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Comparison of hemoglobin, hematocrit, and lactate values measured by bedside blood gas analyzer with laboratory auto-analyzer values and investigation of their correlations in multiple trauma patients

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Abstract

Aim: In this study, we aimed to compare venous Hemoglobin (Hb) and Hematocrit (Hct) values measured by bedside blood gas analyzer with standard laboratory auto-analyzer values in multiple trauma patients and to investigate if lactate level is adequate in this correlation.

Methods: Venous vascular access was obtained in the antecubital regions of the patients. Simultaneous venous blood samples were drawn, and a blood gas analyzer measured Hb, Hct, and lactate values, and Hb and Hct values were also measured by a laboratory auto-analyzer in the emergency laboratory. The correlation between the values was calculated. In addition, the prediction of laboratory auto-analyzer values from venous blood gas analyzer values was performed using linear regression equations (Regression Equation (y) = a + bx).

Results: A total of 51 patients were included in the study. The median difference between antecubital vein laboratory auto-analyzer values and venous blood gas analyzer values was 0.40 g/dL for Hb and 1.10% for Hct. There were high and very high positive correlations between antecubital vein laboratory auto-analyzer values and venous blood gas analyzer values with correlation coefficients of 0.693 and 0.862 for Hb and Hct, respectively. The correlation coefficient for Hb increased from 0.693 to 0.827 in 26 patients with lactate values below the 2.5 mmol/L cut-off limit. We also measured Hb and Hct by laboratory auto-analyzer and blood gas analyzer from simultaneous femoral artery-sourced samples from 40 patients. The median difference between femoral artery-sourced laboratory auto-analyzer values and blood gas analyzer values was 0.20 g/dL for Hb and 0.80% for Hct. There were very high positive correlations between femoral artery-sourced laboratory auto-analyzer values and arterial blood gas analyzer Hb value and femoral artery-sourced laboratory auto-analyzer and arterial blood gas Hct value with correlation coefficients of 0.949 and 0.851, respectively.

Conclusion: In both venous and arterial samples, the differences between the laboratory auto-analyzer and the blood gas analyzer are limited, and the correlations between them are significantly high. Furthermore, the correlation between the venous blood gas auto-analyzer value and the laboratory auto-analyzer value for Hb is even higher when the lactate value is below the 2.5 mmol/L cut-off limit.

Keywords: Blood gas, hematocrit, hemoglobin, lactate, multiple trauma

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Introduction

Trauma is one of the leading causes of death and disability worldwide (1). Despite improved treatment strategies, both mortality and disability rates remain high (2). Early post-traumatic deaths (in the first 24 hours) are associated with hemorrhage in the majority of patients (3,4). Unlike other major causes of traumatic death (e.g., traumatic brain injury and multiple organ failure), hemorrhagic deaths occur rapidly (3). Acute hemorrhage leads to a decrease in tissue perfusion following injury and, if prolonged, a decrease in tissue oxygen delivery, leading to lactic acidosis and organ failure. Treatment of hemorrhagic shock involves maintaining blood pressure and tissue perfusion until bleeding is controlled (5). Intravenous fluid administration with colloid or crystalloid solutions forms the basis of non-surgical treatment of bleeding trauma patients (5). Blood and blood products are also non-surgical treatment options for acute hemorrhage.

In emergency department patients, hemoglobin (Hb) and hematocrit (Hct) values decrease due to hemorrhage resulting from traumatic or non-traumatic causes, and fluid-electrolyte and acid-base balance disorders are frequently observed. Detection of these disorders in a short time is vital for patient management and initiating appropriate treatment (6). Emergency physicians prefer bedside tests such as blood gas measurements that provide rapid results in treatment management. In critically ill patients, arterial or venous blood gas measurement is frequently used in emergency departments. Most devices can measure pH, pO_2, pCO_2, and HCO_3, as well as glucose, sodium, potassium, calcium, chlorine, Hb, and Hct values in blood gas samples (6). In cases requiring urgent results, blood gas samples can also be obtained during blood sampling for laboratory study and obtaining results in as little as 5 minutes provides an essential advantage for diagnosing and treating patients (6).

In the literature, there are studies investigating the correlation of Hb, Hct, and serum electrolytes in blood gas analyzer with standard laboratory auto-analyzer devices, but there is no study investigating the correlation of these values in multiple trauma patients and whether lactate level is adequate in this correlation or not.

