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ORIGINAL ARTICLE

Comparison of blood gas parameters with hematological and biochemical parameters in critically Ill intensive care patients connected to mechanical ventilation

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Received: 17 October 2023, Accepted: 28 November 2023, Published online: 30 December 2023

ABSTRACT

Objective: The primary aim of this study was to compare blood gas parameters with laboratory parameters in critically ill intensive care patients who were connected to mechanical ventilation. Our secondary aim was to evaluate the effects of blood gas and laboratory parameters on mortality.

Materials and Method: Critical patients over the age of 18 who were admitted to intensive care unit from emergency room or clinics and monitored with mechanical ventilation between January 1, 2021, and December 30, 2021, were included in this study. Analyses were done with the R 4.3.1 (R Core Team) program. Statistical significance was defined by $p < 0.05$.

Results: A total of 150 patients were included in this study, and 42.6% of them were male. 62% of the men and 50% of the women in this study died. We studied the trend accuracy of laboratory hemoglobin, hematocrit, sodium, potassium, glucose and blood gas hemoglobin, hematocrit, sodium, potassium, and glucose values using a modified Bland–Altman analysis. When the analyses from the first day were examined, mean bias (LOA g/dl) for hemoglobin was 0.001 (–0.15 to 0.14) and mean bias (LOA mEq/l) for potassium was –0.19 (–0.23 to –0.16). When the third day analyses were examined, mean bias (LOA g/dl) for hemoglobin was 0.29 (–0.05 to 0.63) and mean bias (LOA mEq/l) for potassium was –0.25 (–0.29 to –0.21).

Conclusion: Hemoglobin and potassium, which are blood gas parameters, can be used instead of laboratory parameters in clinical decision-making in critically ill intensive care patients on mechanical ventilation.

Keywords: Blood gas parameters, hemoglobin, intensive care unit, mechanical ventilation, potassium.

INTRODUCTION

Blood gas analysis is performed in many clinical departments, such as emergency services, nephrology, pulmonology, general surgery, and pediatrics, as well as widely used for patient monitoring in critical intensive care units. It helps clinicians working in critical intensive care units to evaluate patients' vital functions, lung capacity, dialysis needs, and organ failure. However, it has been noted that the rate of unnecessary blood gas requests sometimes reaches up to 50% in intensive care units [1,2]. Although controversial, one study found that approximately 80% of blood gas analyses were requested without any indications [3]. The indications for blood gas analysis may also be only acid-base balance disorders, especially pCo2, hCO3, and lactate evaluation. The glucose, hematocrit, hemoglobin, potassium, and sodium values found in blood gas analyses should be used in clinical approaches instead of the values in hematology and biochemical tests [4].

While blood gas analyses use direct ion selectors, laboratory analyses use indirect ion selectors. Potassium measurements are affected by hemolysis in blood gas and laboratory analyses [5]. Studies have been conducted to compare blood gas analyses with hematological and biochemical tests and evaluate their effects on mortality [6–8]. There have also been studies in which similar comparisons were made for intensive care patients [9–11].

The primary aim of this study was to compare blood gas parameters with laboratory parameters in critically ill intensive care patients who were connected to mechanical ventilation. Our secondary aim was to evaluate the effects of blood gas and laboratory parameters on mortality.

MATERIALS AND METHOD

Study design

The retrospective study was conducted with the approval of the University of Karamanoglu Mehmetbey, Faculty of Medicine Ethics Committee (Date: 19/02/2023, Decision No: 2022-KAEK-154/19). This study was prepared following the directions in the Declaration of Helsinki. Critical patients over the age of 18 who were admitted to the intensive care unit from emergency room or clinics and monitored with mechanical ventilation between January 1, 2021, and December 30, 2021, were included in the present study. Patients who were not monitored with mechanical ventilation, received non-invasive mechanical ventilation, received mechanical ventilator treatment for less than three days, had laboratory test results that were found to be incomplete according to the parameters of this study, had a tracheostomy and received mechanical ventilator treatment for a certain period of time, were monitored due to trauma, and were under the age of 18 were excluded from the study. Patients who developed cardiac arrest and underwent cardiopulmonary resuscitation during follow-up were also excluded. The PCR test was performed on all patients included in the study. Patients with a positive PCR test were excluded in the study.

