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Orijinal Araştırma / Original Article

How Important are Arterial Blood Gas Parameters for Severe Head Trauma in Children?

Çocuklarda Ağır Kafa Travmalarında Arter Kan Gazı Parametreleri Ne Kadar Önemlidir?

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Abstract

Aim: Our aim in this study is to consider the relationship between arterial blood gas (ABG) parameters and prognosis in severe head trauma in children.

Material and Method: Patients younger than 17 years of age with a Glasgow Coma Scale (GCS) of 8 and below with a history of head trauma were retrospectively analyzed. The relation of ABG parameters taken at the time of admission with mortality was examined. Independent sample T-test was used for pH, PCO_2 and base extract (BE) parameters in ABG, and Mann Whitney U test was used for PO_2 and lactate parameters.

Results: 48 patients were included in the study. Gender, age, admission blood pressure arterial values, GCS and Abbreviated Injury Scale (AIS) scores, length of stay in intensive care, and the surgical application did not differ statistically between the patient groups who died and survived. Ph and PO_2 values were lower, PCO_2, lactate, and BE values were found to be higher in the deceased patient group compared to the living patient group. The presence of acidosis, hypercapnia, or hyperlactatemia according to ABG values in the patient group who died was statistically significantly higher.

Conclusion: In our study, we found that the presence of acidosis, hypercapnia, and hyperlactatemia in patients according to ABG values increased mortality. We found that high PCO_2 and lactate values are specific indicators of poor prognosis. We think that PCO_2 and lactate measured in arterial blood may be biomarkers that can determine the prognosis.

Keywords: Traumatic brain injury, blood gas, child, lactate

Öz

Amaç: Bu çalışmadaki amacımız, çocuklarda şiddetli kafa travmasında arteriyel kan gazı (AKG) parametreleri ile prognoz arasındaki ilişkiyi ele almaktır.

Gereç ve Yöntem: Glasgow Koma Skalası (GKS) 8 ve altında olan ve kafa travması öyküsü olan 17 yaşından küçük hastalar geriye dönük olarak incelendi. Başvuru anında alınan AKG parametrelerinin mortalite ile olan ilişkisi incelendi. AKG'da pH, PCO_2 ve baz ekstraktı (BE) parametreleri için bağımsız örnek T- testi, PO_2 ve laktat parametreleri için ise Mann Whitney U testi kullanıldı.

Bulgular: Çalışmaya 48 hasta alındı. Ölen ve yaşayan hasta grupları arasında cinsiyet, yaş, başvuru tansiyon arter değerleri, GKS ve Kısaltılmış Yaralanma Skalası (AIS) skorları, yoğun bakımda kalış süresi ve cerrahi uygulama istatistiksel olarak farklılık göstermedi. Ölen hasta grubunda yaşayan hasta grubuna göre Ph ve PO_2 değerleri daha düşük, PCO_2, laktat ve BE değerleri daha yüksek bulundu. Ölen hasta grubunda AKG değerlerine göre asidoz, hiperkapni veya hiperlaktatemi varlığı istatistiksel olarak anlamlı derecede yüksekti.

Sonuç: Çalışmamızda AKG değerlerine göre hastalarda asidoz, hiperkapni ve hiperlaktatemi varlığının mortaliteyi artırdığını bulduk. Yüksek PCO_2 ve laktat değerlerinin kötü prognozu gösteren spesifik göstergeler olduğunu saptadık. Arter kanında ölçülen PCO_2 ve laktatın prognozu belirleyebilecek biyobelirteçler olabileceğini düşünüyoruz.

Anahtar Kelimeler: Travmatik beyin hasarı, kan gazı, çocuk, laktat

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INTRODUCTION

Traumatic injuries cause 50% of deaths under the age of 18.[1] Head trauma is the most common type of trauma seen in childhood and is responsible for 80% of trauma-related deaths.[2,3] Up to 80% of head traumas are mild (GCS 14), 10% are moderate (8 <GCS <14) and about 10% are severe (GCS ≤ 8).[4] Mortality rates, especially in patients with severe head trauma, are around 30% despite all treatments.[5]

The pathological processes that occur in the brain tissue after head trauma is called traumatic brain injury (TBI). TBI is defined as primary, and secondary according to its physiopathology. Primary TBH, with the effect of mechanical forces, occurs as a result of damage to neuronal and vascular tissue. After physical damage to cell membranes, neuronal edema, hypoperfusion, and neurotoxicity occur. Secondary TBI is defined as the result of processes such as ischemia, reperfusion, and hypoxia in the damaged areas of the brain after the first injury.[6] Treatment aims to correct intracranial and extracranial factors that cause secondary TBI.[7]

