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Prognostic Value of Arterial Blood Gas Indices Regarding the Severity of Traumatic Injury and Fractures of the Femur and Pelvis

Leila Mohsenian[1], Mohamad Karim Khoramian[1]*, Sara Sadat Mazloom[1]

[1]Department of Emergency Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

*Corresponding author: *Mohamad Karim Khoramian*
Address: Department of Emergency Medicine, Shiraz University of Medical Sciences, Shiraz, Iran
Cellphone: +98-917-721 4895
e-mail: mkkhoramian @yahoo.com

> **ABSTRACT**

Objective: To evaluate the prognostic value of arterial blood gas (ABG) indices, especially base excess (BE), regarding the severity of traumatic injury.
Methods: A total number of 96 trauma patients with fractures of femur and pelvis were included in this study. Demographic characteristics and clinical information of samples were recorded. The results of ABG test and hemoglobin (Hb) were evaluated at two time intervals (on admission and 6 hours later). The outcome of the patients was evaluated at the end of the study (dead or alive). The ABG indices included O_2 saturation (O_2Sat), PH, PO_2, PCO_2, bicarbonate (HCO_3) and base excess (BE). The mean of the hemodynamic and ABG indices were compared between those who were discharged and mortality cases. The confounders were compensated using a multivariate logistic regression model.
Results: Overall 94 trauma patients with long and pelvic fractures were included. There were 69 (73.4%) men and 25 (26.6%) women among the patients with mean age of 37.43±20.07 years. The mortality rate was 10 (10.6%). The most common mechanism of injury was motorcycle accident in 41 (43.6%) and car collision in 43 (45.7%) patients. We found that mortality was significantly associated with amount of FFP transfusion (*p*=0.005), but was not associated with amount of transfused packed cells (*p*=0.113). We also found that mortality was associated with lower BP after 6 hours of admission (*p*=0.001), higher HR on admission (*p*=0.036), lower HR after 6 hours (*p*=0.017), lower O_2Sat on admission (*p*<0.001), higher PCO2 after 6 hours and lower BE on admission (*p*=0.025).
Conclusion: The ABG indices including O_2Sat, BE and PCO_2 are considered prognostic determinants of outcome in trauma patients with long and pelvic fractures. These findings can be considered as fundamental studies to achieve new diagnostic methods.

Keywords: Prognosis; Injuries; Femur; Pelvis; Mortality; Arterial blood gas (ABG); hemodynamic indices.

Introduction

Trauma is among the most common causes of disability and mortality worldwide [1-3]. Meanwhile, fractures of pelvis and long bones are commonly observed in middle aged people due to osteoporosis and falls and in young people usually due to severe hits [4, 5]. Patients with severe pelvic fractures account for 3% of total fractures [6]. The complications of bone fracture include infection, avascular necrosis, large blood vessel damage, damage to the nerves, damage to the muscles, damage to the tendons, osteoarthritis and in certain cases, shock, fat embolism, compartment syndrome, lower extremity deep vein thrombosis (DVT) and lung embolism [7-9]. It is worth noting that hemodynamic compromise in patients with unstable pelvic fractures associated with arterial bleeding occurs in less than 20% of cases [10-12].

Severity of trauma and development of systemic inflammatory response syndrome have been studied as effective factors by causing inflammation [5, 9, 13]. Recent studies have shown that decreased tissue perfusion, without clear clinical symptoms, led to an increase in the levels of lactate and carbonic acid in trauma patients and was introduced as a predictor of mortality in these patients, and its criterion is measuring serum lactic acid [14, 15]. However, it is not possible to measure this parameter in all trauma centers. On the other hand, BE of the blood is an index of shock and physiological impairment in trauma patients and is associated with blood lactate concentration and the severity of the injury [16, 17]. Factors that affect the base deficit include the use of bicarbonate, hypothermia, hypocapnia, heparin, ethanol and ketoacidosis [18, 19]. Base excess (BE) is the levels of base that is required for titration of one liter of full blood to reach pH 7.4 in the case of full saturation of blood with oxygen, at 37°C and $PaCO_2$=40 mmHg [16, 17]. Studies have shown that in cases of severe base deficit, most of the trauma patients suffer from shock due to bleeding. However, in the absence of shock, it seems that this criterion can be a sign of lactic acidosis [16-19]. Some studies have suggested that the mortality of trauma patients can be predicted by the levels of base deficit within the first 24 hours after the trauma [20, 21].