Data collection

Blood gas samples were obtained from patients accepted to the critical care unit using heparinized syringes (PICO50 Arterial Blood Sampler, Radiometer Medical ApS,Brønshøj,Denmark). The samples were studied with the blood gas analyzers used by the Karaman Education and Research Hospital (Siemens RAPIDPoint 500, Blood Gas Analyzer Siemens Healthcare Diagnostics Inc, Norwood, USA). These blood gas analyzers were calibrated six times each day. A hematology analyzer was used for the hematological samples (Mindray BC-6800 Auto Hematology Analyzer, Shenzhen, P. R. China). The ion-selective diluted technique was used for biochemical data(AU680 Clinical Chemistry Analyzer, Holliston, USA).

The demographic characteristics of these patients, how long it took them to be connected to mechanical ventilation, the biochemistry values taken on the first and third days of mechanical ventilation, and values for glucose, aspartate aminotransferase (AST), alanine aminotransferase (ALT), urea, calcium, creatinine, potassium, sodium, c-reactive protein, hemogram (hemoglobin, hematocrit), and venous blood gas (PH, PCO2, PO2, HCO3, glucose, sodium, potassium, hematocrit and hemoglobin) were simultaneously recorded. Biochemistry, hemogram, blood gas laboratory findings, and 30-day mortality information were obtained using the hospital data system. According to Turkey's national death notification system, the patients were separated into two groups: those who survived (Group S) and those who non-survived (group D). The relationship between the parameters obtained on the first and third days of mechanical ventilation and mortality was evaluated. On the first day of mechanical ventilation, the glucose, potassium, sodium, hematocrit, and hemoglobin values obtained from the biochemistry laboratory and the glucose, potassium, sodium, hematocrit, and hemoglobin values obtained from blood gas were compared with mortality. The biochemistry and blood gas parameters on the third day of mechanical ventilation were also compared in terms of their relationship with mortality.

Statistical analysis

The descriptive statistics of the qualitative data were shown as percentage and frequency, and the quantitative data of the study were shown as median (Q1–Q3), mean, and standard deviation values. The suitability of quantitative variables for normal distribution was determined using the Shapiro–Wilk test. The Mann–Whitney U test was utilized to compare two independent groups of variables that were not normally distributed. Mixed-effects models were used in the analysis of numerical variables. Logistic regression analysis methods were used to find variables associated with mortality. For the logistic regression, univariable and multivariable logistic regression analyses were conducted. Bland-Altman charts and limits of agreement (LOA) values were used to match laboratory and blood gas values, and intraclass correlation coefficients (ICC) were calculated. Bland–Altman plots were utilized to evaluate bias and 95% LOA between the two measurement methods. A paired t-test was utilized to quantify the mean difference between the associated 95% confidence interval (CI) and the two measurement methods. The association between the number of tests per person per day and the variables of interest was evaluated utilizing univariable negative binomial regression models. These associations were noted as incident rate ratios (IRR) with a 95% CI. Analyses were done with the R 4.3.1 (R Core Team) program. $P < 0.05$ was described as the statistical significance level.

RESULTS

A total of 150 patients were included in this study, and 42.6% of them were male. 62% of the men and 50% of the women in this study died. Based on the data we obtained on the first day of being connected to a mechanical ventilator, a statistically significant association was detected between a high laboratory urea value and mortality ($p = 0.025$). There was a statistically significant association between a high APACHE score on the first day and a low Glasgow coma scale and mortality ($p < 0.001$, $p = 0.009$, respectively) (Table 1). The blood gas and laboratory results determined on the first day are shown in Table 2.

There was a statistically significant relationship between low pH and high lactate levels, which were the blood gas parameters taken on the third day of mechanical ventilation, and mortality ($p = 0.045$, $p = 0.009$, respectively). When the laboratory parameters taken on the third day were examined, there was a statistically significant relationship between low calcium and high c-reactive protein levels and mortality ($p = 0.016$, $p = 0.016$, respectively). The blood gas and laboratory results taken on the third day are shown in Table 3.