Knowing the biomarkers that affect the prognosis in head trauma makes it easier to identify patients who may be at risk, determine treatment methods, and predict the clinical outcome.[8] To determine the TBI level and prognosis after head trauma, studies with glucose, S100 calcium-binding protein B and thiol have shown that they can be biomarkers.[9-11]

Arterial blood gas (ABG) is an examination that provides an overview of acid-base balance and can show the oxygen need and requirements of tissues.[12] Studies on the effects of parameters in ABG on prognosis have been mostly conducted on cardiovascular and respiratory system diseases.[13-14] There is an insufficient number of studies on this subject in Head Trauma. Our aim in this study is to evaluate ABG parameters after severe head trauma in children, as well as to find their prognostic effects and their relationship with mortality.

MATERIAL AND METHOD

The study was conducted in accordance with the Declaration of Helsinki after the approval of the Kafkas University Medical Faculty Non-interventional Ethics Committee dated 25.06.2020 and numbered 2020/233. Patients between the ages of 0-17 who were admitted to the emergency service of the Kafkas University Health Research and Application Hospital after severe head trauma between 2014 and 2019, were examined.

Children with proven intracranial pathology with computed tomography and having a GCS score of 8 or less, were included in the study. Demographic characteristics of the patients, Blood Pressure Arterial (TA) measurements at the time of admission, GCS, AIS values, pH, PCO_2, PO_2, lactate and BE values in ABG, the number of days of hospitalization in the intensive care unit, and the data regarding the application of surgery, were all obtained by scanning the patient files. Patients with diabetes, electrolyte disturbances, chronic lung diseases, severe hypovolemia, anemia, and infections that may affect blood gas results, as well as severe multiple trauma (thoracic, abdominal organ injuries, major bone fractures, and cardiac injuries) accompanying head trauma, were excluded from the study.

In ABG parameters, pH: 7.35-7.45, PaO_2: 80-100 mmHg, $PaCO_2$: 35-45 mmHg, lactate level up to 2 mmol/L and BE: up to±3 mmol/L were taken as normal values.[15] In analyzing ABG data, the"Medcalc: Acid-base Calculator" calculation software was used. Ph<7.35 value was defined as acidosis, PaO_2 <80 mmHg value as hypoxia, $PaCO_2$> 45 mmHg value hypercapnia, lactate> 2 mmol/L value hyperlactatemia and BE ≥±3mEq/L values as base deficit.

Statistical Analysis

The data obtained were analyzed with the IBM SPSS Statistics 22 program. Quantitative data were calculated as mean±standard deviation. Categorical variables were presented as numbers and percentages. Statistically, the Chi-square test was used in the analysis of categorical variables. The Shapiro Wilk test was used to find the quantitative values showing homogeneous distribution. The independent sample T-test was used for the analysis of the parameters showing homogeneous distribution among the quantitative variables, and the Mann Whitney U test was used for the analysis of the parameters not showing homogeneous distribution. ROC Curve (receiver process characteristic curve) analysis was performed for ABG parameters. P <0.05 was considered significant in all statistical tests.

RESULTS

In our study, the data of a total of 48 patients were examined. The most common intracranial pathologies were intracerebral hematoma (22.9%), subdural hematoma (16.6%), and traumatic subarachnoid hemorrhage (14.5%), respectively (**Figure 1**). There were 16 (33.3%) female patients, and 32 (66.6%) male patients, according to their gender. No statistically significant difference was found between the patient groups who died and survived in terms of gender and surgical application in **Table 1.** The mortality rate among all patients was 35.41%.

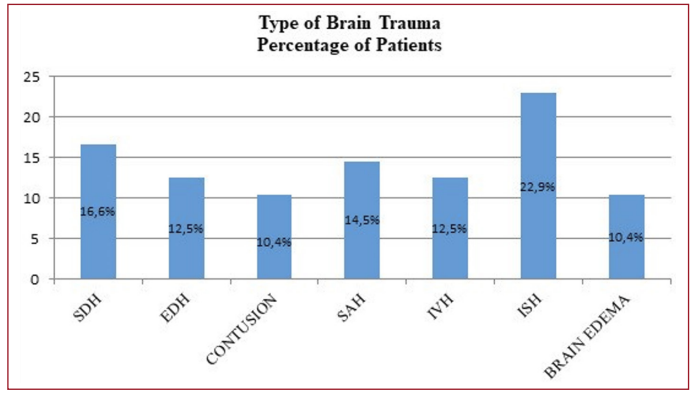

Figure 1. Type of brain trauma percentage of patients
(SDH: Subdural hematoma (8), EDH: Epidural hematoma (6), Contusion (5), SAH: Subarachnoid hemorrhage (7), IVH: Intraventricular hemorrhage (6), ICH: Intracerebral hemorrhage (11), Brain Edema (5))

