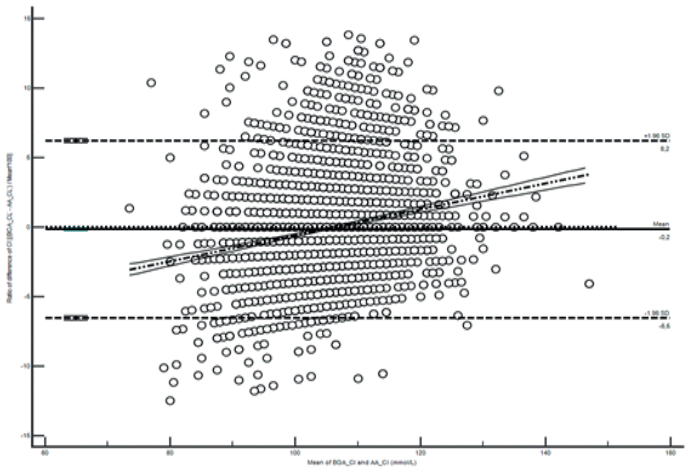

Figure 7. The Bland-Altman plot showing the comparison of the chloride (Cl-) values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

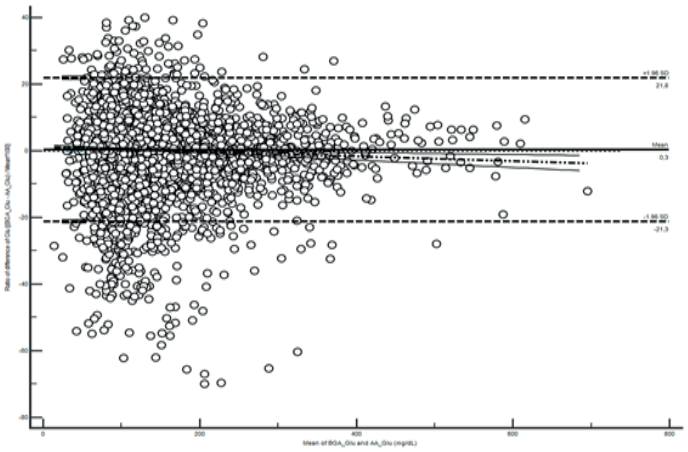

Figure 8. The Bland-Altman plot showing the comparison of the glucose values measured by the blood gas analyzer (BGA) and autoanalyzer (AA)

According to the Bland-Altman analysis, in the comparison of Na^+, K^+, Cl^- and glucose values, the average bias values at the 95% confidence interval were -0.8% (4.8 to -6.4%), -9% (8.6 to -26.5%), -0.2% (6.2 to -6.5%), and 0.3% (21.8 to -21.3%), respectively. In the Bland-Altman plots, bias was observed to be very close to zero for Na^+, Cl^-, and glucose in the comparison of the BGA and AA values, while there was significant negative bias for K^+. According to the Bland-Altman analysis, the limits of agreement and values for Na^+, K^+, Cl^-, and glucose are shown in Figures 5 to 8.

DISCUSSION

Electrolyte disorders can lead to serious and critical events, and represent significant risks with approximate 15% prevalence among emergency patients. In this respect, early acquisition and evaluation of results are important for the functioning of emergency departments (4,6,14). In this study, when the correlation values of the BGA and AA results were examined, there was a high positive correlation between the two devices in terms of the Na^+, K^+, Cl^- and glucose values (r = 0.78, r = 0.88, r = 0.89, and r = 0.97, respectively) (Table 1). In a study by Kozancı et al. conducted in 2015 with 100 patients, the correlation values were obtained as r = 0.72 for Na^+, r = 0.79 for K^+, and r = 0.79 for Cl^- (15), which is in agreement with our results, but the previous study did not include the comparison of glucose levels. In our study, the highest correlation was obtained from the glucose measurements. In a study with 342 patients, Menchine et al. found the correlation coefficients as 0.90 for Na^+ and 0.73 for Cl^- (16). In another study undertaken in 2014, Sezik et al. retrospectively compared the BGA and AA measurements of Na^+ and K^+ in 2,354 patients, and reported a significant difference between the two devices. The mean difference for Na^+ and K^+ was not within acceptable limits, with the correlation coefficients being 0.407 and 0.716, respectively, and therefore the authors concluded that these devices could not be used interchangeably (17). Uyanık et al., who analyzed 40 samples in 2015, reported that the results of the measurements of K^+ were correlated between the devices, but the same agreement was not achieved for Na^+ and Cl^- (18). Since the number of patients in our study was high, we believe that we obtained more accurate results than previous studies.

