

Prognostic role of blood gas analysis in missed prehospital diagnoses among critically ill patients: A pioneering study

Hastane öncesi tanısı atlanmış kritik hastalarda kan gazı analizinin prognostik rolü: Öncü bir çalışma

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Abstract

Objective: The point of this study was to find out how important it is to know blood gas parameters as soon as possible from the accident or event scene for critically ill patients who were missed for prehospital diagnosis but needed a code blue procedure.

Methods: In this retrospective clinical study, a total of 16 critically ill patients who were admitted to our hospital's emergency department at different times were looked at in the past for blood gas parameters like pH, sO₂, FHHb, glucose, and lactate, as well as demographic and critical diagnostic information. A statistical test called the Shapiro-Wilk test was used to see if the data was normal. The Student t-test or the Mann-Whitney U test was used to compare groups.

Results: In terms of demographic characteristics, the mean age of the patients was 56.9±22.1 years, with 81.2% being male. The resuscitation and mortality rates were 87.5% and 68.8%, respectively. Significant associations were found between blood gas parameters and mortality. Deceased patients exhibited lower pH (p = 0.025) and sO₂ levels (p = 0.046), while FHHb (p = 0.018), glucose (p = 0.031), and lactate levels (p = 0.020) were significantly higher.

Conclusion: The results of this clinical trial demonstrate the importance of early knowledge of blood gas parameters in critically ill patients in terms of disease severity and clinical progression. Early access to blood gas parameters can help avoid missing diagnoses before they get to the hospital and speed up the clinical decision-making process to start life-saving treatments right away.

Keywords: Critically ill patient, prehospital, emergency healthcare, missed diagnoses, early blood gas analysis, prognostics.

Özet

Amaç: Bu çalışmanın amacı, hastane öncesi tanı konulmamış ancak acil müdahale gerektiren kritik durumdaki hastalar için kaza veya olay yerinden mümkün olan en kısa sürede kan gazı parametrelerini öğrenmenin ne kadar önemli olduğunu ortaya koymaktır.

Yöntemler: Bu klinik çalışmada, farklı zamanlarda hastanemizin acil servisine getirilen 16 kritik hastanın geçmişe dönük olarak pH, sO₂, FHHb, glikoz ve laktat gibi kan gazı parametreleri ile demografik ve kritik tanı bilgileri incelenmiştir. Verilerin normal olup olmadığını görmek için Shapiro-Wilk testi adlı istatistiksel test kullanılmıştır. Grupları karşılaştırmak için Student t-testi veya Mann-Whitney U testi kullanılmıştır.

Bulgular: Demografik özellikler açısından, hastaların ortalama yaşı 56,9±22,1 idi ve %81,2'si erkekti. Resüsitasyon ve mortalite oranları sırasıyla %87,5 ve %68,8 idi. Kan gazı parametreleri ile mortalite arasında anlamlı ilişkiler bulunmuştur. Ölen hastalar daha düşük pH (p = 0,025) ve sO₂ düzeyleri (p = 0,046) sergilerken, FHHb (p = 0,018), glikoz (p = 0,031) ve laktat düzeyleri (p = 0,020) anlamlı olarak daha yüksek bulunmuştur.

Sonuçlar: Bu klinik çalışmanın sonuçları, kritik hastalarda hastalık şiddeti ve klinik seyr açısından kan gazı parametrelerinin erken bilinmesinin önemini göstermektedir. Kan gazı parametrelerine erken erişim, hastaneye ulaşmadan önce tanının kaçırılmasını önlemeye yardımcı olabilir ve hayat kurtaran tedavilerin hemen başlatılması için klinik karar verme sürecini hızlandırabilir.

Anahtar kelimeler: Kritik hasta, hastane öncesi, acil sağlık hizmetleri, kaçırılan tanılar, erken kan gazı analizi, prognoz.

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INTRODUCTION

Emergency departments (EDs) play a crucial role in the rapid evaluation of patients with severe and often undiagnosed conditions, where timely and accurate assessment is vital for improving survival outcomes. For people who are very sick and need help right away, arterial blood gas (ABG) analysis tells us a lot about their oxygenation, acid-base balance, and tissue perfusion, and the use of blood gas analysis as a prognostic indicator in patients requiring urgent intervention is recommended [1].

