ORIGINAL ARTICLE

Mortality prediction models for severe burn patients: Which one is the best?

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ABSTRACT

BACKGROUND: For prediction of mortality and clinical course, various scoring systems had been developed. We choose four well known burn specific scoring systems and a general scoring system that using in Intensive Care Units. The primary outcome of this study was evaluate the predictive performances of this models and define the optimal one for our patient population.

METHODS: Variables analyzed were age, gender, burn type, total burned surface area (TBSA), total partial thickness burn area, total full thickness burn area, inhalation injuries, mechanical ventilation supports, blood products usage, total scores of Abbreviated Burn Severity Index (ABSI), revised Baux, Belgian Outcome in Burn Injury, Fatality by Longevity, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Measured Extent of burn and Sex (FLAMES) and APACHE II, and their relations with mortality.

RESULTS: In our study, a statistically significant relationship was found with mortality between age, TBSA, full thickness burn percentage, inhalation injury, burn type, and it was similar to literature. Female gender was found to be a significant risk factor for mortality.

CONCLUSION: We compared several burn mortality scoring systems and their predictional mortality rates. ABSI scores of patients for estimated mortality rates were similar to our mortality rate. Consequently, it was thought that ABSI was included all mortality-related parameters.

Keywords: ABSI; BAUX; BOBI; burn; FLAMES; mortality; scoring systems.

INTRODUCTION

Despite all advances in treatment algorithms and surgical techniques, burn injuries continue to cause severe mortality and morbidity. Especially in developing countries, as it affects the young and working population, it causes a severe loss both medically and labor and cost. According to the American Burn Associations' latest data, 486,000 burn cases occurred in the United States of America in 2016, and 3275 of them resulted in death.[1] In this respect, predicting the possibility of mortality and morbidity, especially in severe burn patients, will provide serious advantages to clinicians both in the follow-up and in informing families.

There are various factors associated with mortality in the literature in patients with severe burns followed in the burn intensive care unit. Especially age, Total Burned Surface Area (TBSA), presence of 3rd-degree burns, and inhalation injury are thought to increase mortality seriously. For predicting mortality, various scoring systems have been developed. The purpose of the development of these scoring systems is to guide clinicians about the clinical course of the patient and possible mortality-morbidity with the values determined at the burn patients' hospitalization. Therefore, the scoring system chosen should be easy to use and should yield similar results when applied in different centers. The mainly used scoring systems in the literature were designed in developed countries. However, there were few studies about the results of their use in developing countries. In our study, the relation of the scores of the four major burn scoring systems with mortality, Abbreviated Burn Severity Index (ABSI), revised Baux, Belgian Outcome in Burn Injury (BOBI), Fatality by Longevity, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Measured Extent of burn and Sex

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(FLAMES) and APACHE II, and the comparison of predicted mortality with the observed mortality was examined.

MATERIALS AND METHODS

University of Health Sciences Izmir Bozyaka Training and Research Hospital Burn Treatment Center, as the only burn treatment center in Western Turkey, undertakes the treatment of burn patients of a huge population. In our study, the data of all burn patients hospitalized in the Burn Treatment Center Intensive Care Unit between January 2016 and May 2019 were retrospectively analyzed. Three of the 385 patients were isolated carbon monoxide poisoning and excluded from the study due to the absence of burn wounds on the body surface. The age, sex, TBSA, burn depth (partial thickness burn-full thickness burn), burn types under four groups (flame [thermal injury], electricity, scalding, and chemical), presence of inhalation damage, and blood transfusion data of the 382 patients in total, with the APACHE II, FLAMES, BOBI, ABSI, and rBAUX scores at the time of admission were retrospectively determined. Their relationship with mortality was examined. To determine inhalation damage, history of burn (fire in a closed area, inhalation of chemical gasses, etc.), clinical findings such as burned nasal hair or carbonic crum in the oral cavity, coarsed noise evaluated, also an endoscopic larynx examination was performed. TBSAs of the patients were calculated according to the Lund-Browder scheme. Fluid resuscitations were adjusted according to the sufficient urine output (0.5 cc/hour) after the first 24 h was calculated with the Parkland formula.

This study was approved by the Ethics Committee of the University of Health Sciences, Izmir Bozyaka Training and Research Hospital (decision date: 11.09.2019 no: 7).

