



The analysis and accuracy of mortality prediction scores in burn patients admitted to the intensive care burn unit (ICBU)

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ABSTRACT

Background: To date, multiple scoring systems have been utilised in predicting outcomes in burn patients. The aim of this study is to determine the accuracy of three established scoring systems used for burn patients admitted to the intensive care unit and to determine the risk factors associated with poor outcomes.

Methods: A total of 211 patients who were admitted to the ICBU in a tertiary care centre in Kuwait from January 2017 to December 2019 were analysed retrospectively. Data were collected using patient medical records. The FLAMES, BOBI and revised Baux scores were calculated, and the survivor and non-survivor scores of patients were analysed to determine the sensitivity, specificity and Area Under the Receiver Operating Characteristics (AUROC) of the different scoring modalities.

Results: The majority of the analysed population were male patients (165/211) and the most common mechanism of burns was flame burns (166/211). Most of the patients admitted to the ICBU survived (188/211). Female gender was associated with a higher mortality rate, whilst inhalational injury and co-morbidities were not associated with a higher mortality rate. The revised Baux score had a sensitivity value of 96% and 90% specificity. The BOBI score had a sensitivity of 91% and 76% specificity. The FLAMES score had a sensitivity of 96% and the highest specificity of 99%. All 3 scores had AUC values exceeding 90%.

Conclusion: Statistically, FLAMES score had the highest accuracy of predicting outcomes in burn patients, however all three scores demonstrated acceptable predictive rates when it comes to practical application, permitting the use of either one of the studied scores with satisfactory prognostic outcomes.

1. Introduction

Burn injuries are ranked as the fourth most common type of trauma internationally with significant morbidity, mortality and economic burden [1]. Multiple patient factors have been associated with higher mortality rates amongst burn patients, including gender, total body surface area affected by the burn (TBSA%), mechanism of the burn, the presence of inhalational injury and/or the presence of comorbidities [2–7]. Burn-specific mortality scoring systems use the aforementioned patient parameters along with laboratory values to predict the prognosis in burn patients [8].

Being on the advent of modern medicine, along with the advancement in the management of burns over the past 60 years has led to modifications of established scoring systems – namely the Baux score –

[9] along with the conception of new scores. To date, more than 40 mortality prediction models have been created and validated for the use in burn patients, each having its own accuracy, sensitivity and specificity [5].

The aim of this study is to examine the accuracy of three common mortality prediction scores - The Fatality by Longevity, APACHE II score, Measured Extent of burn, and Sex (FLAMES), Belgian Outcome of Burn Injury (BOBI) and Revised Baux scores. We evaluate their accuracy, sensitivity and specificity in predicting outcomes of burn patients admitted to the intensive care burn unit (ICBU). Furthermore, we identify patient and/or burn related factors associated with increased mortality in our cohort.

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2. Methods

This is a retrospective cohort study conducted at a government affiliated hospital –a tertiary care centre specialised in burns with a catchment area of 4.2 million people covering the entire population of Kuwait. This original article has been drafted in line with the STROCCS criteria [10]. All patients admitted to the Intensive Care Burn Unit (ICBU) from January 2017 to December 2019 due to acute burn injuries were included in the study, including paediatric burn cases. The exclusion criteria included patients with incomplete data records, and patients with concomitant trauma compounding the burn injury. Ethical approval was obtained from the ethical committee at the Ministry of Health, Kuwait. Written consent was not required due to the retrospective nature of the study. The study was registered on [ClinicalTrials.gov](#) under the unique identity number [NCT04737148](#) [11].

The ICBU admission policy included paediatric patients with partial/full thickness burns >10% TBSA, adult patients with partial/full thickness burns >15% TBSA, electric burns, burns involving the face, any patient with suspected inhalational injury and patients with significant comorbidities [12].

Patients admitted to the ICBU are co-managed by board certified plastic surgeons alongside a team of intensive care physicians. Burn percentages were calculated by the admitting plastic surgeon using a Lund-Browder chart. Management protocol deployed by the consultant lead teams are in concordance with the latest American Burn Association recommendations, however initial fluid resuscitation used was 4*TBSA %*weight (kg), whilst patients with suspected inhalational injury received 6*TBSA%*weight (kg).