Post-traumatic management with rapid diagnosis and timely action such as resuscitation is vital in trauma patients [8, 13, 22]. Trauma is one of the major causes of death and disability in Iran. Not only bone fractures cause permanent defects and disability in patients, but also cause death in many cases due to severe bleeding (the pelvic floor and long bone) [23]. Therefore, detection of dependent and prognostic variables can be very important and prevent the complications of these fractures. According to previous studies, the arterial blood gas (ABG) changes seem to be appropriate predictor of severity of traumatic injury [24, 25]. Nevertheless, no comprehensive study has been conducted in this regards. Thus, the present study aims to examine the prognostic relationship between ABG indices, including BE, and bicarbonate, and the severity of traumatic injury.

Materials and Methods

Study Population

In this prospective cohort study, all trauma patients with major bone fracture, defined as long and pelvic fractures, referred to Shahid Rajaie hospital, a Level-I trauma center affiliated with Shiraz University of Medical Sciences located in southern Iran during a 6-month period from March to September 2017 were included. We included adult patients (18-65 years) with fractures of femur or pelvis. The exclusion criteria were patients with small bone fracture or patients whose fracture occurred more than 24 hours ago. Those also excluded those with severe multi-organ injuries, those who passed away less than 48 hours after admission, patients with comorbidities such as diabetes mellitus, ischemic heart disease, chronic obstructive pulmonary disease (COPD) and malignancies. The study protocol was approved by the institutional review board (IRB) and medical ethics committee of Shiraz University of Medical Sciences. All the patients or their legal representatives provided their informed written consents before the study.

Study Protocol

All the included patients were evaluated by an emergency medicine resident on admission. The demographic variables, including age and gender were recorded; clinical information of the samples such as fracture type, fracture site, the mechanism of injury and the level of consciousness were recorded into a data gathering form. The mechanism of injury was classified to motorcycle accident, car accident, exposed burn, fall and gunshot injuries. The vital signs including blood pressure (BP), heart rate (HR) and respiration rate (RR) were recorded. All the patients gave 2 samples for ABG and Hb on admission. The ANG and Hb measurement was repeated 6 hours after the admission.

The ABG was analyzed on arterial blood by using the Nova Biomedical (pHOx Plus, USA). We measured the PH, oxygen saturation (O_2 Sat), PCO_2, HCO_3 and BE. The normal range of these parameter was considered as follow; PH: 7.35□7.45, BE: -2 □ +2 mmol/L, HCO_3: 22□26 mEq/L, PCO_2: 35-45mmHg and O_2Sat: 95-100%. In addition, PH higher than 7.45 was considered alkalemia and lower than 7.35 was recorded as acidemia, PCO_2 higher than 45mmHg was considered as respiratory acidosis and lower than 35mmHg as respiratory alkalosis. HCO_3 higher than 26mEq/L was metabolic alkalosis and lower than 22 mEq/L was recorded as metabolic acidosis [26, 27]. Furthermore, the Sysmex kx21 device was

used to run blood tests and determine the levels of Hb. The outcome of patients, including the length of hospitalization, the transfer of patients, discharge, or mortality was also recorded.

Statistical Analysis

All the data were analyzed using the statistical package for social sciences (SPSS Inc., Chicago, Illinois, USA) version. All the data are presented as mean±SD and proportions as appropriate. Descriptive data were composed from the frequency distribution table, central indexes, distribution and percentages. The changes in the parametric variables of ABG within groups were compared using paired t-test while normal distribution was encountered. In parametric variables without normal distribution, Kruskal-Wallis test was used. The parametric variables were compared between two groups (dead and alive) using independent t-test. The proportions were compared with chi-square test. We also run a multivariate logistic regression model to compensate for confounders such as age, gender and injury mechanism. A 2-sided p-value of less than 0.05 was considered statistically significant.

Results

Overall a total number of 94 patients were included in the current study. There were 69 (73.4%) men and 25 (26.6%) women among the patients with mean age of 37.43±20.07 years. The most common mechanism of injury was motorcycle accident in 41 (43.6%) and car collision in 43 (45.7%) patients. The mean GCS on admission was 13.38±3.27. The demographic and baseline characteristic of the patients is summarized in Table 1. We found that 66 (70.2%) of the patients required full blood, and 17 (18.1%) fresh frozen plasma (FFP) transfusions. The mean packed cells and FFP transfusion were 3.23±3.5 and 1.0±2.5 units per patient, respectively. Overall 48 (51.1%) patients were admitted to the Emergency Room (ER) while 13 (13.8%) were transferred to the orthopedic room immediately. Finally, 33 (35.1%) patients were admitted to the intensive care unit (ICU).

