

# Correlation of Dysoxia Metabolism Markers with Trauma Scoring Systems in Multiple Trauma Patients Admitted to the Emergency Department: A Cross-Sectional Observational Study

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## Abstract

**Background:** All the trauma scoring systems (TSSs) have some limitations, and none is useful for patient monitoring. Recently, investigators have tried to modify the TSSs to improve their use. **Aims:** This study was conducted to determine whether any correlation exists between dysoxia metabolism markers (DMMs), including venous base deficit (BD) and  $\text{HCO}_3$  level with different TSSs. **Materials and Methods:** In this cross-sectional study, all multiple trauma patients admitted to the emergency department were eligible. Blood samples for venous blood gas analysis were taken at the onset of resuscitation process. TSSs, including trauma index (TI), abbreviated injury score (AIS), Injury Severity Score (ISS), Revised Trauma Score (RTS), and Trauma Score-ISS (TRISS), were calculated for the patients. Spearman's rank correlation coefficient test was applied to find the association between the independent variables. **Results:** A total of 285 patients with a mean age of  $33.37 \pm 15.29$  fulfilled the inclusion criteria, of which, 211 cases (74.0%) were male. Statistical analysis revealed that there was a correlation between TI and  $\text{HCO}_3$  level ( $P = 0.0001$ ,  $r = -0.37$ ) and also TI and BD ( $P = 0.0001$ ,  $r = -0.47$ ). Furthermore, there was an indirect correlation between AIS and ISS with  $\text{HCO}_3$  and BD levels and the direct correlation between RTS and TRISS with  $\text{HCO}_3$  and BD levels. **Conclusion:** It is likely that there is a statistical correlation, although weak, between TSSs with DMMs, including  $\text{HCO}_3$  and BD level.

**Keywords:** Acid-base imbalance, correlation of data, hemodynamic monitoring, trauma severity indices

## INTRODUCTION

Trauma is the most common cause of mortality in young and middle-aged patients worldwide.<sup>[1-4]</sup> Several trauma scoring systems (TSSs) have been developed for the classification of trauma patients, grading the severity of the injury, and predicting their outcomes. However, all these scoring systems have some limitations and none is useful for patient monitoring.<sup>[5-7]</sup> It is also well established that systolic blood pressure (SBP), heart rate (HR), shock index (SI), and urine output measurement are not adequate, although useful for appropriate monitoring.<sup>[8-12]</sup>

On the other hand, it was believed that acid–base balance may better reveal the ongoing situation of hemodynamic of such

patients. As recent studies have reported, dysoxia (abnormal tissue oxygen utilization) metabolism markers (DMMs), including serum bicarbonate ( $\text{HCO}_3$ ) and base deficit (BD) levels, could be considered as valuable markers to evaluate

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the actual tissue perfusion in shock state, although some controversies still exist.<sup>[13-17]</sup> BD refers to a deficit in the amount of base existing in blood, with positive numbers indicating an excess of base and negative a deficit. The normal values for BD are  $-2$  to  $+2$  mEq/L. It should also be mentioned that the typical reference range for  $\text{HCO}_3^-$  is  $22-26$  mmol/L.<sup>[18]</sup> The severity of metabolic acidosis is to predict the occurrence of organ failure, length of hospital stay, transfusion requirements, and mortality; normalization of them plays the role of an end-point in therapy or resuscitation.<sup>[19-21]</sup>

Recently, investigators have tried to modify the TSSs to improve their use.<sup>[22-24]</sup>

It was believed that major trauma may cause hypoperfusion could lead to tissue hypoxemia that is indicated as metabolic acidosis.  $\text{HCO}_3^-$  and BD are the markers to measure the tissue hypoxemia and metabolic acidosis. We have a hypothesis that adding DMMs to the current TSSs and developing modified scoring systems would be helpful in better monitoring of traumatic patients. For the first step in evaluating this hypothesis, we had a challenge whether there is a correlation between DMMs and TSSs or not. Although various studies addressed this subject, the controversial results necessitate further studies. Therefore, this study was designed and conducted to determine whether any correlation exists between DMMs, including venous BD and  $\text{HCO}_3^-$  level with different TSSs.