Table 1. Demograhic data

Variable	Group D, N = 77	Group S, N = 73	Total	P value
Age (mean, ±)	78.90±11.51	78.05±11.54	78.49±11.49	
Gender (n, %)				
Male	48 (62%)	38 (52%)	86 (57%)	
Female	29 (38%)	35 (48%)	64 (43%)	
Time until it is intubated (day)	2.99±6.60	2.18±4.53	2.59±5.68	
APACHE score (mean, ±)	28.11±7.47	24.04±6.40	26.13±7.24	*
Mortality (mean, ±)	60.44±18.60	49.32±18.20	55.03±19.17	*
Glaskow coma scale (mean, ±)	6.95±2.64	8.05±2.50	7.49±2.63	**0.009**

(BG: blood gas, ALT; alanine aminotransferase, AST; aspartate aminotransferase; APACHE: Acute Physiology and Chronic Health Evaluation) * $p < 0.05$ was described as the statistical significance level.

Table 2. 1st day blood gas analyzes and 1st day laboratory analyzes and 30-day mortality of patients

	Group D, N = 77	Group S, N = 73	Total	P value
1st day blood gas analyzes (mean, ±)				
PH	7.40±0.11	7.41±0.10	7.41±0.10	
pCO2	41.91±11.63	41.87±10.18	41.89±10.91	
pO2	48.97±13.70	47.00±11.01	48.01±12.46	
HCO3	25.69±6.68	26.81±5.60	26.24±6.19	
Lactate	1.91±1.48	1.62±1.23	1.77±1.36	
Ionised Calcium (mg/dl)	1.05±0.09	1.07±0.12	1.06±0.10	
Carboxyhemoglobin (%)	0.82±0.50	0.85±0.47	0.83±0.49	
BG Hemoglobin (g/dl)	10.91±2.53	10.75±2.28	10.83±2.40	
BG Hematocrit (%)	32.56±7.39	32.04±6.55	32.31±6.97	
BG Sodium (mEq/l)	138.62±5.98	137.35±7.07	138.01±6.54	
BG Potassium (mEq/l)	3.79±0.71	3.71±0.70	3.75±0.70	
BG Glucose (mmol/l)	153.08±51.96	143.88±44.83	148.60±48.68	
1st day laboratory analyzes (mean, ±)				
Blood urea nitrogen (mg/dL)	94.61±59.69	75.46±43.26	85.29±53.05	**0.025***
Creatinine (mg/dL)	1.66±1.25	1.53±1.04	1.60±1.15	
ALT (IU/L)	18.00(11.00-36.00)	22.00(11.00-31.00)	30.00(18.00-47.75)	
AST (IU/L)	32.00(18.00-51.00)	26.00(18.00-41.00)	19.50(11.00-35.00)	
Calcium(mg/dL)	7.85±0.66	8.05±0.68	7.95±0.68	
Clor(mg/L)	104.79±6.91	103.89±7.02	104.35±6.95	
C-reactive proteine (mg/L)	120.60(57.50-174.90)	95.20(29.80-147.30)	106.50(40.70-164.90)	
Hemoglobin (g/dl)	10.99±2.33	10.68±2.20	10.84±2.26	
Hematocrit (%)	33.47±7.97	32.64±6.85	33.07±7.43	
Sodium (mEq/l)	141.65±6.59	140.71±6.56	141.19±6.57	
Potassium (mEq/l)	3.98±0.69	3.91±0.65	3.95±0.67	
Glucose (mmol/l)	160.00±52.60	149.65±45.98	154.96±49.60	

(BG: blood gas, ALT; alanine aminotransferase, AST; aspartate aminotransferase)
* $p < 0.05$ was described as the statistical significance level.

In the regression analysis in which Glasgow coma score (GCS), APACHE scores, laboratory urea, and calcium values taken on the first day were included, the APACHE score was the determining factor (Odds Ratio (OR)= 1.06, 95% CI = 1.00–1.13, p = 0.045). In the regression analysis, which included GCS, Apache scores, blood gas pH taken on the third day, lactate, laboratory c-reactive protein, and laboratory calcium values, it was determined that blood gas lactate values were predictive of mortality (OR = 1.55, 95% CI = 1.02–2.65, p = 0.037). (Table 4).

