Original Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)

Med J Islam Repub Iran. 2024 (1 Jul);38.74. https://doi.org/10.47176/mjiri.38.74

Determining Predictive Power of Base Excess in Comparison with SOFA Score for Predicting Mortality in ICU Patients

Omid Moradi Moghaddam[1,2], Mohammadjavad Gorjizadeh[2], Mohsen Sedighi[1], Alireza Amanollahi[1], Ali Khatibi[2], Mohammadreza Ghodrati[2], Mohammad Niakan Lahiji[1,2]*

Received: 28 Feb 2024 Published: 1 Jul 2024

Abstract

Background: Acid-base disturbances are frequently found in intensive care unit (ICU) patients. Base excess (BE) is commonly used to quantify the degree of metabolic impairment. We aimed to compare the predictive value of BE and Sequential Organ Failure Assessment (SOFA) score for mortality in ICU patients.

Methods: This prospective and observational investigation was performed on 87 ICU patients who underwent mechanical ventilation. SOFA score and acid-base variables at 6 hours of ICU admission were analyzed and compared between survivors and non-survivors. Receiver-operating characteristic (ROC) curve was applied to analyze the predictive value of BE and SOFA for mortality.

Results: Mean age of patients was 63.91±5.03 years, and 60 (69%) were male. The non-survived patients had significantly higher SOFA ($P = 0.001$) and APACHE II scores ($P = 0.001$). The non-survived patients had a lower bicarbonate ($P = 0.002$), PO_2 ($P = 0.001$), pH ($P = 0.0021$), and a higher PCO_2 ($P = 0.001$) compared with survivors, and most patients who died (80%) had a low BE value (< -2) ($P = 0.002$). The estimated AUC of SOFA and BE was 0.83 (95% CI, 0.73 - 0.92) and 0.71 (95% CI, 0.57 – 0.85), respectively.

Conclusion: BE is, to some extent capable of predicting mortality in ICU patients. However, the SOFA score is a more accurate and reliable parameter in comparison to BE for prediction.

Keywords: SOFA, Base Excess, Intensive Care, Mortality

Conflicts of Interest: *None declared*
Funding: *None*

Cite this article as: Moradi Moghaddam O, Gorjizadeh M, Sedighi M, Amanollahi A, Khatibi A, Ghodrati M, Niakan Lahiji M. Determining Predictive Power of Base Excess in Comparison with SOFA Score for Predicting Mortality in ICU Patients. *Med J Islam Repub Iran.* 2024 (1 Jul);38:74. https://doi.org/10.47176/mjiri.38.74

Introduction

Mortality prediction in hospitalized patients in the intensive care unit (ICU) is necessary for planning treatment approaches, making decisions, and also for support and advice to the patient's family (1). Acid-base status has been considered as a parameter for mortality prediction in different subgroups of ICU patients (2, 3). Base excess (BE) is defined as the acid or alkali amount that is required to adjust the pH value to the normal range and considered as one of the parameters reflecting a disturbance in the acid-base balance (4, 5). Moreover, metabolic acidosis at ICU admission and early pH changes are shown to be correlated with higher mortality in critically ill patients (6, 7).

The SOFA (Sequential Organ Failure Assessment) score is widely used in the daily monitoring of acute morbidity to measure organ dysfunction/failure over time and predict short-term mortality in patients admitted to the ICUs (8, 9). In the clinical setting, blood biomarkers can be diagnostic and prognostic values and help physicians make decisions about the appropriate treatment course to take (10, 11). It has been documented that BE and lactate or a combination

Corresponding author: *Dr Mohammad Niakan Lahiji, niyakanlahiji.m@iums.ac.ir*

1. Trauma and Injury Research Center, Iran University of Medical Sciences, Tehran, Iran
2. Department of Anesthesiology and Critical Care, School of Medicine, Iran University of Medical Sciences, Tehran, Iran

↑What is "already known" in this topic:
The SOFA score is widely used in the daily monitoring of acute morbidity and predicting short-term mortality in ICU patients. Also, acid-base status has been considered as a parameter for mortality prediction in different subgroups of ICU patients.

→What this article adds:
BE could predict mortality in ICU patients to some extent. However, the SOFA score is a more accurate and reliable parameter for predicting mortality in ICU.

of both can be used to predict outcomes in patients admitted to ICU (12). We therefore aimed to assess the predictive value of BE for mortality to compare with SOFA in ICU patients.