## MATERIALS AND METHODS

### Study design and population

This cross-sectional observational study was conducted between September 2014 and June 2015 in the emergency department (ED) of a level-1 trauma center in Tehran, Iran. All multiple trauma patients admitted to the ED over the age of 5 years were eligible. A diagnosis of “multiple trauma” implies the presence of two or more separate injuries, at least one or a combination of which endangers the patient’s life.<sup>[25]</sup>

Lack of required data for calculating TSSs or not requesting blood gas analysis by in-charge physicians was considered as excluding criteria. Patients with a major head injury, known acid–base disturbances, and those who received exogenous  $\text{NaHCO}_3$  before laboratory analysis or were pronounced dead on arrival were also excluded from this study. Based on the results of previous studies, assuming a 0.2 correlation between DMMs and TSSs in multiple trauma patients, and considering  $\alpha = 0.05$ ,  $\beta = 0.2$  for assessing this correlation, based on the correlation study formula, the least sample size was calculated as 250.

### Data gathering

The utility of vital signs, metabolic parameters, and different trauma grading systems to detect major injury was evaluated. All patients underwent initial triage using emergency severity index version-4 (ESI-4) and advanced trauma life support (ATLS) was applied for all. A 3<sup>rd</sup> postgraduate

year emergency medicine resident was responsible for data gathering and not interfering with patients’ management. Patients’ demographic information (age and sex), triage level, the mechanism of injury, physical exam findings, on-arrival vital signs (SBP, diastolic blood pressure [BP], HR, respiratory rate (RR),  $\text{O}_2$ -saturation, and calculated SI [defined as a ratio of HR to SBP]), whether transferred by emergency medical service (EMS) or not, and on-arrival Glasgow Coma Scale (GCS), were all documented in a preprepared checklist.

All vital signs were evaluated automatically using a monitoring device (SAADAT/ALBORZ-B9 [based on the device catalog, accuracy in measuring vital signs were as HR:  $-1\%$  or 2 BPM; BP:  $2\%$  or 2 mmHg; T:  $-0.2$  C; RR:  $\pm 2\%$  or 2 BrPM]).

Computed tomography scans pathologic findings, and report of performed surgery, if done, were all also reviewed. Thereafter, TSSs, including trauma index (TI), abbreviated injury score (AIS), Injury Severity Score (ISS), Revised Trauma Score (RTS), and Trauma Score-ISS (TRISS) were calculated for the patients. The exact score range of each scale and method of calculation are available through the link “<http://www.trauma.org/archive/scores/index.html>.”

A blood sample was obtained by the in-charge nurse from the patient for venous blood gas (VBG) analysis, and measured parameters (PH,  $\text{HCO}_3^-$ ,  $\text{PCO}_2$ , and BD) were also recorded in the checklist. VBG analyses were performed by an automated device (GEM Premier 4000 [with the accuracy of 99.2%]).

Following the established clinical practice guideline in the studied ED, the blood samples for VBG analysis were taken at the onset of the resuscitation process. The mentioned data were collected prospectively by an emergency medicine resident who is one of the coauthors of the present study.

### Statistical analysis

Values were expressed as frequency (number and percentage), mean and median (standard deviation [SD], and interquartile range) as appropriate. Shapiro–Wilks test and Q-Q plot were used to check the normality assumption for the variable; thus according to the establishment of assumptions, parametric or nonparametric test was done. Mann–Whitney U and Kruskal–Wallis tests were used to compare the numerical variables. Spearman’s rank correlation coefficient test was applied to find the association of independent variables.  $P < 0.05$  was considered as statistically significant. Statistical analyses were performed using the IBM SPSS software package, version 22.0, (SPSS Inc., Chicago, IL, USA).