In this study, we aimed to compare venous Hb and Hct values measured by bedside blood gas analyzer with standard laboratory auto-analyzer values in multiple trauma patients and to investigate if lactate level is adequate in this correlation.

Materials and Methods

This study was conducted prospectively after obtaining ethics committee approval (with the approval date 07.11.2019 and number 24/16) from the Antalya Education and Research Hospital Clinical Research Ethics Committee by including patients admitted to the emergency department of a tertiary hospital diagnosed with multiple traumas.

The sample size was determined to be 49, with a power of 80% (beta) and a type I error rate of 0.05 (alpha). This calculation was performed using the G*Power software (version 3.1.9.7, Heinrich Heine University, Düsseldorf, Germany) with references from similar studies in the literature.

Trauma zones were divided into four cerebral, thoracic, abdominal, and orthopedic, and patients with any two or more of these zones were considered to have multiple trauma (7). Ecchymosis, abrasion or laceration on the skin, tenderness on palpation, areas where the patient described pain directly, and areas where pathology was detected on imaging were considered traumatic.

Patients aged 18 years and older who met the definition of multiple traumas and whose laboratory auto-analyzer and venous blood gas analyzer test samples were obtained from the same vascular access, at the same time and with the same protocol number at the time of the patient's initial presentation were included in the study. Venous vascular access was obtained from the patients' antecubital regions. Simultaneous venous blood samples were drawn, and Hb, Hct, and lactate values were measured with a blood gas analyzer. Hb and Hct values were also measured with a standard laboratory auto-analyzer in the emergency laboratory. All laboratory and blood gas tests were performed within the indication and due to clinical necessity.

Patients whose laboratory test results were not available, whose blood samples analyzed by laboratory auto-analyzer and venous blood gas analyzer were not taken at the same time, whose venous blood gas analyzer results were obtained more than 30 minutes after the blood sample was taken, whose test results showed hemolysis, whose samples were obtained from different vascular accesses, who did not meet the defined multiple trauma criteria, who received any serum or blood replacement before admission, who was referred to our hospital from another health institution, and who were younger than 18 years of age were excluded from the study.

A standardized data recording form was created before the study. In this form, age, gender, cause of trauma, systolic and diastolic blood pressures, heart rate per minute, oxygen saturation, respiratory rate, trauma sites, total number of deaths and injuries in the event, venous blood gas analyzer Hb, Hct and lactate values, laboratory auto-analyzer Hb and Hct values, Glasgow Coma Scale, revised trauma score and hemorrhagic shock stages were noted.

The results of patients with simultaneous femoral artery blood gas analyzer Hb and Hct levels and femoral artery Hb and Hct values in the results of laboratory auto-analyzer examinations due to medical necessity at the initial presentation were also recorded on this form.

Measurement of hemoglobin, hematocrit, and lactate

The emergency department where the study was performed has a bedside blood gas analyzer and a fully equipped laboratory. Venous and arterial blood gas analyses were performed at the bedside with a Radiometer ABL-800 flex blood gas analyzer within 90 seconds after blood samples were taken from the patients using an Ayset brand blood gas syringe containing 2 ml liquid lithium heparin and the results were obtained. Samples for Hb and Hct laboratory testing were taken simultaneously with venous or arterial blood gas and from the same vascular access, transferred to vacutainer tubes containing ethylene diamine tetra-acetic acid (EDTA) and studied in the emergency department laboratory with a Sysmex XN-1000 standard auto-analyzer without loss of time. All devices were calibrated on time and regularly by the relevant company specifications. Hb levels were given in g/dL, Hct levels in %, and lactate levels in mmol/L. The results obtained were recorded and statistically compared. A graphical illustration of the study is shown in Figure 1.

Statistical analysis

Analyses were performed by using IBM SPSS 26.0 software (IBM Inc., Armonk, NY, USA).

In the statistical analysis, Kolmogorov-Smirnov analysis was first performed to evaluate if the distribution of values was normal. As a result of the normality test, the difference between means for normally distributed variables was analyzed using the Paired samples test, and the Pearson correlation test was used to perform correlation analysis. When the correlation coefficient took a (-) value, it was accepted that there was a negative correlation between the parameters, and when it took a (+) value, it was accepted that there was a positive correlation. When the r coefficient took a value between 0.0 and 0.2, it was interpreted as a very low-level relationship; between 0.2 and 0.4, as a low-level relationship; between 0.4 and 0.6, as a medium-level relationship; between 0.6 and 0.8, as a high-level relationship; and between 0.8 and 1.0, as a very high-level relationship (8).