Based on the scores of the mortality scoring systems, estimated mortality predictions were calculated following the original literature:

APACHE II

This prediction system, which was defined by revising APACHE in 1984, is still used in intensive care units to determine the physiological status of patients.[2] It consists of 12 different parameters and is obtained the data within the first 24 h. The disadvantage is that it is not specific to burn patients and is difficult to calculate.

BAUX

BAUX while the BAUX scoring system, when it was first defined in 1961, it only included the burned surface area and age criteria, was revised in 2010 and took its final form with the addition of inhalation damage. BAUX score: Age + TBSA + 17 * (If there is inhalation damage). Estimated mortality values are calculated according to the BAUX score.[3]

BOBI

It was developed by six different burn treatment centers in Belgium to predicting mortality.[4] It also includes TBSA, age, and inhalation injury and uses them for prediction. Its difference from BAUX that it has cut-off values for each parameter, and it has prediction values for each of them.

FLAMES

That prediction model is a combination of APACHE II score, TBSA, age, and sex.[5] The model uses each parameter crossing with a constant value to find the FLAMES score. Using this score, we get the predicted mortality values of burn patients.

ABSI

This index was published in 1982.[6] The model considers TBSA, age, sex, presence of inhalation injury, and presence of full-thickness burns. All factors give points to calculate the total ABSI score. The total scores resulting in six categories and gives us the probability of survival for each category. Prediction formulas of all scoring systems are shown in Table 1.

SPSS version 24.0 (Spss inc. IBM, Chicago, US) was used for statistical analysis. Mean, median, standard deviation, and min-max values were used for descriptive data. The stu-

Table 1. Mortality prediction formulas of scoring systems

APACHE II	Probability of Death = $e^{Logit}/(1+e^{Logit})$
	Logit = -3.517+(Apache II) * 0.146
Revised BAUX	Probability of Death = e-8.8163+(0.0775*rBaux) / 1 + e-8.8163+(0.0775*rBaux)
BOBI	Probability of Death = ex/1+ex
	Formula: X = -6.3303 + 0.048*age + 0.0691*TBSA +1,1691*inhalation injury
ABSI	Probability of Death = $1/1+e^{-2s}$
	S = B0 + B1 x (ABSI Score)
FLAMES	Probability of Death= $e^{(FLAMES)}/(1 + e^{(FLAMES)})$

APACHE II: Acute Physiology and Chronic Health Evaluation II; BOBI: Belgian Outcome in Burn Injury; ABSI: Abbreviated Burn Severity Index; FLAMES: Fatality by Longevity, APACHE II score, Measured Extent of burn and Sex; TBSA: Total Burned Surface Area.

dent's t-test was used for the analysis of continuous quantitative variables, and the Mann–Whitney U test was used for non-parametric data analysis. The χ^2 test was used to compare qualitative data. Receiver Operator Characteristics (ROC) analysis was performed to determine the determinant power of scoring systems on mortality. Area under the curve (AUC) was used to determine false positives and negativities. AUC values greater than 0.9 were evaluated as a high accuracy rate, between 0.7 and 0.9 as a medium degree, between 0.5 and 0.7 as low accuracy value, and below 0.5 as unexpected findings.

RESULTS

The median age of 382 patients was 40 (11–99), 79 (21%) of them were female. The median TBSA of patients was 26% (0–100). The inhalation injury rate of patients was 19% (n=72). Burn types were divided into four groups, and the most common type of burn was fire injuries (69%). There were 105 mortalities (27.5%). Predicting factors were examined under two categories: survivors and non-survivors. As expected before, the non-survivors group had older median age (57 vs. 36), greater TBSA (52% vs. 20%), and a higher inhalation injury rate (45% vs. 9%). Although there was no statistically significant difference between the two groups' partial thickness burned area, the non-survivors group had a higher full-thickness burned area: 10% (0–62) versus 36% (4–100) (p<0.001). Fire injuries had a statistically significant higher risk for mortality (p<0.001). We used blood products more often than non-survivors (45%). A total of 100 patients needed mechanical ventilation support, and only 8 (8%) of them survived (Table 2).

