

# Association of base deficit with mortality in pediatric trauma

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**Received:** 20 August 2015**Accepted:** 12 September 2015**Published online:** 15 November 2015

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**Competing interests:** Authors declare that they have no conflict of interests.

**Funding information:** None.

**Citation:** Ziaee M, Mirafzal A. Association of base deficit with mortality in pediatric trauma. *Journal of Emergency Practice and Trauma* 2016; 2(2): 50-54. doi: 10.15171/jept.2015.17

## Abstract

**Objective:** To evaluate the association of base deficit (BD) with mortality in traumatized children, and to assess this association in a subgroup of patients with traumatic brain injury (TBI).

**Methods:** In this cross-sectional study performed prospectively on a convenience sample of patients under 16 years of age with trauma presenting to an academic level II trauma center, we obtained venous BD values initially and followed the patients for in-hospital mortality. Initial vital signs were measured and injury severity score (ISS), randomized trauma score (RTS), and pediatric trauma score (PTS) were calculated.

**Results:** A total of 102 patients were included, with 48 patients diagnosed with TBI. Nine patients (8.8%) died during admission, of which 6 were diagnosed with TBI. Based on the univariate analysis, BD was associated with mortality in the whole group ( $P=0.01$ ), but not in the TBI subgroup ( $P=0.08$ ). In multivariable analysis, RTS was the only variable independently associated with mortality ( $P=0.001$ , odds ratio [OR]=0.197). Linear regression model showed that BD was predictive of ISS, RTS, and PTS. Receiver operating characteristics (ROC) curve showed a cutoff point of  $-7$  mmol/L for BD, below which there is a 12 fold increased risk for mortality.

**Conclusion:** BD is a useful parameter in mortality prediction in pediatric trauma like in adult age group, but this predictive role in TBI patients is not supported by our results.

**Keywords:** Base deficit, Mortality, Pediatric trauma

## Introduction

Trauma is the leading cause of death among people in the first half of a normal lifespan and the fifth in all age groups (1-5). In people under 30 years of age, trauma leads to more deaths than the sum of all other causes of mortality (5). Death rate due to road traffic accidents (RTAs) in Iran is reported to be 38 per 100 000 in 2004, with a decline to 31 per 100 000 population in 2011 (6). Pediatric trauma includes nearly 29% of all trauma patients, with fall injuries and motor vehicle collisions (MVCs) being the most common in this age group (7). Base deficit (BD) is defined as the amount of base in millimoles per liter (mmol/L) required for buffering 1 liter of whole blood to a pH of 7.4 in the following conditions: temperature of 37 degrees of Celsius, full oxygen saturation, and an arterial pressure of CO<sub>2</sub> (PaCO<sub>2</sub>) of 40 millimeters of mercury (mm Hg). BD is usually measured by blood gas analysis and normal values are defined as  $-2$  to  $+2$  mmol/L (8). A BD of  $-6$  mmol/L or less is shown to be an indicator for the extent of injury, amount of blood transfusion required, and mortality (9). BD is introduced as a reliable physiologic

parameter in hypovolemic shock by revealing the real perfusion of tissues and aiding in estimation of resuscitation resources required by patients (10-16). There is sufficient data in the literature to show the validity of BD to predict adverse outcomes in various trauma and non-trauma states in adults; in the pediatric age group, however, there is not the same huge data as the adult age group for the value of BD (17). Although there are a number of studies in the literature addressing the association of initial BD with mortality in pediatric trauma patients, most of them are performed using a retrospective design (17-20). In this cross sectional study with a prospective design, we tried to find the answer of two questions: first, is there any association between BD with mortality in pediatric trauma? Second, is there any association between BD and mortality in a subgroup of patients with traumatic brain injury (TBI)?

## Methods

This cross-sectional study was performed prospectively using a convenience sample of children with trauma presenting to Bahonar academic hospital, a level II trauma



center in Kerman, Iran. Bahonar hospital is the main referral center for trauma patients in Kerman-located in the southeast of Iran- with an annual emergency department (ED) census of nearly 70 000.