When blood gas meters were first invented in the 1950s, they could only measure pH, partial pressure of carbon dioxide ($p\text{CO}_2$), and partial pressure of oxygen ($p\text{O}_2$) and the devices were bulky and difficult to use. Point-of-care testing (POCT), which started to be used in blood gas measurement in the 1990s with the rapid development of digital technology, has been an effective approach to provide decentralized, patient-centered health care to patients in intensive care settings. POCT devices are utilized to analyze patient samples. These devices can be employed by health professionals without laboratory training at the patient's bedside or in an external location. Thus, rapid provision of blood measures, particularly blood gases, lactate, and electrolytes, may result in better therapeutic outcomes. According to clinical studies, POCT has multiple benefits, including a shorter time between starting treatment and receiving a doctor's decision, quick access to data, fewer errors during and after testing, simple-to-use instruments, requiring small amounts of blood samples, and frequent whole-blood testing for patients in all age groups. Thus, because they make diagnosis and treatment so much better, blood gas devices with POCT technology are now required in many hospitals' intensive care units, emergency departments (EDs), operating rooms, cardiac and respiratory departments, and intensive care units (ICUs) [2,3]. Currently, some novel techniques, like transcutaneous blood gas monitoring, have made great gains toward minimizing the requirement for ABG. This method continually measures $p\text{CO}_2$ and $p\text{O}_2$ levels through the skin, offering a less invasive option for blood gas analysis [4]. Besides, an enhanced pretest algorithm with capillary ABG analysis can reduce the amount of needless computed tomography pulmonary angiographies in elderly individuals with suspected pulmonary embolism but low pretest likelihood (Wells score ≤ 4) [5].

The early and accurate diagnosis of critical patients is crucial for effective clinical management. In cases of trauma or sudden illness, missed diagnoses before hospital admission can negatively affect patient prognosis. Critically ill patients can quickly assess their hemodynamic and metabolic status by conducting an ABG analysis at the time of hospital admission, and clinical follow-up with the prognostic significance of these analyses is growing [6-8].

Metabolic acidosis is a common condition in critically ill patients and plays an essential role in determining the severity of illness. In such cases, a decrease in bicarbonate levels can lead to worsening acidosis and respiratory/metabolic disorders. Blood gas analyses, particularly parameters such as lactate and bicarbonate levels, serve as powerful tools for predicting mortality risk in critical patients. Monitoring lactate levels is particularly important as an indicator of cellular oxygen imbalance and the risk of severe hypoxia. Additionally, the role of hypercapnia at hospital admission in predicting mortality has been investigated, providing decision support for high-risk patients in terms of prognosis [9-12].

The literature on the prognostic value of blood gas analyses in critically ill patients with undiagnosed conditions prior to hospital admission is limited. This study aims to determine the prognostic value of blood gas analyses conducted under code blue protocols in critically ill patients who had undiagnosed conditions prior to hospital admission. Limited medical resources and uncertain clinical findings in the pre-hospital phase can hinder accurate diagnosis, resulting in delayed treatment. Early analysis of very important blood gas parameters, such as hypercapnia and hypoxia, may facilitate the timely identification of situations that require critical interventions like emergency ventilation support. In this context, the early application of blood gas analyses can contribute to a rapid and accurate assessment of disease severity, accelerating diagnostic and therapeutic processes, and potentially reducing mortality in this patient group. Besides, this study offers an innovative perspective for clinical practice, specifically aiming to improve pre-hospital diagnosis and intervention processes.

METHODS

Study Design and Setting

This scientific retrospective clinical research was conducted at Biruni University Hospital between 2023 and 2024, and it aims to evaluate the prognostic significance of blood gas analyses in 16 critically ill patients who had undiagnosed conditions in the pre-hospital phase and required code blue procedures. Besides, these patients who were aged 18 years and older were admitted to the Emergency Department of Biruni University Hospital under the code blue protocol, and blood gas analysis was performed on these patients upon arrival and were included in the study.