As demonstrated in Figure 1 the hemodynamic variables and the hemoglobin changes were observed between admission and a 6-hour period. The BP increased significantly (*p=0.033*) and HR levels decreased significantly (*p<0.001*). The Hb level also

Table 1. Demographic characteristics and mechanism of injury in the studied samples based on gender.

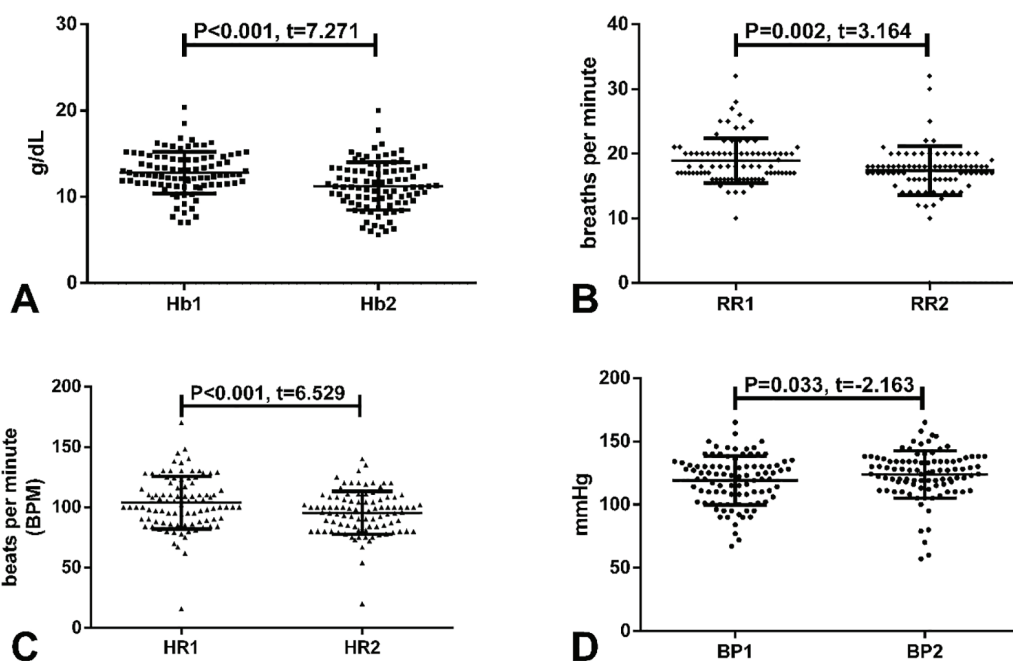| Variable	Men (n=67)	Women (n=25)	Total (n=94)	*p*-value
Age (years)	35.75±17.22	41.44±26.42	37.43±20.07	0.01
GCS[a]	13.03±3.59	14.36±1.93	13.38±3.27	<0.001
Mechanism of Injury				
Motorcycle (%)	37 (39.4%)	4 (4.3%)	41 (43.6%)	<0.001
Car (%)	26 (27.7%)	17 (18.1%)	43 (45.7%)	
Fall (%)	5 (5.3%)	3 (3.2%)	8 (8.5%)	
Gunshot (%)	1 (1.1%)	0 (0%)	1 (1.1%)	
Expose Burning (%)	0 (0%)	1 (1.1%)	1 (1.1%)	

[a]GCS: Glasgow Coma Scale

Fig. 1. Changes in hemoglobin and hemodynamic indices between the two measurement intervals. The level of hemoglobin decreased significantly **(A)** and the respiratory rate also decreased after 6 hours **(B)**. The heart rate decreased significantly after 6 hours of admission **(C)** while the blood pressure increased in this time period **(D)**.

decreased significantly after 6 hours of admission in the study population ($p<0.001$) (Figure 1). As demonstrated in Table 2, the mean PH was below normal either on admission and 6 hours later. In the same way the patients had lower levels of HCO_3, BE and O_2Sat either n admission and 6 hours later (Table 2).