### Ethics

The study methodology was approved by the Institutional Review Board and Ethical Committee of Tehran University of Medical Sciences and code IR.TUMS.REC.1394.2213 was assigned. The investigators did not interfere with patients’ management, and all required data were extracted from their files.

## RESULTS

### Demographic findings

A total of 285 patients with a mean age of  $33.37 \pm 15.29$  fulfilled the inclusion criteria, of whom, 74.0% were male. The demographic and baseline characteristics of studied patients are reported in Table 1. Based on the findings, motor vehicle collisions were the most prevalent cause of trauma ( $n = 109$ , 38.2%). The majority of patients ( $n = 202$ , 71.0%) were delivered to the hospital by the EMSs. The majority of patients had a GCS of 14–15 ( $n = 248$ , 87.0%)

**Table 1: The demographic and baseline characteristics of studied multiple trauma patients**

Variable	Value
Age (year), mean±SD	33.37±15.29
Sex, n (%)	
Male	211 (74.0)
Female	74 (26.0)
Mechanism of trauma, n (%)	
Car accident	46 (16.5)
Motorcycle accident	109 (39.2)
Pedestrian	91 (32.7)
Falling down	11 (4.0)
Rollover collision	20 (7.2)
Gunshot	1 (0.4)
Unknown cause	7 (2.4)
Transfer by EMS, n (%)	
Yes	202 (70.9)
No	83 (29.1)
Triage level, n (%)	
1	44 (15.4)
2	73 (25.6)
3	111 (38.9)
4	55 (19.3)
5	2 (0.7)
On-arrival vital signs, mean±SD	
SBP (mmHg)	115.63±21.09
DBP (mmHg)	73.02±11.77
HR (rate/min)	89.26±15.83
RR (rate/min)	19.19±5.17
O <sub>2</sub> saturation (%)	95.42±3.73
SI	0.30±0.812
On-arrival GCS, n (%)	
14-15	248 (87.0)
9-13	20 (7.0)
3-8	15 (5.3)
Missed	2 (0.7)
Outcome, n (%)	
Discharged from ED	144 (50.5)
Transferred to the operation room	65 (22.8)
Admitted in the ward	42 (14.7)
Admitted in the ICU	28 (9.8)
Expired	6 (2.1)

EMS: Emergency medical service, GCS: Glasgow Coma Scale, SD: Standard deviation, ICU: Intensive care unit, ED: Emergency department, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HR: Heart rate, SI: Shock index, RR: Respiratory rate

and most of them were classified as level 3 triage ( $n = 111$ , 38.9%). The majority of patients were discharged from ED ( $n = 144$ , 50.52%).

### Pivotal findings

The mean ± SD of each calculated TSSs and measured DMMs in studied patients are reported in Table 2. In all participants, the mean of TI was  $9.15 \pm 4.36$ . Calculated TSSs were not significantly different based on sex, mechanism of trauma, and transfer by EMS ( $P > 0.05$ ).

Figure 1 contains 15 graphs in five rows related to each TSS and three columns related to triage level, GCS, and outcomes of the studied patients. Based on the findings revealed in the graphs, calculated TSSs significantly differed based on the triage level, on-arrival GCS, and outcome ( $P < 0.001$ ); therefore, TI was expected to be higher in triage level 1, GCS <9 and dead patients.

Statistical analysis revealed that there was a correlation between TI and HCO<sub>3</sub> level ( $P = 0.0001$ ,  $r = -0.37$ ) and also TI and BD ( $P = 0.0001$ ,  $r = -0.47$ ). Furthermore, there were indirect correlations between AIS and ISS with HCO<sub>3</sub> and BD levels, and the direct correlation between RTS and TRISS with HCO<sub>3</sub> and BD levels [Table 3].