While the blood gas hematocrit value decreased on the third day in all patients, the decrease in deaths was statistically significant (p = 0.006). The blood gas hemoglobin value also decreased on the third day but was statistically insignificant (p = 0.522, p = 0.881, respectively). While there was an increase in blood gas sodium values in Group D and Group S on the third day, it was statistically insignificant (p = 0.271, p = 0.273, respectively). A statistically significant decrease was observed in blood gas potassium values in both groups on the third day (p = 0.027, p = 0.008, respectively). While a decrease was observed in laboratory hemoglobin and hematocrit values on the third day in both groups, the hemoglobin and hematocrit decrease in Group D were statistically significant ($p < 0.001$, p = 0.004, respectively). There was an increase in laboratory sodium values on the third day in both groups, with the sodium increase in Group S being statistically significant (p = 0.108, p = 0.038, respectively). There was an increase in the laboratory potassium value in all patients on the third day, and the increase in potassium in Group S was statistically significant (p = 0.087, p = 0.050, respectively). While there was an increase in laboratory glucose levels in both groups on the third day, it was statistically insignificant (p = 0.537, p = 0.703, respectively).

Table 3. Third-day blood gas analyzes, 3rd day laboratory analyzes, and 30-day mortality of patients

Variable	Group D, N = 77	Group S, N = 73	Total, N=150	P value
3rd day blood gas analyzes				
Ph	7.43±0.09	7.46±0.07	7.44±0.08	**0.045**
pCO2	41.19±10.08	40.22±9.80	40.72±9.93	
pO2	46.86±11.91	46.27±10.95	46.57±11.42	
HCO3	27.16±7.34	28.27±6.59	27.70±6.99	
Lactate	1.99±1.78	1.42±0.57	1.71±1.36	**0.009**
Ionised Calcium (mg/dL)	1.07±0.10	1.08±0.09	1.07±0.10	
Carboxyhemoglobin (%)	0.81±0.46	0.78±0.42	0.80±0.44	
BG Hemoglobin(g/dl)	10.72±3.76	10.70±2.08	10.71±3.05	
BG Hematocrit (%)	30.90±7.24	31.99±6.33	31.43±6.81	
BG Sodium(mEq/l)	139.49±6.57	138.25±5.90	138.89±6.26	
BG Potassium(mEq/l)	3.60±0.70	3.48±0.73	3.54±0.71	
BG Glucose (mmol/l)	159.22±52.42	146.26±49.48	152.91±51.25	
3rd day laboratory analyzes				
Blood urea nitrogen (mg/dL)	98.84±61.22	83.37±55.93	91.31±59.02	
Creatinine (mg/dL)	1.62±1.29	1.49±1.24	1.56±1.27	
ALT (IU/L)	23.0(12.0-46.0)	21.00(10.0-42.0)	21.00(11.0-43.0)	
AST (IU/L)	32.0(17.00-59.0)	26.00(17.0-54.0)	30.50(17.0-57.75)	
Calcium(mg/dL)	7.75±0.58	7.98±0.57	7.86±0.59	**0.016**
Klor(mg/L)	106.21±7.33	105.00±6.48	105.62±6.93	
C-reactive proteine (mg/L)	104.10(57.7-186.5)	92.50(31.0-132.4)	95.00(44.93-141.98)	**0.016**
Hemoglobin(g/dl)	10.33±2.27	10.51±2.06	10.42±2.16	
Hematocrit (%)	31.84±7.20	31.96±6.25	31.90±6.73	
Sodium(mEq/l)	142.80±6.65	142.24±5.76	142.53±6.22	
Potassium(mEq/l)	3.84±0.68	3.74±0.66	3.79±0.67	
Glucose (mmol/l)	163.90±54.58	152.12±52.53	158.17±53.74	

(BG: blood gas, ALT; alanine aminotransferase, AST; aspartate aminotransferase)