Overall 84 (89.4%) patients were discharged in good condition while 10 (10.6%) patients died during the hospital course. Among the mortality cases were 8 (8.5%) men and 2 (2.1%) women. The mean GCS was significantly lowed in deceased patients compared to those who were discharged from the hospital (9.4±5.5 vs. 13.8±2.5; $p<0.001$). We also found that mortality

was significantly associated with amount of FFP transfusion ($p=0.005$), but was not associated with amount of transfused packed cells ($p=0.113$). We found that mortality was associated with lower BP after 6 hours of admission ($p=0.001$), higher HR on admission ($p=0.036$), lower HR after 6 hours ($p=0.017$), lower O_2Sat on admission ($p<0.001$), higher PCO2 after 6 hours and lower BE on admission ($p=0.025$). The results are summarized in Table 3. We have also run a multivariate logistic regression analysis to compensate for confounders including the age, gender and mechanism of injury. All the variables remained statistically significant predictors of mortality after compensating for confounders.

Table 2. The changes in parameters if of the arterial blood gas (ABG) on admission and 6 hours later in 94 trauma patients with long and pelvic fractures.

Variable		Mean	t	Threshold	*p*-value
PH	On admission	7.34±0.088	-5.777	7.4	<0.001
	6-hour	7.32±0.086	-8.244		
O_2Sat	On admission	92.1±6.68	-7.838	97.5	<0.001
	6-hour	95.98±2.47	-5.968		
PCO_2	On admission	40.69±11.02	0.596	40	0.122
	6-hour	37.99±10.44	-1.814		
HCO_3	On admission	22.12±4.18	-4.087	24	<0.001
	6-hour	20.40±4.05	-8.128		
BE	On admission	-3.251±4.117	-7.491	0	<0.001
	6-hour	-4.531±5.748	-7.436		

Table 3. The correlation of changes in hemodynamic and arterial blood gas indices with the outcome of 94 trauma patients with long and pelvic fractures.

	Dead (n=10)	Alive (n=84)	*p*-value
Blood pressure (mmHg)			
On admission	118.1±26.1	119.12±18.4	0.148
6-hour	102.6±29.9	126.3±15.4	0.001
Respiratory rate (per min)			
On admission	17.33±3.32	19.02±3.43	0.686
6-hour	17.36±3.84	17.36±3.84	0.799
Hear rate (per min)			
On admission	105.9±39.3	103.7±19.1	0.036
6-hour	92.1±31.8	95.9±15.5	0.017
Hemoglobin (g/dL)			
On admission	13.26±1.5	12.75±2.5	0.182
6-hour	11.67±2.1	11.26±2.7	0.224
PH			
On admission	7.25±0.07	7.35±0.08	0.670
6-hour	7.20±0.09	7.33±0.07	0.141
O_2Saturation (%)			
On admission	83.9±12.6	93.1±4.8	<0.001
6-hour	94.4±2.45	96.17±2.4	0.801
PCO_2 (mmHg)			
On admission	50.8±12.7	39.5±10.3	0.551
6-hour	47.9±16.8	37.1±9.2	0.007
HCO_3 (mEq/L)			
On admission	23.8±5.22	21.9±4.17	0.213
6-hour	18.9±5.12	20.5±3.93	0.244
BE (mmol/L)			
On admission	-4.68±5.8	-3.09±3.8	0.025
6-hour	-8.72±5.4	-7.11±5.6	0.557

Discussion

In recent years, trauma has been one of the most important causes of disability and mortality worldwide [1-3]. This problem can be caused by several factors, the most important of which are motorcycle accidents, car accidents and falling down. Trauma can cause various complications. Rupture of organs such as spleen, and lung, rupture of major vessels and internal bleeding are some of the most important complications of trauma. The most important complication that can be caused by trauma is bone fracture, which may lead to organ defects or disability [7-9].

Fractures of major bones such as femur and pelvic bone are among the most severe and complex injuries of the skeletal system [7, 13]. Due to the proximity of these bones to blood vessels and nerves, and organs such as the intestine and bladder, these bones increase the risks caused by this fracture. After bone fracture, due to the contraction of strong muscles around the bone, the fracture edges cross each other, the fractured organ becomes shorter and the injuries increase [7-9, 11, 13].

For these reasons, bleeding in the pelvic floor and long bones causes shock and even death in some cases [28-30]. Thus, identifying the prognostic criteria of the patients' conditions can be very important and help prevent complications. It seems that ABG changes can be considered as good predictor of the severity of traumatic injury.