The data was collected via a paper-based chart review of the cohort’s medical records. This included patient identification, gender, age, length of stay in ICBU, hospital length of stay, TBSA%, depth and mechanism of burn, intubation status, the presence of inhalational injury, medical history, any complications and total fluid balance of the patient. Parameters used to calculate the examined scores were also harvested, which included vital signs and the results of standard haematological and biochemical investigations alongside blood gas analysis. The mortality scores were calculated using the immediate data set following admission to the ICBU. The FLAMES, BOBI and revised Baux scores were calculated for each of the patients. Details on the mortality scores are available in [Fig. 1](#) [13–17]. Within the FLAMES score, mixed partial thickness burns were calculated using half of the TBSA as partial thickness coefficient and the other half of the TBSA using the full thickness coefficient. The APACHE II prediction score was also included in the analysis.

3. Statistical analysis

The data analysis on the dataset composed by 211 observations was performed using R software, version 3.6.3. The categorical variables were expressed as frequencies and percentages, and the continuous variables were expressed as mean and standard deviation (SD). The variables were the risk factors of interest for mortality. They were analysed for the two groups of survivors and non-survivors of burn injuries, to find statistically significant associations between the variables and mortality.

The categorical variables were tested by using the Chi-squared test

Mortality score	Equation	Mortality rate calculation
FLAMES	$(-8.285) + (0.045 \times \text{age}) + (0.157 \times \text{APACHE II score}) + (0.062 \times \text{TBSA\% partial thickness}) + (0.104 \times \text{TBSA\% full thickness}) + (-1.214 \times \text{male})$	$e^{(\text{FLAMES})} / (1 + e^{(\text{FLAMES})})$
BOBI	Age: <50 = 0 50–64 = 1 65–79 = 2 >80 = 3 Burn TBSA%: <20 = 0 20–39 = 1 40–59 = 2 60–79 = 3 80-100 = 4 Inhalation injury: Yes = 3 No = 0	Sum of score: 0 = 0.1% mortality 1 = 1.5% mortality 2 = 5% mortality 3 = 10% mortality 4 = 20% mortality 5 = 30% mortality 6 = 50% mortality 7 = 75% mortality 8 = 85% mortality 9 = 95% mortality 10 = 99% mortality
Revised Baux	$(\text{Burn TBSA\%} \times 100) + (\text{Age}) + (17 \times \text{Inhalational Injury})$	Percentage as a sum of the equation

Fig. 1. Mortality scores.

(at $\alpha = 0.05$), and the standardized residuals (SR) were calculated. The continuous variables were tested by the *t*-test and Mann-Whitney test (at $\alpha = 0.05$), and the point-biserial correlation coefficients (r_{pb}) were calculated.

Multivariable logistic regression was performed to determine the potential risk factors of morbidity from burn injuries; using the statistically significant variables ($SR| > 2, r_{pb} > 0.5$) We adjusted for confounders and calculated the odds ratios (OR), the 95% confidence intervals (CI) and the corresponding p-values. To evaluate the performance of the multivariable logistic regression model, we used the Area Under the Receiver Operating Characteristics (AUROC) metric (Fig. 2).

4. Results

A total of 297 burn cases were admitted between January 2017 and December 2019, however 86 were excluded as inclusion criteria was not met. Of the 211 patients analysed, 165 (78.2%) were males and 46 (21.8%) females, the average age was 32 and the average weight was 67.7 kg. Most of the patients suffered flame burns (166, 78.7%), and the majority sustained partial thickness burns (147, 69.7%). The average TBSA% was 24.6%. The average length of stay (LOS) in the hospital was 18.3 days, the average length of ICBU stay was (8.4 days) and the average fluid intake in the first 24 h was 6513 ml. 92 (43.6%) patients required mechanical ventilation, and less than half of those were confirmed to have inhalational injury (46, 21.8%). Only 11% of the patients had co-morbidities. The clinical characteristics of patients are summarised in Table 1.

The observed data shows 188 survivors and 23 deaths (10.9%). Majority of the non-survivors were males and with an average age of 39.7 years. Non-survivors had a greater average weight (74.7 kg), a greater TBSA% (71.6%), and more fluid intake in the first 24 h (18701.9 ml). All average burns mortality scores were greater for the patients who did not survive the burn injuries, as shown in Table 2. The variables listed in Table 2 were tested one-by-one in relation to mortality.