### Ancillary findings

Although weak, there was a statistical correlation between ESI and HCO<sub>3</sub> level ( $P = 0.02$ ,  $r = 0.19$ ) and ESI and BD ( $P = 0.0001$ ,  $r = 0.32$ ). In addition, a correlation was detected between ESI and length of hospital stay ( $P = 0.0001$ ,  $r = -0.42$ ) and hospitalization costs ( $P = 0.0001$ ,  $r = -0.52$ ). A correlation was also found between TI and length of hospital stay ( $P = 0.0001$ ,  $r = 0.33$ ) and hospitalization costs ( $P = 0.0001$ ,  $r = 0.44$ ).

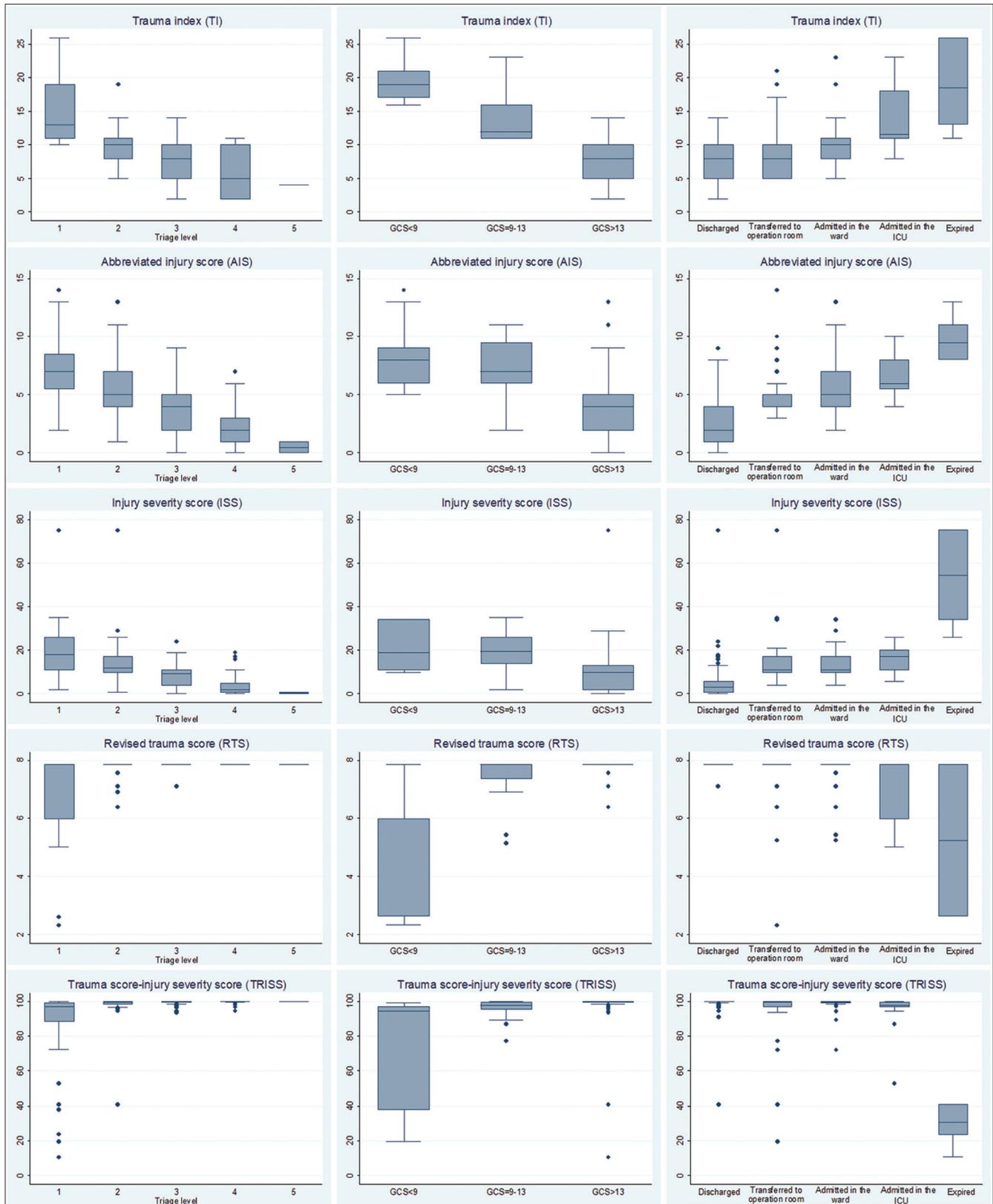
## DISCUSSION

This study was conducted to determine the correlation between

**Table 2: The mean±standard deviation of each calculated trauma scoring systems and measured dysoxia metabolism markers in studied multiple trauma patients**

Variable	Mean±SD
TSS	
TI	9.15±4.36
AIS	4.26±2.53
ISS	11.45±12.59
RTS	7.36±0.77
TRISS	95.79±13.44
VBG analysis parameters	
pH	7.35±0.09
HCO <sub>3</sub>	22.42±4.32
PCO <sub>2</sub>	40.05±8.53
BD	-2.07±4.80

SD: Standard deviation, TI: Trauma index, AIS: Abbreviated Injury Score, ISS: Injury Severity Score, RTS: Revised Trauma Score, TRISS: Trauma Score-ISS, VBG: Venous blood gas, HCO<sub>3</sub>: Serum bicarbonate, BD: Base deficit, TSS: Trauma scoring system



**Figure 1:** Distribution of trauma scoring systems in triage level, on-arrival Glasgow Coma Scale, and outcome in studied multiple trauma patients

DMMs, including venous BD and  $\text{HCO}_3$  level with different TSSs. The results of this study showed a relative correlation between TSSs with measured DMMs.