Prediction of laboratory auto-analyzer values from venous blood gas analyzer values was performed using linear regression equations (Regression Equation (y) = a + bx). Values; y: laboratory auto-analyzer values; x: blood gas analyzer values; a and b: constant coefficients). $P<0.05$ was considered statistically significant.

Results

A total of 51 patients were included in the study. 25.5% of the patients were female, the mean age was 46.67 ± 20.49 years, the median value of Systolic TA was 113 mmHg, the median value of revised trauma score was 7.84, and the most common trauma zone was the combination of cerebral and orthopedic zones (Table 1). When the trauma zones were analyzed individually, it was seen that the most common zones were cerebral with 38/51, orthopedic with 37/51, abdominal with 32/51, and thoracic with 22/51 in descending order of frequency.

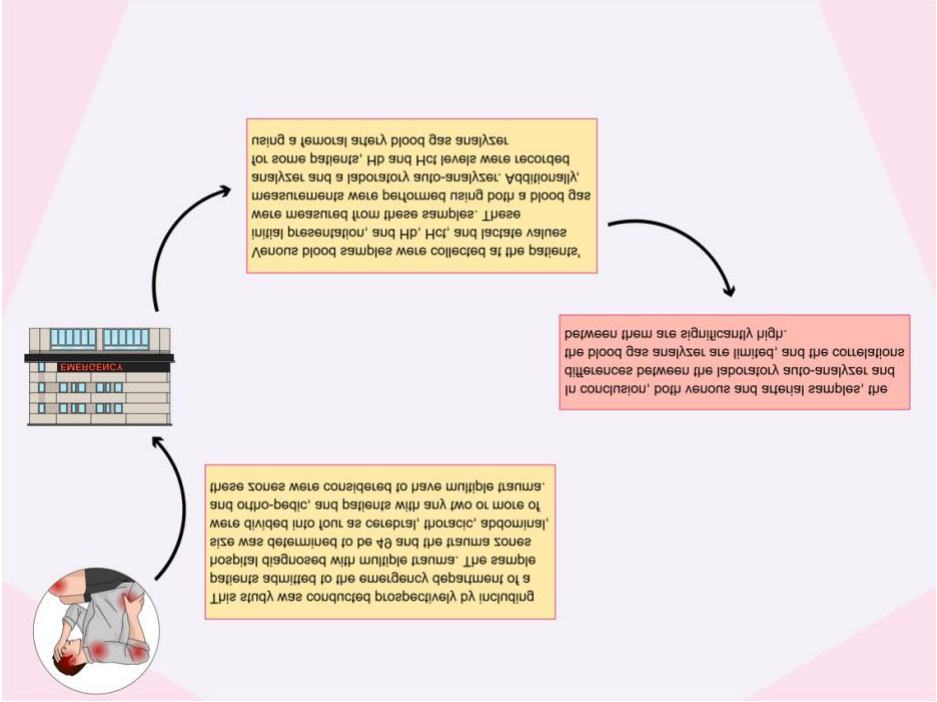


Figure 1. Graphical illustration of the study

Table 1. Demographic data and initial presentation characteristics of patients

Variable	Mean ± SD	Median	Min-max	Trauma Zones	N (%)
Age, year	46.67 ± 20.49		18-85	Cerebral + Thoracic	1 (2)
Systolic TA, mmHg		113	40-190	Cerebral + Abdominal	8 (15.7)
Diastolic TA, mmHg		70	0-100	Cerebral + Orthopedic	9 (17.6)
Pulse rate, /min		82	69-155	Thoracic + Abdominal	1 (2)
SaO_2		96	68-98	Thoracic + Orthopedic	4 (7.8)
Respiratory rate, /min		16	4-32	Abdominal + Orthopedic	5 (9.8)
Injuries in the event		1	1-23	Cerebral + Thoracic + Abdominal	3 (5.9)
Deaths in the event		0	0-1	Cerebral + Thoracic + Orthopedic	5 (9.8)
Glasgow Coma Scale		15	3-15	Cerebral + Abdominal + Orthopedic	8 (15.7)
Revised Trauma Score		7.841	1.023-7.841	Thoracic + Abdominal + Orthopedic	3 (5.9)
Hemorrhagic Shock Stage				Cerebral + Thoracic + Abdominal + Orthopedic	4 (7.8)
1, n (%)	29 (56.9)				
2, n (%)	4 (7.8)				
3, n (%)	7 (13.7)				
4, n (%)	11 (21.6)			**Total**	**51 (100)**
Gender, Female, n (%)	13 (25.5)				

The median difference between antecubital vein laboratory auto-analyzer and venous blood gas analyzer values was 0.40 g/dL for Hb and 1.10% for Hct. There was no difference between the antecubital vein laboratory auto-analyzer and venous blood gas analyzer mean Hb and Hct values (p:0.303 and p:0.070), and there were high and very high positive correlations with correlation coefficients of 0.693 and 0.862, respectively (Table 2).