All five mortality prediction models had a higher score for the patients who were non-survivors, as expected (Table 3). To determine predictive performances, a ROC curve

Table 2. Patient demographics and comparison of burn characteristics between survivors and non-survivors

	Total (n=382)	Survivors (n=277)	Non-Survivors (n=105)	p
Age (years) (Median)	40 (11–99)	36 (11–85)	57 (16–99)	<0.001
Gender F/M, n (%)	79 (21)/303 (79)	41 (52)/236 (78)	38 (48)/67 (22)	<0.001
Burn type				
Fire (%)	(n=265) (69)	174 (65)	91 (35)	<0.001
Electrical (%)	(n=72) (19)	64 (89)	8 (11)	
Scaled (%)	(n=34) (9)	28 (83)	6 (17)	
Chemical (%)	(n=11) (2)	11 (100)	0	
TBSA % (Median)	26 (0–100)	20 (1–82)	52 (5–100)	<0.001
Inhalation injury (%)	72 (19)	25 (9)	47 (45)	<0.001
Burn depth (Median) (Min-Max)				
Partial-Thickness (%)	16 (1–82)	16 (1–82)	23 (1–72)	0.343
Full-Thickness (%)	15 (0–100)	10 (0–62)	36 (4–100)	<0.001
Blood transfusion (%)	76 (20)	29 (12)	47 (45)	<0.001
Mechanical ventilation** (%)	100 (26)	8 (2)	92 (81)	<0.001

TBSA: Total burned surface area. **Mechanical ventilation support minimum 24 hours.

Table 3. Prediction models' comparison between survivors and non-survivors

Total (n=382)	Survivor (n=277)		Non-Survivor (n=105)		p
Scores	Mean±SD	Median (Min-Max)	Mean±SD	Median (Min-Max)	
APACHE II	9.57±4.36	9 (2–38)	17.1±6.2	16 (6–33)	<0.001
FLAMES	-4.2±1.9	-4.4 (-7.9–8.6)	0.9±2.8	0.5 (-4.5–8.4)	
BAUX	62.4±21.8	62 (17–164)	115.7±26.6	112 (44–189)	
BOBI	1.2±1.3	1 (0–7)	4.5±2	4 (1–10)	
ABSI	5.9±1.8	6 (2–16)	10.7±2.3	11 (5–17)	

APACHE II: Acute Physiology and Chronic Health Evaluation II; BOBI: Belgian Outcome in Burn Injury; ABSI: Abbreviated Burn Severity Index; FLAMES: Fatality by Longevity, APACHE II score, Measured Extent of burn and Sex; TBSA: Total Burned Surface Area; SD: Standard deviation.

Table 4. Receiver operating characteristic curve analyzes

	Sensivity	Specifity	AUC±SE	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
APACHE II	0.72	0.83	0.86±0.02	0.82	0.90
FLAMES	0.89	0.87	0.95±0.01	0.93	0.97
BAUX	0.91	0.85	0.94±0.01	0.92	0.97
BOBI	0.87	0.85	0.91±0.01	0.88	0.94
ABSI	0.95	0.80	0.94±0.01	0.92	0.97

APACHE II: Acute Physiology and Chronic Health Evaluation II; BOBI: Belgian Outcome in Burn Injury; ABSI: Abbreviated Burn Severity Index; FLAMES: Fatality by Longevity, APACHE II score, Measured Extent of burn and Sex; TBSA: Total Burned Surface Area; AUC: Area Under the Curve; SE: Standart eror.

analysis was performed to calculate the discriminative values (Fig. 1). All four burn-specific prediction models were shown high accuracy with AUC over 0.9. FLAMES score had the highest AUC of 0.95±0.01, followed by both ABSI and rBAUX scores with an AUC of 0.94±0.01. BOBI model had the lowest AUC of 91±0.01. APACHE II score, that the only predicting model for general ICUs, had moderate accuracy with an AUC of 0.86±0.02 to discriminate mortality of burn patients (Table 4).

Based on the original cohort, estimated mortality predictions for each scoring model were calculated. APACHE II gave the most different result for mortality prediction, as expected. ABSI model predicted mortality the most similar to observed mortality (28.9%). FLAMES, rBAUX, and BOBI estimated lower mortality rates than the observed mortality. Only ABSI had no statistically significant difference with observed mortality (p=0.342). All three burn-specific models and APACHE II's prediction had a statistically significant difference (p<0.001) (Table 5).