It was well demonstrated that major disturbances in acid–base balance should be diagnosed and managed immediately in critically ill or injured patients; and it was assumed that

**Table 3: Correlation of trauma scoring systems and measured venous blood gas analysis components in studied multiple trauma patients**

TSS	pH	PCO <sub>2</sub>	HCO <sub>3</sub>	BD
TI	-0.310*	-0.087	-0.371*	-0.476
AIS	-0.430*	-0.066	-0.383	-0.596
ISS	-0.427*	-0.022	-0.337	-0.533
RTS	0.224*	-0.002	0.285	0.364
TRISS	0.318*	0.060	0.296	0.430

\*Significant correlation coefficient in  $P < 0.001$  (two-tailed). TI: Trauma index, AIS: Abbreviated Injury Score, ISS: Injury Severity Score, RTS: Revised Trauma Score, TRISS: Trauma Score- ISS, BD: Base deficit, HCO<sub>3</sub>: Serum bicarbonate, TSS: Trauma scoring system

major traumatic events could start a process of physical and electrochemical functions that may result in acute changes of acid–base balance.<sup>[26]</sup> Accordingly, here, we discussed the current challenges regarding hemodynamic monitoring in multiple trauma patients and the possible role of HCO<sub>3</sub> and BD further in this regard.

Multiple variables such as evaluation of BD, lactate, anion gap and mixed venous oxygen saturation, and also the efficiency of modalities such as sublingual capnometry, gastric tonometry, transcutaneous oxygen, or carbon dioxide monitoring have been studied to determine the occurrence of tissue hypoperfusion and/or the acidosis.<sup>[27-30]</sup> But obviously, some of them do not apply to patients with trauma and some are more feasible to use. Albeit, there is continuing debate regarding the relative advantages and feasibility of each technique, especially in trauma patients.