Table 1. Demographic and clinical data

	All (n=48)	Exitus(n=17)	Surviving (n=31)	p value
Boys	32 (66.7%)	13 (40.6%)	19 (59.4%)	0.350
Girls	16 (33.3%)	4 (25%)	12 (75%)	
Intracranial Operation				
Yes	14 (29.2%)	6 (42.9%)	8 (57.1%)	0.478
No	34 (74.8%)	11 (32.4%)	23 (67.6%)	

The mean age of the patients included in the study was 7.56±4.28 years. The mean age of the deceased patient group was 6.29±4.57 years and the average age of the surviving patient group was 8.25±4.02 years. No statistically significant difference was found between the mean age, TA values measured at hospital admission, several days of intensive care hospitalization, GCS and AIS values, of the patient groups who died and survived (**Table 2**).

It was observed that the mean values of Ph, PO_2 were lower, the mean values of PCO_2, lactate, and BE were higher in the patient group who died, compared to the living patient group, and the difference between the groups was found to be statistically significant (p <0.05) in **Table 3**.

Table 2. T test results of the difference in Age, GCS, AIS, mean TA and IC days between the fatal and surviving cases

	Groups	n	$\bar{x}$	Ss	sd	t	p
Age	Exitus	17	6.294	4.579	29.593	1.482	.149
	Surviving	31	8.258	4.024			
GCS	Exitus	17	5.941	1.390	29.187	1.677	.104
	Surviving	31	6.612	1.202			
AIS	Exitus	17	17.647	6.918	31.928	0.156	.877
	Surviving	31	17.967	6.645			
TA	Exitus	17	108.529	12.344	31.657	0.093	.926
	Surviving	31	108.871	11.740			
Hospitalized days to ICU	Exitus	17	5.470	3.299	28.714	1.516	.140
	Surviving	31	6.903	2.797			

(GCS: Glasgow Coma Scales, AIS: Abbreviated Injury Scale, TA: Tension Arterial, ICU: Intensive Care Units)

Table 3. Proportions and p values of ABG results in living and deceased patient groups

	All	Exitus (n=17)	Surviving (n=31)	OR	%95 CI	p value
Acidosis						
Yes	26 54.2%	14 29.2%	12 25.2%	7.389	1.748-31.225	0.004
No	22 45.8%	3 6.3%	19 39.6%			
Hypoxia						
Yes	17 35.4%	8 16.7%	9 18.8%	2.173	0.636-7.420	0.212
No	31 64.6%	9 18.8%	22 45.8%			
Hypercapnia						
Yes	21 43.8%	13 27.1%	8 16.7%	9.344	2.352-37.123	0.001
No	27 56.3%	4 8.3%	23 47.9%			
Hyperlactataemia						
Yes	19 39.6%	14 29.2%	5 10.4%	24.267	5.039-116.865	0.000
No	29 60.4%	3 6.3%	26 54.2%			
BD						
Yes	10 20.8%	6 12.5%	4 22.9%	3.682	.867-15.640	0.068
No	38 79.2%	4 8.3%	27 56.3%			

(BD: Base Deficit, OR: Odds Ratio)

According to ABG values, 14 (53.8%) of 26 patients with acidosis, 13 (61.9%) of 22 patients with hypercapnia, and 14 (73.7%) of 19 patients with hyperlactatemia died. Acidosis, hypercapnia, and hyperlactatemia were higher in the patient group who died, and this difference was statistically significant (p <0.05). In our study, 8 (47.1%) of 17 patients with hypoxia and 6 (60.0%) of 10 patients with BE (20.8%) died. The presence of hypoxia and BE did not show a statistically significant difference between the groups who died and survived (p> 0.05) (**Table 4**).