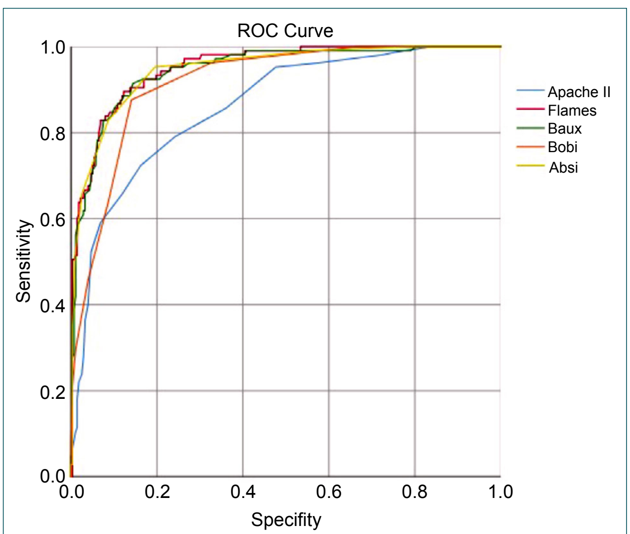

Figure 1. Receiver operating characteristic curves for prediction models.

Table 5. Mortality predictions of scoring systems and comparison with observed mortality

n=382	Prediction of mortalitiy		p-value
	Mean (%)	Median (min-max)	
APACHE II	16.9	11.3 (3.8–88.4)	<0.001
FLAMES	19.8	2.7 (0.03–99.9)	
BAUX	17.8	4 (0.05–99.7)	
BOBI	23	9.5 (0.4–98.9)	
ABSI	28.9	20 (1–100)	0.342
Observed mortality: %27.5.			

APACHE II: Acute Physiology and Chronic Health Evaluation II; BOBI: Belgian Outcome in Burn Injury; ABSI: Abbreviated Burn Severity Index; FLAMES: Fatality by Longevity, APACHE II score, Measured Extent of burn and Sex.

DISCUSSION

Although many studies were comparing scoring models used for mortality prediction in burn patients, their superiority to each other could not be clearly demonstrated. With the common consensus in the literature, age and TBSA are used as mortality factors in all models. The models' differences are the presence of 3rd-degree burns, the presence of inhalation injury, and sex parameters. Therefore, in the study, we aimed to explain the estimated mortality expectation differences between the models by revealing the mortality relations of these parameters containing differences.

The mortality number observed in patients hospitalized in the Burn Intensive Care unit included in the study was 105 (27.5%). There are studies in which the mortality rate is similar, as well as studies in which it is lower and higher.[7,8] Similar to all the literature, in our study, a statistically significant relationship was found between age and mortality (p<0.001).[9,10] This result supports that age should be included in scoring models. There is a consensus that TBSA is also associated with mortality.[11,12] The inhalation injury rate is 18.8% (72)

of our patients and this is similar to the literature.[13] Burn patients with inhalation injury were statistically significantly higher than patients without mortality (p<0.001). It has been shown in almost all studies that the presence of inhalation damage is associated with mortality.[14,15] In our study, the relationship of full-thickness burns with mortality was determined, and there are studies with similar findings.[16] There is no consensus in the literature regarding the gender-mortality relationship. There are studies showing that there is no significant relationship between sex and mortality, as well as studies showing that female sex is a risk factor.[17,18] Some studies fought that the height of estrogen or the amount of adipose tissue in female sex may be factors that increase mortality.[19,20] When the distribution of burn types was examined, the flame burn was the most common (69%), and flame burns were found to have the highest mortality rates (p<0.001). Although a significant relationship was demonstrated with mortality in patients who received a blood transfusion and mechanical ventilator support (p<0.001), these parameters were thought to be a part of the treatment, not a mortality factor in patients with severe burns.

All prediction models were found to be significantly associated with mortality. There was a statistically significant difference between the scores of the surviving and non-living patients (p<0.001). FLAMES was demonstrated as the model with the highest AUC value, with 0.95 (±0.01). This number is similar to the original and different publications.[5,21] ABSI and rBAUX were the models with the highest AUC value (0.94±0.01) after FLAMES. For ABSI, our data had a higher AUC value than other studies in the literature.[22,23] Like Osler et al.,[3] where the original BAUX was revised in 2010, there were studies with similar results.[21] However, there were also publications achieving lower AUC values.[24] For BOBI, it was Blot et al.[4] where it was first published. For BOBI, the result was lower than the AUC value obtained in the first Blot et al.[4] study. It was thought that the mean TBSA value was only of 11% and the mortality rate 4.3% of burn patients in this study, might cause this difference. The lowest AUC value in the study was APACHE II's. Although it is not specific for burn patients, the value of 0.86±0.02 shows that APACHE II can give us important data about patients' physiological status with severe burns.