Table 2. Venous blood gas analyzer Hb, Hct, lactate, and antecubital vein laboratory auto-analyzer Hb and Hct values

Variable	**Antecubital Vein Laboratory**, mean ± SD (min-max)	**Venous blood gas** Mean ± SD / Median (min-max)	**Mean Difference** Median (min-max)	r*	p*	p#
Hb g/dL	13.24 ± 2.73 (1.50-17.30)	13.53 ± 2.45 (7.00-18.20)	0.40 (-4.00- +11.70)	0.693	<0.001	0.303
Hct %	40.56 ± 6.21 (21.40-51.90)	41.49 ± 6.99 (22.00-55.60)	1.10 (-10.40- +14.20)	0.862	<0.001	0.070
Lactate mmol/L		2.30 (1.10-13.40)				

*Pearson correlation, r: Correlation coefficient, # Paired samples test, p: probability of the hypothesis, Hb: Hemoglobin; Hct: Hematocrit; SD: Standard deviation.

When the lactate value of 2.5 mmol/L was considered as the cut-off limit (inclusive), 25 patients were above and 26 patients were below the 2.5 mmol/L cut-off limit. In both groups, the correlation test was re-performed for antecubital vein laboratory auto-analyzer values and venous blood gas analyzer values. The correlation coefficient for Hb was 0.827 in the group of patients with lactate values below the cut-off limit of 2.5 mmol/L and 0.641 in the group with lactate values above the cut-off limit of 2.5 mmol/L. When the same evaluation was made for Hct, the correlation coefficient was 0.844 in the group of patients with lactate values below the cut-off limit of 2.5 mmol/L and 0.875 in the group of patients with lactate values above the cut-off limit of 2.5 mmol/L. When the lactate value was below the 2.5 mmol/L cut-off limit, the correlation coefficient between antecubital vein laboratory auto-analyzer Hb values and venous blood gas analyzer Hb values increased from 0.693 to 0.827 (Table 3).

Table 3. Correlation of antecubital vein laboratory auto-analyzer and venous blood gas analyzer Hb and Hct values when the lactate value of 2.5 mmol/L was considered as the cut-off limit.

Variable	Lactate < 2.5 mmol/L, n = 26 Mean ± SD		Lactate ≥ 2.5 mmol/L, n = 25 Mean ± SD	
Antecubital vein Hb	13.99 ± 1.84	r: 0.827* p < 0.001* p: 0.476#	12.45 ± 3.27	r: 0.641* p: 0.001* p: 0.157#
Venous Blood gas Hb	13.83 ± 1.92		13.22 ± 2.92	
Antecubital vein Hct	42.05 ± 4.94	r: 0.844* p < 0.001* p: 0.630#	39.02 ± 7.08	r: 0.875* p < 0.001* p: 0.063#
Venous Blood gas Hct	40.17 ± 5.34		40.60 ± 8.40	

*Pearson correlation, r: Correlation coefficient, # Paired samples test, p: probability of the hypothesis, Hb: Hemoglobin; Hct: Hematocrit; SD: Standard deviation.

Hb and Hct measurements were also performed simultaneously with a femoral artery-sourced blood gas analyzer and a laboratory auto-analyzer in 40 patients from the same patient group. The median difference between femoral artery-sourced laboratory auto-analyzer and blood gas analyzer values was 0.20 g/dL for Hb and 0.80% for Hct. There was no difference between the femoral artery-sourced blood gas analyzer and femoral artery-sourced laboratory auto-analyzer mean Hb and Hct values (p: 0.300 and p: 0.092) and very high positive correlations were found with correlation coefficients of 0.949 and 0.851, respectively (Table 4).