In most studies comparing electrolytes measured by BGA and AA, the mean acceptable differences specified by the United States Clinical Laboratory Improvement Amendment (US CLIA) (19) were used as reference, and total allowable error (TAE) values were taken into account. In a study by Bozkurt et al., who conducted VBG analysis, the authors found the mean difference for K^+ as 0.56 mmol/L and stated that the correlation coefficient was significantly high (r = 0.882), but BGA could not be used to replace AA due to the acceptable difference being high (20). Jain et al. reported no significant difference between the K^+ values obtained from BGA and AA (mean difference = 0.46 mmol/L; r = 0.72) but noted a significant difference in the Na^+ values (mean difference = 5.96 ± 5.09 mmol/L; r = 0.68) (21). In our study, the mean differences were found to be 1 mmol/L for Na^+, 0.3 mmol/L for K^+, 1 mmol/L for Cl^-, and 1 mg/dL for glucose, and all were within acceptable limits for AA calibrator materials according to the US CLIA. However, the criteria for TAE are used for the repeat measurements of the same sample using the same instrument with the same method, especially for analytical precision. By eliminating all other error factors, it is used only for the evaluation of the amount of analytical error resulting from the device. In our study, the same sample was analyzed on two different devices, and the correlation on the results was evaluated. Therefore, we considered that it would not be appropriate to use the TAE criteria in the evaluation of the data, differences and percentages obtained from this study.

A comparative evaluation of the results of the same sample obtained from different devices is known as an external quality control (EQC) procedure. While evaluating the results in a single device in EQC, the results of the peer group are also taken into consideration. However, in cases where there are differences in the method and device used, all results related to that test parameter are considered. When analyzing the same parameter from the same material in two different devices, for the agreement on the results obtained from two devices, the acceptance criterion at the 95% confidence interval is practically four times the coefficient of variation (%CV) for an appropriate group in EQC analysis (ratio of the limits, obtained by adding and subtracting two standard deviations to and from the mean). In the study period, when the ECQ analysis, of which the AA device is a member, was evaluated, the three-month ECQ results were 8.6%, 12.3%, 14.6%, and 15.5% for Na^+, K^+, Cl^-, and glucose, respectively considering four times of the root mean squares (RMS) of the %CV values for all participants (22). Ideally, the ratio of the differences in results to the mean would be expected to be less than these values for each parameter. The Bland-Altman analysis revealed that the ratio of differences to the mean values for Na^+, K^+, Cl^-, and glucose were 98.5%, 75.4%, 100%, and 88.4%, respectively, indicating that all

were within expected limits. In the Bland-Altman plots, negative bias was observed in the glucose results of BGA, and more significantly in the K^+ results of BGA.

The correlation coefficient (r), which shows the power of relation between two variables, was 0.78 for Na^+, but 98.5% of the differences in the mean values were within acceptable limits. We attributed the low r value to the data distribution range being relatively narrow (90.1% of data ranged from 129.1 to 148.0 mmol/L). Similarly, for the Cl- results, since the data was distributed in a narrow range, despite the low r value obtained from the correlation analysis, the differences in all results between the devices were within acceptable limits. For the test data on K^+, we evaluated that both the r value and the percentage of acceptable results being low (24.6% of the data were outside acceptable limits) were due to the significant negative bias. For this disagreement, we considered that it would be useful to evaluate both the method and internal and external control procedures and calibrations of both devices more closely, and if necessary, adjust the raw results obtained from the device using a factor multiplier. Lastly, for the glucose test data, the r value was 0.97, although the data up to 11.6% were outside acceptable limits, which we thought was due to most data having a wide distribution range (69.5-267 mg/dL for 90% of data)

When we conducted the paired-samples Wilcoxon test, there was a significant difference between the results obtained from the two devices ($p < 0.001$ for Na^+, K^+, Cl^- and glucose data). However, in laboratory practices comparing methods, devices, and kits, agreement percentages are usually determined based on data, such as plot distribution, linear relationship between two variables, correlation coefficient, coefficient of determination, and regression formula obtained by a correlation-regression analysis; therefore, we did not take into account the results of the Wilcoxon test. Furthermore, as the number of data analyzed increases, it is clear that even very small differences will have statistical significance.

LIMITATIONS

The most important limitation of our study is its retrospective design, which did not allow for the standardization of blood gas collection or determination of whether this was performed under appropriate conditions. In the comparison of data, especially for glucose, the matrix effect of whole blood should be taken into account. In addition, since BGA serves as a point-of-care device in the emergency department, any emergency staff who is not a lab technician may load samples into this device in emergencies, and control and calibration procedures not being undertaken as in a laboratory may have caused errors that were overlooked.

CONCLUSION

Na^+ and Cl^- results obtained from the BGA can be used instead of the results obtained from the AA; however, we concluded that BGA K+ and glucose results of the former could not replace those of the latter. Any solutions to eliminate negative bias for K^+, e.g., determination of the correction coefficient may be a remedy for K^+ results. Furthermore, any solution that can reduce the matrix effect can be applied for glucose results. When the laboratory results are inconsistent with the patient's clinical findings, more satisfactory results can be achieved by repetition, control and calibration studies through coordinated work with the laboratory. Regular control and calibration of BGA and AA and strict monitoring of both internal and external quality control processes will reduce the differences in the results obtained from the two devices.

Competing interests: The authors declare that they have no competing interest.

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Ethical approval: For this study, approval was obtained from the Pharmaceuticals and Non-Medical Devices Ethics Committee of KTO Karatay University Faculty of Medicine (Number: 2019/0012, Date: 20.03.2019).

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