Among the all mortality prediction models, only ABSI predicted the best estimated mortality, which would not have a significant difference with the observed mortality. ABSI includes gender, full-thickness burns, and female gender parameters that are not common to all other scoring systems. All these three data show a statistically significant relationship with mortality in our patient population. Starting from this, the determination of ABSI as the model with the strongest mortality prediction overlaps with our data. The BOBI model was the model that predicted the most similar estimated mortality after ABSI. Although the burn cases in the original cohort were different from the population in this study, it can be thought that it predicted better mortality rates than expected. The lack of gender parameters may have been effective in this model's different results. Despite the high predictive results in the original cohort, we had calculated an estimated 19.8% mortality prediction for FLAMES. Adding the male sex as a risk factor may be one of the reasons for the difference. However, we thought that the main reason for this difference is that inhalation injury was not used in the model. In addition, the fact that FLAMES gives this different result despite the high values in the ROC curve, a need for re-evaluation within the scope of the estimated mortality formula can be reviewed. rBAUX was found to be the most different predictor of mortality among burn specific models with the observed value. It was thought that the fact that full-thickness burns were not considered separately and the absence of a sex factor might lead to this result for rBAUX.

Limitations

There were a few limitations to this study. First, this was a retrospective study with the samples of a single Burn Treatment Center. In addition, only cases that were treated in BICU were used to find the results of all mortality prediction models. So, this might affect the models' prediction values. Nevertheless, this study could be a guide for following multicenter prospective studies.

Conclusion

Despite many studies, a consensus could not be reached regarding the advantages of mortality scoring models over each other. According to the results in the literature, it has been observed that the parameters excluding TBSA, age, and inhalation damage, may differ depending on the centers' patient population. ABSI system was the most useful predicting model for our patient group that seemed in the current study. Therefore, it will be more beneficial to decide on the best model for predicting their patients' clinical status.

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Ethics Committee Approval: This study was approved by the İzmir Bozyaka Training and Research Hospital Clinical Research Ethics Committee (Date: 11.09.2019, Decision No: 07).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Ciddi yanık hastalarında skorlama modellerinin kullanımı: Hangisi en iyisi?

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AMAÇ: Ciddi yanık hastalarında klinik gidişi ve mortaliteyi öngörebilmek için çeşitli skorlama sistemleri geliştirilmiştir. Yaygın kullanılan dört yanık skorlama sistemi ile, bir tane yoğun bakım üniteleri için kullanılan genel skorlama sistemi seçerek, bu modellerin mortalite öngörme performanslarının karşılaştırılması amaçlanmıştır.

GEREÇ VE YÖNTEM: Hastaların yaş, cinsiyet, yanık tipi, toplam yüzey yanık alanı (TYYA), toplam kısmi kalınlıktaki yanık alanı, toplam tam kat yanık yüzey alanı, inhalasyon hasarı, mekanik ventilatör desteği gereksinimi, kan ürünü replasmanı, Abbreviated Burn Severity Index (ABSI), revised Baux, Belgian Outcome in Burn Injury (BOBI), Fatality by Longevity, APACHE II score, Measured Extent of burn and Sex (FLAMES) and Acute Physiology and Chronic Health Evaluation II (APACHE II) skorları ve bunların mortalite ile ilişkileri incelendi.

BULGULAR: Çalışmamızda, yaş, TYYA, tam kat yanıklar, inhalasyon hasarı, yanık tiplerinden alev yanığının, literatür ile benzer şekilde mortalite ile istatistiksel olarak anlamlı ilişkisi tespit edildi. Kadın cinsiyet, mortalite için anlamlı risk faktörü olarak tespit edildi.

TARTIŞMA: Skorlama sistemlerinin tahmin güçlerini karşılaştırdığımızda, ABSI skorunun tahmin ettiği mortalite rakamı, gözlemlenen mortalite ile en yakın olan olarak tespit edildi. Bunun da, yalnızca ABSI'nın, mortalite ile ilişkili tüm parametreleri içermesi nedeniyle olabileceği düşünüldü.

Anahtar sözcükler: ABSI; BAUX; BOBI; FLAMES; mortalite; skorlama; yanık.

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