The tests showed statistically significant association between mortality and burn depth (full thickness, $SR = 7.8$) and need for mechanical ventilation ($SR = 3.1$), respectively. The results also showed a statistically significant difference between the average TBSA%, total fluid intake in the first 24 h for survivors and non-survivors (p-value < 0.01), and statistically significant associations ($r_{pb} > 0.6$).

We built a multivariable logistic regression model, including the

Table 1
Patient demographics.

Variable	All cases (n = 211 (%))
Gender	
Female	46 (21.8)
Male	165 (78.2)
Mechanism of burn	
Chemical	2 (0.9)
Contact	2 (0.9)
Electric flash	12 (5.7)
Electrical	7 (3.3)
Flame	166 (78.7)
Scald	22 (10.4)
Burn depth	
Full thickness	38 (18.0)
Mixed partial thickness/full thickness	26 (12.3)
Partial thickness	147 (69.7)
Mechanical ventilation	
No	119 (56.4)
Yes	92 (43.6)
Inhalational injury	
No	165 (78.2)
Yes	46 (21.8)
Comorbidities	
No	188 (89.1)
Yes	23 (10.9)
Age*	32 (16.21)
Length of hospital stay (days)*	18.3 (26.8)
ICBU Length of Stay*	8.4 (12.8)
Weight (kg)*	67.7 (25.3)
Burn (%)*	24.6 (22.5)
Total fluid intake in first 24 h (ml)*	6513 (7522.7)

Table 2
Comparison of clinical characteristics and mortality.

Variable	All cases (n = 211 (%))	Survived (n = 188 (%))	Died (n = 23 (%))	p-value
Gender				
Female	46 (21.8)	37 (80.4)	9 (19.6)	0.06
Male	165 (78.2)	151 (91.5)	14 (8.5)	
Mechanism of burn				0.46
Chemical	2 (0.9)	2 (100)	0 (0)	
Contact	2 (0.9)	2 (100)	0 (0)	
Electric flash	12 (5.7)	12 (100)	0 (0)	
Electrical	7 (3.3)	7 (100)	0 (0)	
Flame	166 (78.7)	144 (86.7)	22 (13.3)	
Scald	22 (10.4)	21 (95.5)	1 (4.5)	
Burn depth				<0.01
Full thickness	38 (18.0)	18 (47.4)	20 (52.6)	
Mixed partial thickness/full thickness	26 (12.3)	26 (100)	0 (0)	
Partial thickness	147 (69.7)	144 (98.0)	3 (2.0)	
Mechanical ventilation				<0.01
No	119 (56.4)	116 (97.5)	3 (2.5)	
Yes	92 (43.6)	72 (78.3)	20 (21.7)	
Inhalational injury				0.18
No	165 (78.2)	150 (90.9)	15 (9.1)	
Yes	46 (21.8)	38 (82.6)	8 (17.4)	
Comorbidities				<0.01
No	188 (89.1)	167 (88.8)	21 (11.2)	
Yes	23 (10.9)	21 (91.3)	2 (8.7)	
Age*	32 (16.21)	31.1 (15.6)	39.7 (19.0)	0.053
Length of hospital stay (days)*	18.3 (26.8)			
Length of ICBU stay (days)*	8.4 (12.8)	17.9 (22.3)		
7.6 (11.4)				
15.6 (19.9)	0.93			
0.15				
Weight (kg)*	67.7 (25.3)	66.9 (25.6)	74.7 (21.8)	0.12
Burn (%)*	24.6 (22.5)	18.9 (14.1)	71.6 (23.3)	<0.01
Total fluid intake in first 24 h (ml)*	6513 (7522.7)	5021.3 (5377.5)	18701.9 (10956.8)	<0.01

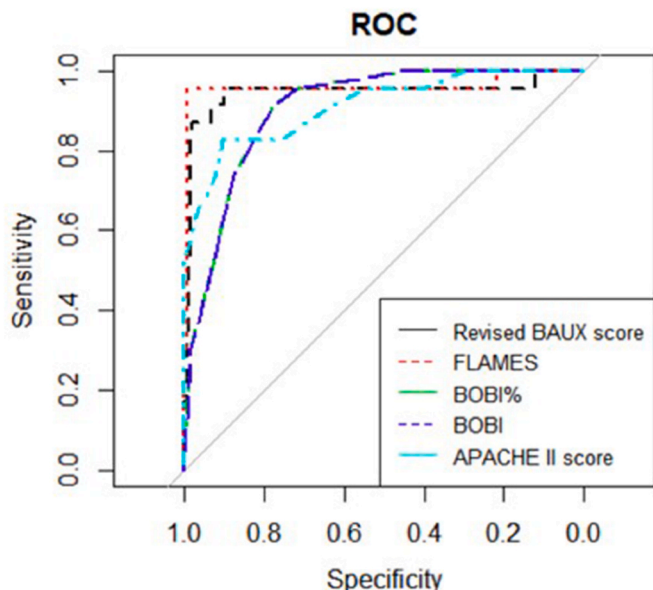


Fig. 2. ROC curves of the burn mortality scores.