Table 4. Average values in ABG

	All	Exitus	Surviving	P value
Ph	7.56±0.13	7.15±0.12	7.35±0.08	0.00
PO_2 (mmHg)	81.66±15.38	71.17±17.12	87.41±10.86	0.02
PCO_2 (mmHg)	40.89±8.03	49.29±5.59	36.29±4.75	0.00
Lactate (mmol/L)	3.54±2.52	6.25±2.05	2.06±1.12	0.00
BD (mmol/L)	2.52±1.56	3.75±1.07	1.85±1.36	0.00

By performing ROC analysis, sensitivity, specificity, 95% confidence interval of sensitivity, 95% confidence interval (CI) of specificity, 95% confidence interval of AUC, and AUC were examined in terms of mortality of parameters measured in ABG. According to the ROC analysis results, AUC values for Ph, PCO_2, and lactate were above 0.500. (**Figure 2**), (**Table 5**). We obtained significant results for PCO_2 and lactate in the analysis performed to find out at what values each of Ph, PCO_2, and lactate is associated with mortality. For PCO_2, the sensitivity of 49 mmHg and above for mortality was 58.8%; the specificity of 96.8% and for lactate above 4.5 mmol/L, the sensitivity for mortality was 82.4%: we found that its specificity was 93.6%.

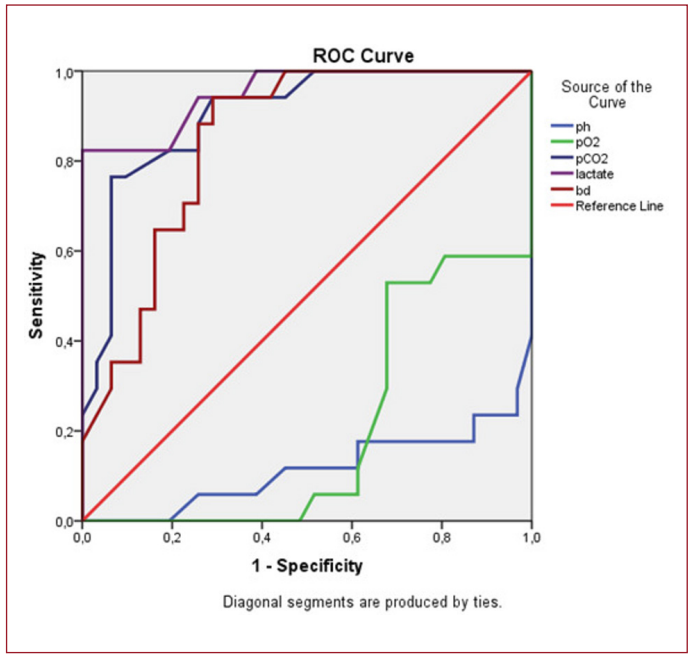

Figure 2. ROC curve for the values of ABG parameters

Table 5. AUC values of ABG parameters in patients who died

Area Under the Curve					
Test Result Variable(s)	Area	Std. Errora	Asymptotic Sig.b	Asymptotic 95% CI	
				Lower Bound	Upper Bound
PH	0.114	0.058	0.000	0.000	0.228
PO_2 (mm Hg)	0.203	0.064	0.001	0.077	0.329
PCO_2 (mm Hg)	0.954	0.027	0.000	0.900	1.000
Lactate (mmol/L)	0.952	0.030	0.000	0.892	1.000
BD (mmol/L)	0.847	0.054	0.000	0.741	0.954

The test result variable(s): ph, PO_2, PCO_2, lactate, be has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased. a. Under the nonparametric assumption b. Null hypothesis: true area=0.5

For the simplest in-group and between-group comparisons, at alpha=0.05, the sample size needed for the effect value determined for a statistical power of 0.50 is approximately n=46. Within the scope of this study, the sample size is above the sufficient number for the study. The Cohen's d scores of the power analysis performed for all quantitative values resulted above 0.90.

DISCUSSION

TBI after head trauma is one of the main causes of morbidity and mortality in the pediatric age group.[16] Since brain development continues in children, axonal myelination is not fully formed and brain tissue has a higher water content than adults. While focal damage is frequently seen in adults after head trauma, this is common damage in children. Although children after TBI have a higher survival rate than adults, sequelae are more devastating in children.[17]

Acidosis may cause neural death by disrupting acid-base homeostasis in brain tissue.[18] Therefore, the presence of acidosis has been accepted as an important indicator of morbidity and mortality.[19] Kushi stated that jugular venous blood pH levels are useful as an early prognostic indicator in the evaluation of neurological function in patients with TBI.[20] In our study, the mean pH value was 7.15 in the patients who died and 7.35 in the survivors, and the presence of acidosis in the patients who died was statistically significantly higher, which shows us that acidosis is an important indicator for mortality.