Study Group and Data Collection

The study group consisted of critically ill patients who had either undiagnosed or misdiagnosed conditions before hospital admission. Inclusion criteria included having completed blood gas analyses and the availability of comprehensive data. Patients' demographic information (age, gender) and blood gas parameters (pH, $p\text{CO}_2$, $p\text{O}_2$, bicarbonate (HCO_3), base

excess (BE), total hemoglobin (tHb), oxygen saturation (sO₂), fractional deoxyhemoglobin (FHHb), Na, K, Ca, glucose, and lactate) were retrospectively examined, and their associations with survival and mortality were analyzed.

Blood Gas Analysis

Blood gas samples taken from critically ill patients were analyzed using arterial blood within the first 15 minutes after Code Blue application. All analyses were performed with a bedside blood gas device (Siemens Healthineers RAPIDLab™ 1265 Blood Gas Analyzer Erlangen, Germany).

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY, USA). The normality of the data distribution was evaluated with the Shapiro-Wilk test and skewness-kurtosis values. Continuous variables with normal distribution were compared between two independent groups using the Student's t-test, while non-normally distributed continuous variables were analyzed using the Mann-Whitney U test. Qualitative data are presented as frequencies and percentages, whereas quantitative data are presented as mean ± standard deviation or median (minimum-maximum). A p-value of < 0.05 was considered the threshold for statistical significance.

The Shapiro Wilk test is the most powerful normality test followed by Anderson-Darling test, Lilliefors test and Kolmogorov-Smirnov test. Outliers are typically checked using box plot.

RESULTS

The general characteristics of the cases included in the study are presented in Table 1. The mean age was 56.94 ± 22.18, with the youngest patient being 20 years old and the oldest 87 years old. Of the cases, 18.8% (3 patients) were female and 81.2% (13 patients) were male, with a resuscitation rate of 87.5% (14 patients). The survival rate was determined as 31.3% (5 patients), while the mortality rate was 68.8% (11 patients).

An analysis of blood gas parameters revealed significant associations between mortality and pH, sO₂, FHHb, glucose, and lactate levels (p<0.05). The pH and sO₂ levels of deceased patients were found to be significantly lower than those of survivors (p=0.025 and p=0.046, respectively). Conversely, FHHb, glucose, and lactate levels in surviving patients were significantly lower compared to deceased patients (p<0.05). These findings suggest that blood gas parameters may have a prognostic impact on mortality in critically ill patients (Table 2).

DISCUSSION AND CONCLUSION

The most vital components in managing critically ill patients in the ED and ICU are tissue oxygenation, ventilation, and acid-

base balance. The abrupt alterations in these parameters may lead to life-threatening circumstances; therefore, prompt results are often required. In this context, POCT offers benefits such as decreased therapeutic turnaround time, abbreviated door-to-clinical-decision time, prompt data accessibility, minimized preanalytic and postanalytic testing errors, autonomous user-friendly devices, minimal sample volume requirements, and the capability for frequent serial whole-blood testing [13,14].

In critically ill patients, not only physicians but also other authorized healthcare personnel need to be competent in interpreting rapid blood gas parameters and initial clinical approaches. Zabolli et al. (2025) reported that emergency department and intensive care unit nurses' skills in interpreting blood gas analysis results were adequate; however, using these interpretations in clinical decision-making was inadequate [15].

These results indicate that early evaluation of blood gas parameters could improve survival prospects in critical patients and underscore the importance of tailoring treatment approaches based on these parameters. In this study, the relationship between blood gas parameters and mortality in critically ill patients with missed pre-hospital diagnoses was examined. It was found that pH, sO₂, FHHb, glucose, and lactate levels were significantly associated with mortality. Our findings support the use of blood gas parameters as prognostic indicators and suggest that early assessment of these parameters may enhance patients' survival chances. The gold standard for determining a patient's oxygenation, ventilation, and acid-base balance is ABG monitoring, and it is also still useful for validating and calibrating non-invasive monitoring methods, even though non-invasive monitoring has mostly supplanted it [16].