variables that showed statistically significant association with mortality. Burn depth with partial thickness and percentage burn remained significant. The odds ratios are presented in Table 3. The average burns mortality scores were higher in the non-survivor group, as shown in Table 4, which predicts death from the severity of burn injuries. The high values of sensitivity (true positive rate), specificity (true negative rate) and AUC metrics, calculated for each burns mortality score show that all scores have a strong contribution to the prediction of burn mortality.

5. Discussion

The utilisation of an accurate, practical and reliable method of assessing a patient's likely outcome is of vital significance, particularly when it comes to centres with limited resources and a large catchment area [18]. The use of scoring systems aids not only in clinical decision-making, but also in the evaluation of local healthcare protocols. Furthermore, having an objective prognostic indicator can aid in counselling patient relatives regarding outcomes of the patient. Often times, the more humane approach in burn cases in which intervention is futile is to offer palliative care, particularly when there is scant healthy skin to graft debrided areas, leading to temporary coverage using allografts, which is both costly and typically require reapplication of said grafts accordingly.

In our study, we identified a number of risk factors associated with poor outcomes in burn victims admitted to the ICBU. Female patients were observed to have a higher mortality rate (19.6% versus 8.5% in males, p value = 0.06), but also had a higher mean age (39.7 vs 31.1 in males) and a higher TBSA% (23.3% vs 14.1%). These two factors alone could account for the higher mortality rate; however, a number of theories have been previously proposed as to why female burn victims may have a poorer outcome when compared to their male counterparts. These include differences in immune response and adipose tissue distribution [19,20]. The inclusion of paediatric patients in our study may impact the mean age of survivors, as burns in the young are rarely fatal – which is reflected in most scoring systems, and only one patient in the age group <18 suffered a morbid outcome.

Despite multiple articles reporting inhalational injury and the presence of comorbidities as a poor prognostic factor in burn patients [9,12,19], in our population those appeared to have no correlation. Meanwhile, factors such as the need for mechanical ventilation, presence of full thickness burns and higher TBSA% burns were associated with higher mortality rates.

We report a high AUC result of greater than 0.90 for all 3 scores being examined (BOBI, FLAMES and revised Baux scores), which is in concordance with the current literature [9] Table 3 multivariable analyses of clinical characteristics influencing mortality [18,19,21]. The FLAMES score, which was developed by Gomez et al., in 2008, is an intricate calculation which factors in the APACHE II score, gender, age, and depth of burn [24]. The score demonstrated the highest AUC score from the three examined scores in this study – proving to be the better score to determine the morbid patients, whilst also boasting the highest sensitivity and specificity at 95.6% and 99.5% respectively. This is in line with Gomez's initial evaluation of the scoring system. (AUC score; 0.93 vs. our reported score of 0.96). A critique of the score is that it depends on the assessment of the depth of burn, and -as is evident by

clinical practice – deep burns may not be evident on the initial examination of the patient.

APACHE II score is a benchmark in assessing mortality in critically ill patients [22], however a notable drawback of the scoring system is the extensive patient parameters that are required to calculate the score, which include haemodynamic status, ventilation status and laboratory values [13]. When it comes to critically ill burn patients, the APACHE II score had a lesser sensitivity and specificity in predicting mortality. This is expected, given the fact that the FLAMES score is ultimately a modified scoring system incorporating the APACHE II score and other burn-specific variables. Having said that, the FLAMES score might not be favoured by certain physicians as a practical and applicable tool in everyday practice despite its accuracy.