Table 4. Multivariate regression analysis of Glasgow coma scale, APACHE score, 1st day blood urea nitrogen, calcium and 3rd day PH, lactate, c-reactive protein, calcium

Variable	OR	95% CI	P value
1st day Glasgow coma scale	0.91	0.78-1.05	0.2
1st day APACHE score	1,06	1.00-1.13	0.045
1st day blood urea nitrogen (mg/dL)	1.00	1.00-1.01	0.3
1st day calcium (mg/dL)	0.65	0.37-1.09	0.10
Variable	OR	95% CI	P value
1st day Glasgow coma scale	0.87	0.74-1.02	0.082
1st day APACHE score	1,05	0.98-1.12	0.14
3rd day PH	0.01	0.00-1.29	0.064
3rd day lactate	1,55	1.02-2.65	0.037
3rd day c-reactive protein (mg/L)	1.00	1.00-1.01	0.2
3rd day calcium (mg/dl)	0.52	0.26-1.01	0.052

(APACHE: Acute Physiology and Chronic Health Evaluation)

We studied the trend accuracy of laboratory hemoglobin, hematocrit, sodium, potassium, glucose, and blood gas hemoglobin, hematocrit, sodium, potassium, and glucose values using a modified Bland–Altman analysis. When the analyses from the first day were examined, the mean bias (LOA g/dl) for hemoglobin was 0.001 (–0.15 to 0.14) (Figure 1), and the mean bias (LOA mEq/l) for potassium was –0.19 (–0.23 to –0.16) (Figure 2). When the third-day analyses were examined, the mean bias (LOA g/dl) for hemoglobin was 0.29 (–0.05 to 0.63) and the mean bias (LOA mEq/l) for potassium was –0.25 (–0.29 to –0.21) (Table 5).

DISCUSSION

In this study, we compared blood gas and laboratory parameters taken on the first and third days in critically ill intensive care patients who were connected to mechanical ventilation. We found that the hemoglobin and potassium values taken on the first day were compatible with the blood gas and laboratory results. However, when we looked at the blood gas and laboratory values taken on the third day, a higher agreement was achieved in the blood gas and laboratory values of hemoglobin and potassium compared to hematocrit, sodium, and glucose.

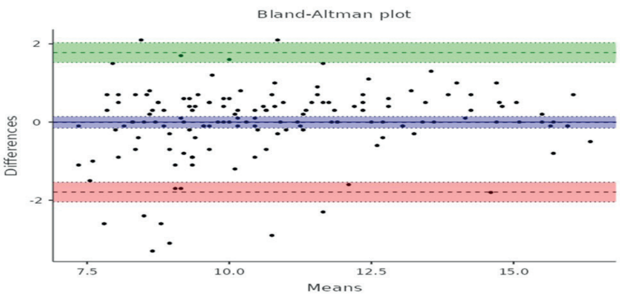

Figure 1. Bland-Altman Scatter plots for the means and differences of laboratory analyzer and blood gas analyzer first-day hemoglobin values.

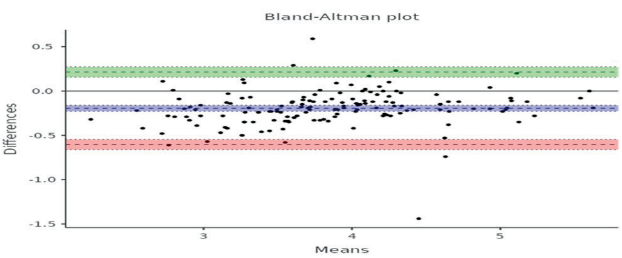

Figure 2. Bland-Altman Scatter plots for the means and differences of laboratory analyzer and blood gas analyzer first-day potassium levels.

We know that blood gas evaluation is important for clinicians to manage early treatment, especially in critically ill intensive care patients who are on ventilators. A similar situation applies to emergency services. However, various results were acquired in the literature in studies comparing blood gas and laboratory parameters [6,8].