Table 4. Laboratory auto-analyzer and blood gas analyzer Hb and Hct values of femoral artery-sourced samples

Variable	Femoral Artery Laboratory, mean ± SD (min-max) (n:40)	Arterial blood gas, mean ± SD (min-max) (n:51)	Mean Difference median (min-max)	r*	p*	p#
Hb g/dL	13.29 ± 2.23 (7.50-17.10)	13.41 ± 2.33 (7.60-18.10)	0.20 (-1.90 - +2.50)	0.949	<0.001	0.300
Hct %	40.13 ± 6.95 (21.40-53.10)	41.14 ± 6.43 (23.70-52.20)	0.80 (-12.50 - + 11.10)	0.851	<0.001	0.092

*Pearson correlation, r: Correlation coefficient, # Paired samples test, p: probability of hypothesis, Hb: Hemoglobin; Hct: Hematocrit; SD: Standard deviation.

Since a significant positive correlation was found between the antecubital vein and femoral artery-sourced laboratory auto-analyzer values and arterial and venous blood gas analyzer values at a 95% confidence interval, formulas were designed to calculate laboratory analyzer values from arterial and venous blood gas analyzer values (Table 5). Each of these formulas was applied to the patients included in the study, and the results were found to be reliable. The correlation of lactate value with antecubital vein laboratory auto-analyzer Hb value (spearman's rho -0.247 and p: 0.080), lactate value with venous blood gas analyzer Hb value (spearman's rho -0.238 and p: 0.092), lactate value antecubital vein laboratory auto-analyzer Hct value correlation (spearman's rho -0.222 and p: 0.118), lactate value venous blood gas analyzer Hct value correlation (spearman's rho -0.2139 and p: 0.329) were not formulated by regression analysis.

Table 5. Formulas for calculating laboratory auto-analyzer values from blood gas analyzer values

Laboratory auto-analyzer values	Regression Equation (y) = a +bx
Antecubital vein Hb (g/dL)	(2.823) + (0.769 x Venous blood gas Hb)
Antecubital vein Hct (%)	(8.791) + (0.766 x Venous blood gas Hct)
Femoral Artery Hb (g/dL)	(1.105) + (0.908 x Arterial blood gas Hb)
Femoral Artery Hct (%)	(2.282) + (0.920 X Arterial blood gas Hct)

Hb: Hemoglobin; Hct: Hematocrit

Discussion

In our study comparing antecubital vein laboratory auto-analyzer - venous blood gas analyzer Hb - Hct and femoral artery-sourced laboratory auto-analyzer - arterial blood gas analyzer Hb - Hct values in multiple trauma patients, we found that the values were at least highly correlated in both evaluation methods and the correlation of antecubital vein laboratory auto-analyzer - venous blood gas analyzer Hb value was higher when the lactate value was below 2.5 mmol/L cut-off limit. Furthermore, since there was a significant positive correlation between antecubital vein laboratory auto-analyzer - venous blood gas analyzer Hb - Hct and femoral artery-sourced laboratory auto-analyzer - arterial blood gas analyzer Hb - Hct values at a 95% confidence interval, we were able to produce formulas to calculate antecubital vein and femoral artery laboratory auto-analyzer Hb - Hct values from venous and arterial blood gas analyzer values, respectively.

A very short turnaround time for tests is essential for accurate diagnosis and management planning of critically ill patients in the emergency department. It may take 30 minutes or more to obtain standard laboratory auto-analyzer results. Urgent diagnosis and treatment are necessary in patients with life-threatening diseases, especially in trauma patients (6). In patients admitted to the emergency department, diagnosing patients earlier by using tests with rapid results at the bedside or in the laboratory is possible. In this way, treatment of the patients can be started earlier, and treatment for the cause can be decided earlier. Tests with rapid results play an important role in discharging patients from the emergency department, ensuring hospitalization in the relevant clinic, or deciding to operate earlier. Jose et al. (9) reported that 48.4% of physicians trusted blood gas analyzer results and made important critical decisions in acute illness.

In one study, venous blood laboratory auto-analyzer and bedside venous blood gas analyzer Hb results obtained from 191 random patients admitted to the emergency department were compared, and the difference was 0.29 g/dL (10). In another study including 81 intensive care unit patients, the difference between venous blood laboratory auto-analysis and bedside venous blood gas analyzer Hb results was 0.19 ± 0.64 g/dL (11). In another study evaluating patients admitted to the emergency department, the difference between the results of venous blood laboratory auto-analysis and venous blood gas analyzer results was 0.14 g/dL for Hb and 1.54% for Hct (6). In another study in which 213 patients with emergency hemodialysis indication were evaluated and venous samples were evaluated, this difference was found to be 0.19 ± 2.06 g/dL for Hb and 1.79 ± 5.64% for Hct (12). In our study, this difference was found to be 0.40 g/dL for Hb and 1.10% for Hct in accordance with the literature. The correlation coefficient was 0.693 for Hb and 0.862 for Hct. In a similar study, the correlation coefficients were 0.757 for Hb and 0.749 for Hct ($p<0.001$ in both) (6). In patients with emergency hemodialysis indication, this correlation was found to be 0.738 for Hb and 0.751 for Hct ($p<0.001$ in both) (12). In our study and the literature, high correlations were observed between laboratory auto-analyzer Hb and Hct values taken from venous sources and venous blood gas analyzer Hb and Hct values. These results are essential in terms of showing that venous blood gas analyzer values are compatible and correlated with antecubital vein laboratory auto-analyzer values.