A convenience sample of children under 16 years of age presenting to Bahonar ED with trauma and triaged to emergency severity index (ESI) levels 1 or 2 (in the 5 level system) comprised our study population. We selected ESI level 1 and 2 patients because blood sampling from children in levels 3, 4, or 5 is not routine in Bahonar hospital and we did not aim to perform blood sampling only for the research purpose. Moreover, the ED interventions done for critical patients with higher ESI levels are not similar to the non-critical ones, acting as an interfering factor itself. In Bahonar hospital, ESI level 1 or 2 patients are routinely transported to the critical care unit. Evaluation and management is done on the basis of Advanced Trauma Life Support (ATLS) guidelines by a team completely independent of research purposes. Our researcher was a post-graduate year 3 resident of emergency medicine who was acting as an observer, collecting the data using a pre-designed standardized sheet. After collection of variables defined in the pre-programming of this study (demographic data, mechanism of injury, pulse rate [PR] in 1 minute, blood pressure [BP] by an oscillometric pneumatic cuff, respiratory rate [RR] in 1 minute, Glasgow Coma Scale [GCS] or Pediatric Coma Scale [PCS] depending on patients' developmental level, injury severity score [ISS], randomized trauma score [RTS], pediatric trauma score [PTS], and venous blood BD), the patient was followed for in-hospital mortality by a nurse blinded to the initial results for the variables. This process was supervised and randomly checked by an attending physician of emergency medicine to monitor the data collection process, particularly calculating the 3 trauma scores. The agreement between the 2 calculations performed on random cases was more than 85%, with the remaining cases solved by

consensus. The subgroup with TBI was identified by the clinical diagnosis of the management team. In-hospital mortality was defined as the study outcome.

Values are reported as mean  $\pm$  Standard Deviation (SD) for normally distributed continuous variables. To report variables without a normal distribution, median  $\pm$  inter quartile range (IQR) was used. Proportions are presented as percentages with 95% CI. For univariate analysis, continuous data were analyzed using the Student *t* test if the data were normally distributed (according to the Kolmogorov-Smirnov, Shapiro and Levene test); otherwise, the adjusted *t* test was used. Categorical data were compared using Pearson  $\chi^2$  test. A *P* value less than 0.05 was considered to be statistically significant. In multivariable model, we entered all variables with a potential to predict the outcome according to our clinical experience. The multivariable analysis was performed by constructing a logistic regression model according to forward Wald method. Linear regression model was used to assess the prediction of continuous variables (ISS, RTS, and PTS) by BD. Receiver operating characteristic (ROC) curves were generated to test the ability of variables to predict the outcome. Statistical analysis was performed by SPSS version 17.0 (SPSS Inc Headquarters, Chicago, IL) software program.

## Results

A total of 102 patients were enrolled in the study, 48 (47%) diagnosed with TBI. Mean age (SD) was 9.8 (4.8), with an age range of 1 to 16 years. 72(70.6%) were males and 30 (29.4%) were females. The most common mechanism of injury was MVC (86.3%). The mean (SD) value for GCS/PCS of patients was 13.6 (2.6), with a range of 3 to 15. Overall, 9 (8.8%) patients died during the admission period, 6 of them suffering from moderate to severe TBI. The mean (SD) value for BD was -5.3 (3.0), with a range of -19 to +2 mmol/L (Table 1). From 48 patients with a clini-

**Table 1.** Patient statistics

Variables	Values
Hours elapsed from trauma to ED presentation, median (IQR)-Min/Max	1 (1)-1/6
Pulse rate (BPM) at ED presentation, mean (SD)-Min/Max	105.0 (21.1)-67/169
Respiratory rate at ED presentation, mean (SD)- Min/Max	23.4 (7.2)-10/46
Systolic blood pressure (mm Hg) at ED presentation, mean (SD)- Min/Max	107.5 (21.9)-65/170
Intubated in the ED, No. (%)	12 (11.7)
ICU admitted, No. (%)	28 (27.4)
Head and neck injury, No. (%)	49 (48.0)
Chest injury, No. (%)	6 (5.8)
Abdominal injury, No (%)	22 (21.5)
Injury to the extremities, No. (%)	57 (55.8)
Admission length (days), median (IQR)	3 (3)-1/26
RTS, mean (SD)- Min/Max	11.1 (1.1)-7/12
ISS, median (IQR)- Min/Max	9 (9)-3/41
PTS, median (IQR)- Min/Max	11 (4)-1/14

Abbreviations: ED, emergency department; BPM, beats per minute; Min, Minimum; Max, Maximum; IQR, Inter-quartile range; SD, standard deviation; RTS, revised trauma score; ISS, injury severity score; PTS, pediatric trauma score.

cal diagnosis of TBI, 13 (27%) had a diagnosis of concurrent abdominal injury and 18 (37%) were diagnosed with concurrent limb injury. From 6 expired by head trauma, 1 was categorized as moderate TBI (GCS=12) and 5 were documented as severe TBI, with a presentation time GCS of 8 or less.