When glucose, hematocrit, hemoglobin, potassium, and sodium values were examined in a study conducted in an emergency room, it was observed that there was no correlation between blood gas and laboratory parameters in any of these values [6]. In another emergency room study on glucose, hematocrit, hemoglobin, sodium, and potassium values, a correlation was detected between laboratory and blood gas analyses [8]. In a study, which was planned to be multicentric, of 584 intensive care patients, a high correlation was detected between blood gas CO_2 and serum CO_2 values [9]. There are different results in the literature when comparing sodium values with blood gas and laboratory analyses [5,10,11]. In another study conducted on critically ill intensive care patients, no statistically significant relationship was detected between blood gas sodium and potassium values and sodium and potassium values in hypernatremic patients [5]. On the other hand, another study observed that the sodium and potassium values obtained in blood gas analyses were correlated with sodium and potassium in laboratory parameters [10]. In a study conducted on patients with heart and lung diseases, no statistically significant difference was observed

Table 5. Bland–Altman analysis of blood gas and laboratory parameters

Variables	Bias	95% Confidence Interval	
		Lower	**Upper**
1st day values			
Hemoglobin(g/dl)	-0.01	-0.15	0.14
Hematocrit (%)	-0.76	-1.32	-0.19
Sodium(mEq/l)	-3.19	-3.76	-2.61
Potassium(mEq/l)	-0.19	-0.23	-0.16
Glucose (mmol/l)	-6.36	-8.70	-4.03
3rd day values			
Hemoglobin(g/dl)	0.29	-0.05	0.63
Hematocrit (%)	-0.47	-0.97	0.03
Sodium(mEq/l)	-3.64	-4.02	-3.25
Potassium(mEq/l)	-0.25	-0.29	-0.21
Glucose (mmol/l)	-5.26	-6.95	-3.56

between arterial blood gas and laboratory sodium values in critical intensive care unit patients with lung disease; blood gas sodium values in patients with heart disease were statistically significantly higher than laboratory sodium values [11]. In a prospective observational study conducted on 219 intensive care patients, there was no statistically significant difference between blood gas and laboratory values in terms of hemoglobin, as in our study, but, unlike in our study, potassium and sodium values were statistically significantly lower in blood gas analyses than in laboratory analyses, and the average bias was small for all three values [12]. In a multicentrically planned study, it was shown that the sodium and potassium values obtained from blood gases could be used in clinical decision-making instead of laboratory parameters [13]. In a study involving 200 patients, statistical significance was detected with an acceptable bias between the blood gas parameters of potassium and sodium and laboratory parameters; no statistically significant relationship could be detected between blood gas and laboratory hemoglobin values [14].

While this study, unlike other studies, showed that the blood gas parameter values of hematocrit, sodium, and glucose were not compatible with laboratory parameters, the association between blood gas and laboratory parameters and mortality was also evaluated. We found that the values on the first and third days of hemoglobin, hematocrit, sodium, potassium, and glucose did not have a statistically significant association with mortality. Alternatively, we observed that the decrease in blood gas hematocrit, laboratory hematocrit, blood gas potassium, laboratory potassium, and laboratory haemoglobin values was statistically significant on the third day in deceased patients compared to on the first day. Although there was a decrease in blood gas hemoglobin values in those who died, it was not statistically significant.

Limitations

In this study, we did not correlate the duration of hospital stays with the parameters. While we tried to reduce the risk of errors by including only patients connected to mechanical ventilation, the possibility of missing clinical conditions, such as multiple organ failure, and treatments, such as fluid and blood transfusions, were among the factors that affected this study. Although we included patients over the age of 18 and there were also patients under the age of 65, the mean age was over 65 years of age in our study.

In conclusion, hemoglobin and potassium, which are blood gas parameters, can be used instead of laboratory parameters in clinical decision-making in critically ill intensive care patients on mechanical ventilation. Laboratory parameters must be used for sodium, hematocrit, and glucose values.

Author contribution

Study conception and design: AB and HŞA; data collection: AB; analysis and interpretation of results: HŞA; draft manuscript preparation: AB and HŞA. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the University of Karamanoglu Mehmetbey, Faculty of Medicine Ethics Committee (Date: 19/02/2023, Decision No: 2022-KAEK- 154/19).

Funding

The authors declare that the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

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