There are studies on the increasing effect of hypoxia after head trauma on secondary brain injury.[21] Adequate oxygenation is important to reduce brain damage, with or without surgery. Rapid intubation and mechanical ventilation are recommended to achieve this.[22] In children with severe head trauma with oxygen saturation <90% or PaO_2 <60 mmHg, the importance of correcting hypoxia and increasing cerebral perfusion pressure was initially mentioned in the literature.[23,24] Studies showing that the presence of hypoxia after head trauma negatively affects the prognosis are common.[25-27] But some studies have stated that hypoxia is not seen as a factor affecting poor prognosis.[28,29] Although one study conducted on patients with severe head trauma indicated that those with normal PO_2 levels showed a better prognosis, no statistically significant result was found.[30] In our study, PO_2 values were lower in patients who died, but the presence of hypoxia did not show a statistically significant difference between the groups and was not seen as a factor affecting prognosis.

Since it is known that low PCO_2 levels in the blood in patients with severe head trauma increase blood flow and volume through cerebral vasodilation, it is important to bring PCO_2 to normal levels as soon as possible.[31] Dumont studied 65 adult patients with a severe head injury to determine the effect of PCO_2 levels on mortality: it was reported that the survival rate in patients with normocapnia was better than in patients with hypercapnia, and stated that blood PCO_2 levels could be used as a prognostic biomarker.[32] In addition, Rahimi et al. reported that there was no relationship between blood PCO_2 levels and mortality in children with severe head trauma.[28] In our study, blood PCO_2 mean values and the presence of hypercapnia were statistically significantly higher in the group of patients who died. In the ROC analysis, it was found that PCO_2 values of 49 mmHg and above in arterial blood had 58.8% sensitivity for mortality. Our study showed that the presence of hypercapnia negatively affects the prognosis and increases mortality.

Lactate is a by-product of anaerobic metabolism, and blood lactate level also reflects the degree of tissue hypoperfusion and hypoxia.[8] There are studies with varying results about the role of lactate levels in brain damage. Some studies indicate that high lactate levels in the blood increase the use of lactate as cerebral energy and this protects cerebral glucose in the damaged brain.[33,34] It has been reported that with the increase of lactate level in the blood, vasodilation occurs in the cerebral vessels, and cerebral blood flow increases and this situation has a neuroprotective effect on cerebral cell metabolism.[35] On the other hand, studies are reporting that brain damage and mortality increase with impaired cerebral blood flow regulation in cases where lactate levels in the blood are too high.[36-38] Therefore, the role of lactate in TBI is not clear yet. Although Ramanathan et al. and Shah et al. reported that blood lactate levels were high in children after trauma, they did not address the relationship between lactate and prognosis.[39,40] In our study, the mean blood lactate values and the presence of hyperlactatemia were statistically significantly higher in the patient group who died. In the results of ROC analysis, it was found that lactate values of 4.5 mmol/L and above in ABG had 82.4% sensitivity for mortality.

In patients with general body trauma, BE has been reported as an important indicator of tissue perfusion and hypoxia and blood BE values have been reported to be a prognostic biomarker in such traumas.[41,42] There is an insufficient number of clinical studies regarding the effect of blood BE values on brain injury after head trauma. In our study, although blood BE values were high in the patient group who died, they did not give statistically significant results in terms of mortality.

Limitations

Our study has some limitations, the first of which is that our patient population was small. The other limitation is that it is a retrospective study. In addition, patients with multiple trauma accompanying severe head injuries were excluded from the study. Finally, there is an arterial condition for blood gas and venous blood gas was not accepted in the sample.

CONCLUSION

It is very important to identify and measure some prognostic biomarkers beforehand to prevent secondary brain damage. ABG measurement is an advantageous method with its widespread use and rapid results. Our study showed that the presence of acidosis, hypercapnia, and hyperlactatemia according to ABG values, are associated with poor prognosis in children with severe head trauma, and their presence increases mortality. Our study has shown that PCO_2 and lactate levels in ABG can be a biomarker for prognosis

ETHICAL DECLARATIONS

Ethics Committee Approval: Approval of the Kafkas University Medical Faculty Non-interventional Ethic Committee dated 25.06.2020 and numbered 2020/233.

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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