No significant difference was shown between males and females regarding mortality in the univariate analysis ( $P=0.96$ ). Of all variables tested, the mean values of BD, GCS, RTS, ISS, and PTS were significantly different between the two groups (expired and survived to discharge). Interestingly, BD was not correlated significantly with mortality in the TBI subgroup ( $P=0.08$ ; Table 2).

All variables considered as potentially associated independently with mortality were entered in the multivariable logistic regression model; except for sex, admission length, and hours elapsed from trauma to ED presentation, other variables were included in the analysis. In the final model, RTS was the only variable showing an independent association with mortality ( $P=0.001$ , odds ratio [OR] = 0.197). In the next step, we repeated this analysis after exclusion of GCS, PR, and SBP because they play a significant role in the calculation of RTS; however, there was not any difference between the results of these two steps. In the TBI subgroup, multivariate analysis also showed RTS as the only independent variable associated with mortality ( $P=0.009$ , OR=0.263). In the linear regression model created for evaluating prediction of trauma scores, BD was predictive of RTS, ISS, and PTS in our study (Table 3).

Although not shown to be independently associated with mortality, we generated a ROC curve to evaluate the predictive value of BD for this outcome (Figure 1). As shown in the figure, the area under curve (AUC) was 0.871, making BD highly predictive of mortality. A cutoff point of  $-7.15$  mmol/L was found for BD, below which the accuracy of prediction is in the highest value. Patients were categorized with regard to BD cutoff point of  $-7$  mmol/L; those with BD less than this point showed an increased risk of mortality by a factor of almost 12. In the probability distribution curve (Figure 2), it was shown that below a cut point of  $-7$  mmol/L, the curve steepens sharply; this finding was in concordance with those shown for the ROC curve.

### Discussion

BD was shown to be associated with mortality and transfusion requirements in many previous studies in the adult age group. In a recent study by Mutschler et al, initial BD was associated with ISS and transfusion rate; the authors concluded that BD may be superior to the current ATLS classification of hypovolemic shock in identifying the presence of hypovolemic shock and in risk stratifying patients in need of early blood product transfusion (21). Trauma associated severe hemorrhage (TASH) score, reported as a reliable predictor of massive transfusion after multiple trauma, includes BD in the scoring as well as several other parameters (22). Studies revealing these associations were done using adult or mixed pediatric

**Table 2.** Correlations found by univariate analysis

Variable	Survived (Mean)		Dead (Mean)		P value	
	All patients	TBI patients	All patients	TBI patients	All patients	TBI patients
Age	10.0	9.1	7.3	7.5	0.15	0.52
Hours elapsed from trauma to ED presentation	1.9	2.4	2.4	2.3	0.57	0.94
BD at presentation	-5.1	-5.8	-8.1	-8.4	0.01*	0.08
PR at presentation	104.1	109.0	117.0	114.8	0.12	0.54
RR at presentation	23.0	25.4	27.7	25.5	0.10	0.97
BP at presentation	108.4	105.8	96.0	97.5	0.14	0.66
GCS at presentation	14.0	12.9	8.2	7.6	<0.001*	<0.001*
Admission length (days)	4.5	5.5	3.5	3.6	0.56	0.40
RTS	11.3	10.9	8.8	8.8	<0.001*	<0.001*
ISS	13.4	17.4	20.4	22.3	0.04*	0.25
PTS	10.2	9.4	6.0	5.0	<0.001*	0.004*

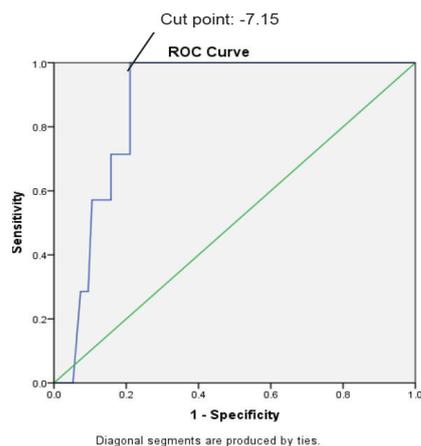
Abbreviations: TBI, traumatic brain injury; ED, emergency department; BD, base deficit; PR, pulse rate; RR, respiratory rate; BP, blood pressure; GCS, Glasgow Coma Scale; RTS, randomized trauma score; ISS, injury severity score; PTS, Pediatric Trauma Score.