The best marker must be precise, reliable, and cost-effective in terms of time and equipment and must be easily obtained. Modalities, such as orthostatic vital signs, capillary refill, and central venous oxygen saturation, have been used to identify low circulating blood volume, but several criteria, including age or gender may influence the results.<sup>[17,31]</sup>

A direct measure of systemic oxygen delivery and consumption had been conventionally evaluated through central cannulation as an invasive monitoring method. Central arterial/venous oxygen saturation and lactate are superior to BP, HR, and central venous pressure in evaluating and monitoring after trauma. However, central venous cannulation is not always practical and is not commonly performed in patients with normal vital signs.<sup>[13,17,19,31]</sup> On the other hand, pH and BD are the most frequently applied markers considered as indicators of anaerobic metabolism that have been used as an endpoint of resuscitation could easily and repetitively be available with a simple peripheral blood sampling for VBG analysis. By applying VBG evaluation, the risk of local arterial-related complications from arterial manipulation such as hand ischemia was eliminated.<sup>[20,21]</sup>

Several studies have demonstrated that the admission BD is a prognostic marker of morbidity and mortality in trauma patients and the normalization of which correlates with

enhanced outcomes.<sup>[30]</sup> According to the study of Paladino *et al.*, BD and lactate increase the ability to differentiate major from minor trauma if being added to triage vital signs.<sup>[17]</sup> The results of the study of Mutschler *et al.* revealed that BD may be superior to the current ATLS classification of hypovolemic shock in identifying the need for early blood product transfusion in patients with hypovolemic shock.<sup>[32]</sup> Similar results were obtained in the study of Kincaid *et al.* suggesting the correlation between a steadily high arterial BD and distorted oxygen utilization, elevated risk of multiple organ failure, and mortality in trauma patients.<sup>[33]</sup> Accordingly, it was recommended that serial monitoring of BD may be a practical method in evaluating the sufficiency of resuscitation. Mofidi *et al.* suggested that BD can be applied as an early accessible indicator of intra-abdominal injury and a high transfusion requirement in patients with blunt abdominal trauma.<sup>[34]</sup> Schmelzer *et al.* demonstrated that central venous BD was a more accurate predictor of survival compared to arterial BD that may be due to the fact that venous blood reflects systemic effects of shock; whereas the arterial BD imitates ventilation and oxygenation deficits.<sup>[35]</sup> Similarly, VBG analysis was performed in the current study to evaluate acid–base parameters and different trauma scores.

Serum HCO<sub>3</sub> measurement may be an accurate and reliable substitute for the arterial BD evaluation. The study conducted by Martin *et al.* showed that serum HCO<sub>3</sub> assessment provides an equal information to the arterial BD and may be applied as a substitute marker.<sup>[36]</sup> In the present study, admission parameters that may affect the outcome of trauma patients were evaluated and showed that TSSs were statistically but weakly correlated with HCO<sub>3</sub> level.

The TSSs may be applied as important determinants of clinical outcome in critically injured patients and may be safely and reliably substituted with previously applied measurement techniques for trauma patients. However, considering the fact that trauma is multi-factorial in origin, these modalities should not be replaced with a total evaluation of the critically traumatized patient. HCO<sub>3</sub> alternation may precisely identify metabolic acidosis that demands prompt assessment and immediate interventions. There is a strong correlation between a steadily altered BD and altered oxygen consumption, extravascular fluid appropriation, and an increased risk of mortality in severely injured trauma patients. Therefore, an insight into the sufficiency of therapy may be provided by serial monitoring of BD. Along with a total assessment of the trauma patient, correction of BD may be associated with improved cellular oxygen applied that may be one of the suitable goals of resuscitation.

### Limitations

The current study has several limitations. In spite of strong and reliable correlation found between TI with HCO<sub>3</sub> level and BD in the whole population, this relationship may be varied or even invalid on an unidentified subgroup of patients. For example, considering the age limit and some other baseline characteristics would be interfering with the results. This article would be

suitable as a pilot study on this challenging topic to attract the attention of other researchers to make better studies on this topic.

## CONCLUSION

Based on our findings, it is likely that there is a statistical correlation between TSSs with DMMs, including HCO<sub>3</sub> and BD level. There was an indirect correlation between TI, AIS, and ISS with HCO<sub>3</sub> and BD levels and the direct correlation between RTS and TRISS with HCO<sub>3</sub> and BD levels.

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## Conflicts of interest

There are no conflicts of interest.

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