The results show a significant relationship between BP and HR and mortality rate in the study samples; the lack of increase in BP to normal levels in the early hours can be considered a prognostic factor. In addition, the results showed that among the ABG indices, O_2Sat, BE and PCO_2 could be prognostic indices of the status of patients with major bone fractures. In this study, it was found that the mean O_2Sat, BE and PCO_2 levels in samples who were deceased due to the fracture of femur and pelvis showed significant difference compared with the recovered samples; the mean on admission O_2Sat and BE levels in deceased samples was significantly lower than that of recovered samples. Moreover, mean PCO_2 after 6 hours in deceased samples was higher than that of recovered samples. The results showed that PH in the study samples was significantly lower than normal levels and the samples had acidemia. In addition, the mean O_2 Sat, HCO_3 and BE levels in the first and second times showed that these factors were significantly lower than the normal range. Furthermore, the results show a significant decrease in BE and HCO_3 levels in the second time compared to the first one. These results indicate the prognostic power of ABG indices regarding the complications of major bone fractures such as shock and death.

As stated earlier, decreased tissue perfusion without clear clinical symptoms is one of the complications of fracture, which leads to an increase in the levels of lactate and carbonic acid in trauma patients and is introduced as a predictor of mortality in these patients. Some studies suggest that the lack of BE was the same as the clinical measurement of metabolic acidosis, which becomes normal with proper resuscitation and control of bleeding, and can be used for monitoring the primary care of a trauma patient [31]. In addition, blood pressure can be a major contributor to the complications of trauma and concealed hemorrhages. In particular, one of the best indicators of hypotension is BE, which estimates metabolicacidosis. Callaway *et al.* in their study stated that mortality due to hypoperfusion may increase in trauma patients with initial BE lower than -6mmol/L [32]. Moreover, according to the study of Peñasco et al., low levels of BE and BP could be an important risk factor for patients with trauma; BE<-6mmol/L increases the risk of death in patients with abnormal BP [33]. In a study by Kincaid et al., it was found that initial BE showed the severity of injury and could predict mortality and the possibility of increased mortality in children was associated with base deficit and was a warning sign for potentially lethal injuries or uncompensated shock [34]. In a study by Ibrahim et al., it was concluded that as BE decreases, blood pressure, mortality, injuries and complications constantly increase [20]. Similar to the results of the present study, the study of Mofidi et al. concluded that in patients with blunt abdominal trauma, BE is an important indicator for identifying intra-abdominal injuries and the lack of attention to it can increase mortality in patients. In addition, BE can be a prognostic factor for determining the need for more blood transfusions [35].

In a study by Toth *et al.*, it was argued that hypotension and low BE levels could be decisive factors for performing angiography, identifying vascular problems and controlling pelvic bleeding in patients with pelvic fracture [36]. Similar results were reported in the study by Jeroukhimov *et al.*, which stated that the rates of blood transfusions and the reduction of BE levels can be indicators for early angiography and emergency follow-up in patients with severe pelvic pain [37].

Similar to our results, the study of Neville et al. indicated that BE lower than -4mmol/L increases the mortality rate. They concluded that high BE and lactate could be very important predictors of early death (in the first 24 hours) in trauma patients [21]. These findings were in line with the study of Jung *et al.*, [38].

Our results suggest that the BE, BP, O_2Sat and HCO_3 parameters are useful in the initial evaluation of these patients and are consistent with previous studies. These findings suggest that these parameters can be predictors of the patient's condition. It is worth noting that our study results, similar to Neville et al., show that BE<-4mmol/L is a risk factor and increases the chance of death. However, some studies have reported this value to be lower than

-6mmol/L [21]. However, it is crystal clear that this factor can be cited as a prognostic factor. Ultimately, the limitations of this study were: not evaluating the cause of death or joint effects or other injuries. Moreover, underlying diseases were not specifically evaluated. Nonetheless, other factors that can affect BE at the time of admission, such as hemoglobin levels, were evaluated.

In conclusion, the results of this study showed that ABG indices such as O_2Sat, BE and PCO_2 could be predictors of the status of patients with major bone fractures. Furthermore, BP acts as a determining factor. In this study, the mean O_2Sat, BE and PCO_2 levels in samples who were deceased due to fractures of femur and pelvis showed significant difference compared with the recovered samples. These findings can be considered as fundamental studies to achieve new diagnostic methods. It is suggested that supplementary studies be carried out to achieve reliable results.

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Conflicts of Interest: None declared.

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