In 1961 Professor Baux created a formula aimed at predicting mortality in burn patients. The calculation is the sum of both the TBSA% and patient age to give a mortality score, the Baux score [25]. It is a relatively straightforward method of calculating mortality in a clinical setting. A large study analysing 5280 patients from the years 2000–2008 reported a 50% mortality rate in patients with a score of 110, and a 100% mortality rate when the score exceeds 160 [23]. This is similar to what was seen in our study, patients who died had an average Baux score of 117.2. A revised Baux score which was developed in 2010 by Osler et al. incorporated the presence of inhalational injury as an important risk factor, which increases mortality by an equivalent of 17% [9], however, despite this report, our study reports no association between inhalational injury and an increased mortality rate. This may be due to the increased awareness and advances in modern medicine, leading to the early recognition of patients with potential inhalational injury, with rapid modification in the treatment being offered to this cohort of patients. Despite its simplicity, the Baux score still maintained a significant (95.7%) sensitivity and (89.9%) specificity in our examined population.

The BOBI score utilises a point-based system based on age, TBSA% and the presence of inhalational injury for a maximum total of 10 points. A score of 10 equates to a 99% chance of mortality [15,17]. The mean BOBI score in our examined population with a fatal outcome was 4.6, which is reflected by and the lowest AUC score of 0.91 and specificity of 77.7%. Despite these findings, BOBI incorporates what is thought to be the most important predictors of mortality as is reflected by the revised Baux score [19].

A number of limitations exist in our study. The retrospective nature of the study, the lack of an electronic healthcare system at our centre and the use of a paper-based charting system, could have led to the omission of some of the patients due to misplaced files or incomplete data. Furthermore, our study was conducted in a tertiary care centre in which burn patients are transferred from multiple secondary level centres. We did not account for time taken from the first assessment to the transfer and care under our service, as delays in expert management may have contributed to poorer outcomes. Therefore, a study involving a larger sample of burn patients admitted immediately to a centre with a dedicated burn team could lead to more accurate results, along with the potential to compare even more scoring modalities.

6. Conclusion

In everyday practice, the utilisation of a prognostic scoring system based on objective parameters is advantageous. This is particularly true in critically ill patients, such scores serve as a clinical, auditing and counselling aid. The ideal prognostic scoring system is disease-specific, accurate, easily reproducible and practical. In our experience, the FLAMES score proved to be statistically-superior, presenting the strongest predictive value in the prognosis of burn patients admitted to the ICBU. Nonetheless, FLAMES, BOBI and Revised Baux scores, all showed valid capability of predicting outcomes in burn patients, leaving the choice of score choice down to personal preference.

Table 3
Multivariable analyses of clinical characteristics influencing mortality.

Variable	p-value	OR	C.I. (95%)
Burn depth			
Partial thickness	0.0009	0.04	0.005–0.23
Mechanical ventilation	0.15	4.15	0.62–33.5
TBSA (%)*	0.006	1.07	1.02–1.13
Total fluid intake in first 24 h (ml)*	0.76	1.00	0.99–1.0

Table 4
Burn mortality mean scores.

Burn mortality Scores	All cases (n = 211)	Survived (n = 188)	Died (n = 23)	Sensitivity	Specificity	AUC (95% CI)
Revised Baux score*	60.3 (31.5)	53.3 (24.2)	117.2 (26.4)	0.9565	0.8989	0.9458 (0.8708–1.0)
Flames*	10.0 (26.6)	1.8 (7.6)	76.3 (32.8)	0.9565	0.9947	0.9625 (0.8958–1.0)
BOBI*	1.6 (1.9)	1.3 (1.6)	4.6 (1.7)	0.9130	0.7766	0.9074 (0.8593–0.9555)
APACHE II score*	7.5 (5.7)	6.4 (4.3)	16.9 (7.4)	0.8261	0.9043	0.9123 (0.8420–0.9827)

*Mean (SD)

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Ethical Approval

Ethical approval was obtained from the ethical committee at the Ministry of Health, Kuwait.

Author contribution

Zakariya Hassan- MD Study design, data collection, literature review, writing first draft, paper submission, final review of paper. Waleed Burhamah- MD Study design, Data collection, literature review, writing first draft, paper submission, final review of paper. Shahad Alabdulmuhsen- MD Data collection and writing the first draft. Abdullah Al Saffar- MD data collection, writing of the first draft. Melinda Oroszlányová- PhD. Statistical analysis, writing of the results. Hasan Aziz- MD: Study design, supervision and final review

Guarantor

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Declaration of competing interest

No conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amsu.2021.102249>.

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