In our study, patients who expired had significantly lower pH and sO₂ levels compared to surviving patients. This result aligns with the findings of Wang et al. (2020), who reported that pH levels were associated with mortality in patients hospitalized due to COVID-19. Their study indicated that low pH levels were related to severe hypoxemia and metabolic acidosis, both of which increase the risk of mortality [17]. Similarly, Jousi et al. (2010), in their study on the benefits of blood gas analysis in trauma resuscitation, reported that pre-hospital pH levels were associated with poor prognosis, highlighting the significance of low pH in reflecting patients' acid-base balance and oxygenation status [6].

Along with pH, HCO₃, and pCO₂ readings, the first step of the four-step interpretation guide of ABG parameters suggested in the four-step ABG evaluation offers crucial hints regarding acid-base imbalance in critically ill patients [18]. When assessing hypoventilation (pH and pCO₂ levels) in critically ill patients, central venous blood gas may be a viable substitute for arterial blood gas, according to Chong et al. (2021) [7].

Additionally, Xuwei He et al. (2025) reported independent risk factors for trauma patients, including low pH, elevated PaCO₂, increased lactate, high potassium, elevated Neutrophil Lymphocyte Ratio (NLR), high D-dimer, high Injury Severity Score (ISS), and high National Early Warning Score (NEWS) [19].

Despite the limited number of critical ill patients, our study found a significant association between lactate levels and mortality. Consistent with this preliminary study of ABG, several studies have demonstrated the predictive usefulness of serum lactate levels in terms of mortality and ICU/hospital stay. Soliman and Vincent (2010) found in their study that having hyperlactatemia (serum lactate concentration ≥ 2 mEq/l) when admitted to the intensive care unit (ICU) was linked to a higher risk of death (23% vs. 9%) and more organ dysfunction, resulting in a longer stay in the ICU and higher Sequential Organ Failure Assessment (SOFA) scores (≥ 5) [9, 20].

Nichol et al. (2010), in a study on the prognostic value of lactate in septic patients, found that high lactate levels were linked to a greater risk of mortality. Lactate elevation generally occurs when tissues are inadequately oxygenated and is considered an indicator of anaerobic metabolism, often seen in critical illnesses like trauma and sepsis [21].

The association between hypercapnia and mortality was also evaluated in our study, showing that hypercapnia at hospital admission could be a prognostic factor. Vonderbank et al. (2020) reported that patients with hypercapnia at hospital admission had higher mortality rates [12]. Hypercapnia is generally associated with respiratory failure and elevated pCO₂ levels, serving as a critical indicator in the management of critically ill patients.

Our findings also indicated that glucose levels were associated with mortality. Many studies have shown that hyperglycemia in critically ill patients correlates with poor prognosis. For example, Pasquel et al. (2021) suggested that hyperglycemia in intensive care could increase mortality by exacerbating the inflammatory response [22]. This condition, known as stress hyperglycemia, commonly occurs during acute stress events, such as infections, and can impair immune response, increasing the risk of complications. The study by Calderone et al. (2022), which examined the noninvasive monitoring of deoxyhemoglobin (HHb) levels during cardiac surgery, noted that HHb levels increase in cases of inadequate cerebral oxygenation, marking hypoxia as an important indicator. Their study emphasized that elevated HHb levels signal the need for prompt intervention in hypoxic conditions [23]. Similarly, in our study, patients who expired had high FHHb levels, suggesting that hypoxic conditions may be more specifically assessed by FHHb.

Although HCO₃ and BE (base excess) values did not show a distinct effect on mortality in our study, Lo et al. (2020), in a meta-analysis examining the impact of bicarbonate use in patients with metabolic acidosis, reported that low HCO₃ levels and significant base excess deficiency might be indicators of poor prognosis [10]. These findings highlight the role of acidosis and metabolic imbalances in critical illness, suggesting that low bicarbonate levels could influence clinical decisions.