Unlike other studies, our study also took the venous blood gas analyzer lactate value of 2.5 mmol/L as the cut-off limit and re-performed these correlations for patients with values above and below this cut-off limit. In 26 patients with lactate values below 2.5 mmol/L cut-off limit, the correlation coefficient for Hb increased from 0.693 to 0.827, exceeding the very high correlation limit of 0.8. Although recent research suggests change, lactate has often been hypothesized as a metabolic waste product with multiple deleterious effects under hypoxic conditions. It is also considered an indicator that the metabolism is under stress (5, 13). The lower correlation between laboratory auto-analyzer values for Hb and venous blood gas analyzer values in the setting of high lactate levels than in the setting of low lactate levels may be due to the potential of lactate to affect almost all systems and disrupt physiological mechanisms due to metabolic stress.

Due to clinical necessity, we also studied femoral artery blood gas analyzer and laboratory auto-analyzer Hb - Hct values obtained from 40 patients in the same patient group. The difference was 0.20 g/dL and 0.80% for Hb and Hct, respectively. These results were lower than the difference in Hb and Hct tests from venous samples (0.40 g/dL vs 0.20 g/dL for Hb and 1.10% vs 0.80% for Hct). The correlation coefficients for the femoral artery laboratory auto-analyzer and arterial blood gas analyzer Hb - Hct values were very high as 0.949 and 0.851. The correlation coefficient of the Hb femoral artery sourced was higher than the correlation coefficient of the Hb antecubital vein sourced (0.693 vs 0.949, respectively). A complete example like our study, in which the laboratory auto-analyzer and blood gas analyzer samples were arterial, has not been seen in the literature. However, one study studied a venous blood sample with a laboratory auto-analyzer and an arterial sample of unclear origin with an arterial blood gas analyzer and found a difference of 0.91 g/dL (p:0.02) for Hb (14). In another study comparing venous laboratory auto-analyzer Hb value with arterial blood gas analyzer Hb value, the difference was 0.3 g/dL ($p<0.001$) (15). The difference between laboratory auto-analyzer and blood gas analyzer was minor, and the correlation between them was higher in arterial samples than venous samples because arterial samples reflect the metabolic status better than venous samples.

Since there was a significant positive correlation and 95% confidence interval between laboratory auto-analyzer and venous blood gas analyzer values, formulas were created to calculate laboratory auto-analyzer values from venous blood gas analyzer values. It was

observed that this formulation was calculated in two studies in the literature, also conducted in the emergency department (6, 12). In situations where urgent decisions are required in patient evaluation, such as trauma, real-time results can be obtained by making calculations from blood gas analyzer values instead of waiting longer for laboratory auto-analyzer results. These can also be used in patient evaluation decisions.

The limited number of patients is the most important limitation of our study. More valid results can be obtained with larger samples.

Conclusion

As long as the devices are calibrated and regularly checked, laboratory auto-analyzer Hb and Hct values can be calculated in real-time from venous and arterial blood gas analyzer Hb and Hct values and used in patient management. For both venous and arterial samples, the differences between laboratory auto-analyzer values and blood gas analyzer values are limited, and the correlation between them is significantly high. Furthermore, the correlation between the venous blood gas analyzer Hb value and the laboratory auto-analyzer Hb value is even higher when the lactate value is below the 2.5 mmol/L cut-off limit.

Disclosures

Ethical Approval: Ethics committee approval was received for this study from the Antalya Education and Research Hospital Clinical Research Ethics Committee, in accordance the World Medical Association Declaration of Helsinki, with the approval number: 2019-24/16.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.A.; Design – M.A.; Supervision – M.A.; Materials – M.A.; Data collection &/or processing – M.A.; Analysis and/or interpretation –M.A.; Literature search – M.A.; Writing – M.A.; Critical review – M.A.

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