\*Statistical significance.

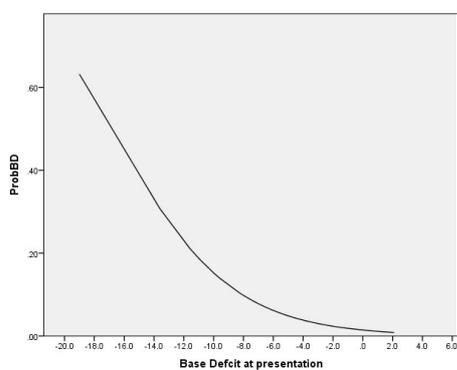
**Table 3.** Prediction of injury scores by base deficit

Dependent variable	Unstandardized Coefficients		Standardized Beta	P value	Model type, and R-square
	Beta	SE of beta			
ISS	-0.70	0.28	0.015	-0.25	Stepwise, 0.06
RTS	0.16	0.03	0.43	<0.001	Stepwise, 0.19
PTS	0.36	0.09	0.37	<0.001	Stepwise, 0.13

Abbreviations: ISS, injury severity score; RTS, randomized trauma score; PTS, pediatric trauma score; SE, standard error.



**Figure 1.** Receiver Operating Characteristic (ROC) curve regarding Base Deficit and mortality.



**Figure 2.** Probability distribution curve regarding base deficit and mortality.

and adult aged patients. A number of studies have been done exclusively on pediatric trauma patients. Admission time BD was also shown to be associated with mortality in these studies; in a study by Jung et al (17), the authors concluded that initial BD in pediatric trauma was an independent predictor of mortality and blood transfusion requirements except in severe brain injury. All of these studies were performed using a retrospective design (17-20). In the whole group of 102 patients, 9 were dead by multiple trauma in our study. A cut point of -7 mmol/L for BD, below which there is a 12 times probability of mortality for these patients, is confirmative of most previous studies by which a cut point value of -8 mmol/L had been reported. In contrast to Jung et al, however, BD did not show an independent association with mortality in multivariable regression analysis; RTS was the only variable remained in the model. In concordance with Mutschler et al report, BD was also predictive of RTS, ISS, and PTS in our study. In the TBI subgroup, however, we did not find a significant correlation between BD and mortality. This finding was in concordance with the study of Jung et al. This difference between the total group and the TBI subgroup may be described by the clinical rationale that in TBI, mortality is more likely due to a primary or sec-

ondary injury to the brain rather than hypovolemic shock. The major limitation of our study is the low number of expired cases, making any conclusion and recommendation difficult. This limitation is even more evident in the TBI subgroup with no association found between BD and mortality, which is the most interesting finding in our study. The previous larger retrospective studies, however, can be helpful in drawing conclusions from our study; the cut points are very close and the results are almost similar; the finding that BD may not be useful in head trauma is also in concordance with the study of Jung et al.

## Conclusion

BD is a reliable predictor of mortality in traumatized children. The agreement of BD with trauma scores like RTS, ISS, and PTS may be used in doubtful cases. According to our findings, BD can be used to aid in categorizing patients for injury severity and the intensiveness of resuscitation, but in the presence of moderate or severe TBI, the usefulness of BD is under question. The findings of our study are not confirmatory and according to the questionable value of BD in children with TBI by our results, more prospective studies with higher number of expired cases are needed to validate this conclusion. However, it can be recommended that multiple trauma children with admission BD less than -7mmol/L should be considered as high risk patients and receive critical care service.

## Ethical issues

This study was conducted according to the Declaration of Helsinki and reviewed by the Institutional Review Board of Kerman University of Medical Sciences.

## Authors' contributions

MZ produced the first draft, AM commented on and revised several drafts. Both authors approved the final manuscript.

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