Methods

Study Design and Ethics

This prospective and observational study was carried out on 87 ICU patients who underwent mechanical ventilation. The protocol of investigation was reviewed and approved by the Medical Research Ethics Committee (IR.IUMS.FMD.REC.1399.568), and written informed consent was obtained from participants. Inclusion criteria were age older than 18 years and patients with at least 5 days of ICU stay. Patients with hypercalcemia (blood Ca >10.8 mg/dL), cirrhosis, HIV or HCV infection, kidney dialysis, and those who were hospitalized in ICU for postoperative care were excluded from the study. All participants were followed until discharge from the ICU or death, whichever happened earlier for measuring clinical outcomes. The required sample was 87 patients based on a type I error of 10%, power of 96%, and 65.4% mortality in the Samanta et al. study (13).

Data Collection

All included patients were mechanically ventilated by admission to the ICU and received intravenous propofol at the dose of 25-50 µg/kg/min for sedation under a ventilator machine. SOFA score was determined and arterial blood gas (ABG) was analyzed in a varied blood gas analyzer (Techno Medica, GASTAT 700 series, Yokohama, Japan) to determine pH, $PaCO_2$, bicarbonate, PO_2, and BE at 6 hours of admission. Demographic and clinical data from patient's medical documents were recorded. Study variables were classified as outcome (mortality in ICU), exposures (BE and SOFA score), and independent variables (age, gender, Acute Physiology and Chronic Health Evaluation (APACHE II), cause of admission to ICU).

Statistical Analysis

Continuous data was compared by student's t-test, and categorical data was analyzed by Fisher's exact test between survivors and non-survivors. The receiver-operating characteristic (ROC) curve was utilized to analyze the predictive value of BE and SOFA for mortality in ICU patients. Potential confounding variables were age, gender, and ABG parameters since they influenced the outcome. Results with $P < 0.05$ were considered to be statistically significant. All statistical tests were done using IBM, SPSS version 26 (SPSS Inc., Chicago IL, USA).

Results

From a total of 87 patients, 60 (69%) were male, and the mean age of patients was 63.91±5.03 years. The most frequent illnesses for which patients were admitted to ICU were respiratory disease (31%) and heart failure (24%) followed by renal failure (17%), coagulopathy (15%), and liver disease (13%). Finally, 15 patients (17%) died and 72 patients (83%) survived and were transferred from ICU to general ward.

Table 1 represents a comparison of demographic and clinical data between non-survivors and survivors. The non-survived patients had significantly higher SOFA (P = 0.001) and APACHE II scores (P = 0.001). Regarding ABG parameters, patients who died had a lower bicarbonate (P = 0.002), PO_2 (P = 0.001), pH (P = 0.0021), and a higher

Table 1. Baseline characteristics of the study population (n=87)

Variable	Survivors (n=72)	Non-survivors (n=15)	*P* value
Age (years) [a]	64.08±5.02	63.07±5.14	0.479
Gender (n,%) [b]			
Male	50 (69%)	10 (67%)	0.832
Female	22 (31%)	5 (33%)	
BMI [a]	25.50±1.91	25.80±1.89	0.582
SBP (mmHg)[a]	122.90±17.25	130.40±18.95	0.136
DBP (mmHg)[a]	78.14±9.50	83.80±15.24	0.065
MPA (mmHg)	93.06±10.39	99.33±15.76	0.057
HR (bit/min)[a]	82.78±12.59	83.73±12.86	0.791
SOFA score [a]	9.83±3.82	15.26±2.28	0.001
APACHE II [a]	15.06±5.11	20.66±4.92	0.001

Abbreviations: ICU, intensive care unit; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; SOFA, sequential organ failure assessment; APACHE, Acute Physiology and Chronic Health Evaluation; BE: base excess.
[a] Continues data are presented as mean ± SD.
[b] Categorical data are presented as frequency (percentage).

Table 2. Comparison of BE and blood gas parameters in the study population (n=87)

Variable	Survivors (n=72)	Non-survivors (n=15)	*P* value
pH value [a]	7.38±0.71	7.24±0.10	0.001
BE (n,%) [b]			
> +2	37 (51%)	3 (20%)	
-2 to +2	13 (18%)	0	0.002
< -2	22 (31%)	12 (80%)	
Bicarbonate [a]	22.69±1.58	21.07±2.40	0.002
PO_2 [a]	187.33±10.86	169.07±12.39	0.001
PCO_2 [a]	36.47±4.68	43.14±7.51	0.001

BE: base excess. [a] Continues data are presented as mean ± SD. [b] Categorical data are presented as frequency (percentage).