In conclusion, this study highlights the prognostic importance of blood gas parameters in critically ill patients with missed pre-hospital diagnoses. Significant associations between mortality and levels of pH, sO₂, FHHb, glucose, and lactate were identified, suggesting that these parameters could serve as reliable prognostic indicators. Performing arterial blood gas testing in prehospital emergency health care and understanding the key parameters can help to identify the patient's clinical severity early on. However, transcutaneous monitoring should be used, as it may lessen the requirement for ABG analysis during the prehospital period or during ambulance transfers. Thus, early assessment of blood gas parameters may improve patient outcomes by enabling timely clinical intervention. Consistent with the existing literature, our findings reinforce the utility of these parameters in critical care management. Routine blood gas analysis, along with treatment strategies tailored to these results, could play a crucial role in reducing mortality in critically ill patients.

STRENGTHS

This pioneering study is particularly important in that it indicates that early analysis of blood gas parameters such as hypercapnia and hypoxia may facilitate the timely detection of conditions requiring critical interventions such as emergency ventilation support. In other words, early application of blood gas analysis can contribute to the rapid and accurate assessment of disease severity, thereby accelerating diagnosis and treatment processes and reducing mortality in this patient group. Furthermore, this study offers an innovative perspective for clinical practice, particularly aimed at improving prehospital diagnosis and intervention processes.

LIMITATIONS

This study has some limitations. The small sample size in this pioneering research limits the generalizability of clinical findings and therefore, prospective studies with larger cohorts should be conducted to further confirm these findings and solidify the prognostic value of ABG gas parameters.

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Ethics Committee Approval

This clinical study, conducted in accordance with the Helsinki Declaration, was approved non-interventional clinical research by the Ethics Committee of Biruni University (approval number: BIAEK/04-58, date: 21.10.2024).

Conflicts of Interest

The authors declare no conflicts of interest.

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Author Contributions

Conceptualization, T.G, M.D. and S.K.; methodology, T.G. and M.D; formal analysis, M.K.; data check, M.D and M.K.; writing—original draft preparation, T.G., M.D. and S.K.; writing—review and editing, T.G, M.D., M.K. and S.K.

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Table 1. General characteristics of critically ill patients

Variable	Mean ± SD (min-max)
Age	56.94 ± 22.18 (20-87)
Female	3 (18.8%)
Male	13 (81.2%)
No Resuscitation	2 (12.5%)
Resuscitation	14 (87.5%)
Survivor	5 (31.3%)
Exitus	11 (68.8%)

Table 2. Relationship between blood gas parameters and mortality in of critically ill patients

Characteristics	Survivor (n=5)	Exitus (n=11)	Effect size (d)	Mean Differences (%95 CI)	p-value
	Mean±SD	Mean±SD			
Age	51,4±23,84	59,45±22,1	-0,035	-8,05(-34,21 - 18,1)	0,520
pH	7,35±0,1	7,11±0,28	1,14	0,24(-0,04 - 0,52)	0,025
pCO ₂	50,96±11,71	64,04±25,36	-0,66	-13,08(-38,9 - 12,75)	0,296
pO ₂	55,2±13,56	56,15±66,52	-0,02	-0,95(-66,52 - 64,63)	0,976
HCO ₃ std	25,2±5,92	18,74±6,7	1,02	6,46(-1,04 - 13,96)	0,086
BE(B)	5,02±3,72	9,25±7,87	-0,69	-4,23(-12,26 - 3,79)	0,277
tHb	11,7±1,69	13,16±2,67	-0,65	-1,46(-4,28 - 1,35)	0,284
sO ₂	86,5±17,05	60,46±29,99	1,07	26,04(-5,12 - 57,2)	0,046
FHHb	15,2±16,96	46,31±32,92	-1,19	-31,11(-64,96 - 2,74)	0,026
Sodium (Na)	143,3±5,26	139,24±5,26	0,77	4,06(-2,02 - 10,15)	0,174
Potassium (K)	3,34±0,6	4,9±1,24	-1,60	-1,56(-2,82 - -0,3)	0,019
Calcium (Ca)	1,18±0,06	1,2±0,33	-0,08	-0,02(-0,34 - 0,31)	0,921
Glucose	152±44,11	277,18±144,17	-1,17	-125,18(-268,75 - 18,39)	0,021
Lactat	1,38±0,35	5,67±5,11	-1,18	-4,28(-9,29 - 0,72)	0,020

SD: Standard Deviation, p-value obtained from Student's t-test. CI: Confidence Interval, Effect size: Cohen d.