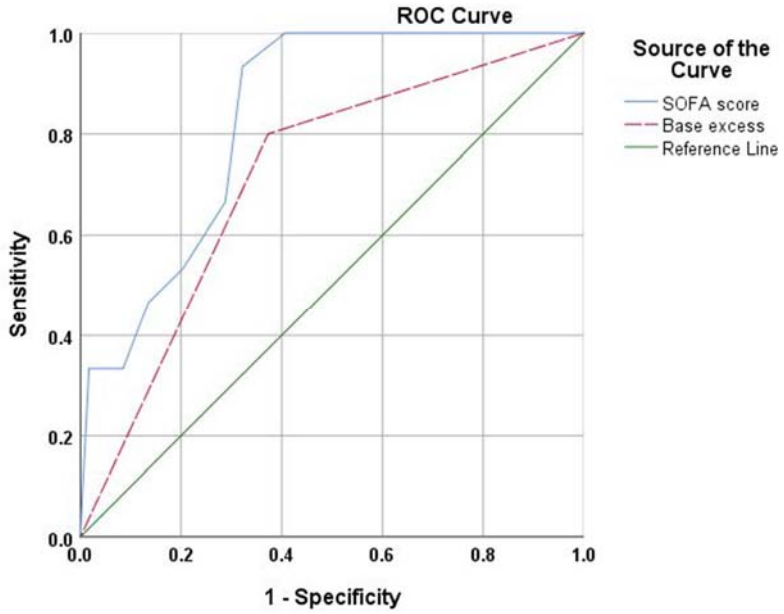

Figure 1. ROC curve of BE and SOFA to discriminate mortality in ICU patients

Table 3. Comparison of SOFA and BE for mortality prediction in ICU patients at admission time

Variable	AUC	P value	Sensitivity	Specificity	PPV	NPV
SOFA	0.83	0.001	100%	18%	20.3%	100%
BE	0.71	0.011	100%	66.7%	38.5%	100%

Abbreviations: AUC, area under the curve; BE: base excess; ICU, intensive care unit; NPV, negative predictive value; PPV, positive predictive value; SOFA, sequential organ failure assessment.

PCO_2 (P = 0.001) when compared with survived patients. Also, most of the patients in the non-survived group (80%) had a low BE value (< -2) at baseline (P = 0.002) (Table 2). AUCs indicated that BE and SOFA score's discrimination for mortality in ICU was good (Figure 1). By cutoff point 11.5, the SOFA score showed 100% sensitivity and 67% specificity with an AUC of 0.83 (95% CI, 0.73 - 0.92, P = 0.001). Also, BE could discriminate the mortality in ICU patients by 100% sensitivity and 82% specificity with an AUC of 0.71 (95% CI, 0.57 - 0.85, P = 0.011) (Table 3).

Discussion

The present study evaluated the predictive value of BE at 6 hours of admission for mortality in ICU patients. About 80% of non-survived patients had metabolic acidosis (BE < -2). However, the BE value was not superior to SOFA for the prediction of mortality in ICU patients (ROC-AUC of 71% vs 83%). Numerous clinical investigations have used a variety of tools, including SOFA, APACHE II, and ABG parameters, for the prediction of mortality and identification of patients at risk of deterioration (2). The BE value on ICU admission is reported as a great indicator for predicting clinical outcomes in patients, and a continuously negative or increasingly negative BE value can prognosticate mortality and shock-related events such as renal failure, respiratory distress, acute lung injury, and multiple organ failure (4). In the current investigation, we detected that ICU patients with metabolic acidosis resolution (BE < -2) had higher mortality. Also, the pH was significantly lower in non-survivors than survivors and had higher ICU severity scores (APACHE II and SOFA). Consistent with us, Samanta et al. reported that metabolic acidosis is related to a higher mortality in ICU and the rate of change in pH could be a better predictor for mortality in ICU than other metabolic indicators (13).

Our investigation is limited by the single-center design and small sample size of participants. Moreover, ABG errors during blood sample withdrawal, collection, transportation, and analysis were not considered in this study. This study also evaluated only the baseline BE value; hence, we could not assess the influence of dynamic changes in the BE parameter on the survival endpoint.

Conclusion

Our findings in this study showed that BE is, to some extent capable of predicting mortality in ICU patients. However, the SOFA score is a more accurate and reliable parameter in comparison to BE for prediction.

Authors' Contributions

Omid Moradi Moghaddam and Mohammad Niakan Lahiji conceived and designed the study protocol; Mohammadjavad Gorjizadeh, Ali Khatibi, and Mohammadreza Ghodrati contributed to data collection and execution of experimental tests; Alireza Amanollahi performed statistical analysis; Mohsen Sedighi wrote the manuscript draft and

also contributed to the creation of the tables; Mohammad Niakan Lahiji, contributed to the critical revision of the article.

Ethical Considerations

This research was designed with the approval of the Research Ethics Committee of Iran University of Medical Sciences, Iran, with the number IR.IUMS.FMD.REC. 1399.568.

Acknowledgment

Declared none.

Conflict of Interests

The authors declare that they have no competing interests.

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