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External Validation of Three Burn-Specific Mortality Prediction Models in Adult Burn Patients at a Tertiary Care Hospital in India

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Abstract

Background Several burn-specific mortality prediction models have been formulated and validated in the developed countries. There is a dearth of studies validating these models in the Indian population. Our objective was to validate three such models in the Indian burn patients.

Methods A prospective observational study was performed after ethical clearance on consecutive eligible consenting burn patients. Patient demographics, vitals, and results of hematological workup were collected. Using these. the Abbreviated Burn Severity Index (ABSI), the revised Baux score (rBaux), and the Fatality by Longevity, APACHE II score, Measured extent of burn, and Sex score (FLAMES) were calculated. The discriminative ability of the ABSI, rBaux, and the FLAMES was tested using the receiver operating characteristic (ROC) curve at 30 days and the area under the ROC curve (AUROC) compared. A p-value ≤ 0.05 was considered significant. Probability of death was calculated using these models. Hosmer–Lemeshow goodness of fit test was run.

Results The ABSI (AUROC 0.7497, 95% CI 0.67796–0.82141), rBaux (AUROC 0.7456, 95% CI 0.67059–0.82068) and FLAMES (AUROC 0.7119, 95% CI 0.63209–0.79172), had fair discriminative ability. The Hosmer–Lemeshow test reported that ABSI and rBaux were a good fit for the Indian population, while FLAMES was not a good fit.

Conclusion The ABSI and rBaux had a fair discriminative ability and were a good fit for the adult patients with 30 to 60% thermal and scald burn patients. FLAMES despite having fair discriminative ability was not a good fit for the study population.

Keywords
- burn mortality
- abbreviated burn severity index
- revised Baux score
- FLAMES score
- mortality prediction

Introduction

In India, burn injuries are the second largest group of injuries following road traffic accidents.[1] Most of these patients require intensive care and will succumb to their injuries despite appropriate and adequate care.[2] Prognostication forms an important aspect of care in these patients, for which, burn-specific mortality prediction models are required. Along with prognostication, these models provide a framework for auditing a burn unit's performance, and, comparing it with other burn units.

The commonly used, well-established mortality prediction models have been formulated and validated in the developed countries. India being a developing country differs

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from these nations with respect to the incidence and severity of burns as well as the availability of resources and infrastructure.[3] These disparities preclude the use of these models in our population without extensive validation.

Models developed in the native population perform best, followed by models validated in the native population. Keeping this in mind, the authors studied predictors of burn mortality among adult Indian burn patients and formulated the AT score.[3] This score awaits external validation. External validation of a model assesses if the predictions made by these models are generalizable to the native population. Therefore, we decided to validate three meticulously developed models,[4] the Abbreviated Burn Severity Index (ABSI),[5] the revised Baux score (rBaux),[6] and the Fatality by Longevity, APACHE II score, Measured extent of burn, and Sex score (FLAMES)[7] in the study population.

Methods

Study Design

This prospective observational study was started in December 2018 after clearance from the institute ethics committee and patients recruited until April 2021.

Participants

Consecutive, eligible, consenting adult patients, presenting to the burn casualty within 24 hours of sustaining 30 to 60% scald and thermal burns, in the age group of 18 to 55 years were enrolled. Other types of burns and burns associated with trauma, pregnancy, and comorbidities were excluded.

Patient Enrolment and Data Collection

The patients were treated and assessed as per departmental protocols. After obtaining consent, patient demographics, vitals and results of the hematological workup were collected. Using these variables, the ABSI, rBaux, and FLAMES were calculated. The probability of death for the ABSI, rBaux, and FLAMES was calculated using the formulae presented in the papers by Tobiasen et al,[5] Osler et al,[6] and Gomez et al,[7] respectively.

The patients were followed at 10, 20, and 30 days for assessing mortality. Discharged patients were followed up telephonically.

Statistical Analysis

Qualitative data have been presented as frequency and percentage. Quantitative data have been presented as mean $\pm$ SD (normally distributed data) or median [IQR] (skewed data).

Performance of the Models

The discriminative ability of the models was tested using the receiver operating characteristic (ROC) curve for 30-day mortality and the area under the ROC curve (AUROC) compared for 30-day mortality. A p-value ≤ 0.05 was considered significant.

Probability of death was calculated using the models. A case with a calculated probability of death ≥ 0.5 was considered more likely to die and < 0.5 more likely to survive. Hosmer–Lemeshow goodness of fit test was run.

Statistical Packages

IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.

Observations and Results

One hundred sixty-three consecutive patients were enrolled and followed up for 30 days. During the stipulated time period, 2,610 new burn patients were admitted to the department, of which 368 met the inclusion criteria for the study. Out of these, 210 consenting patients were enrolled for the study and follow-up could be completed for 163 patients. The data from these 163 patients were used for analysis.

Patient Demographics

The median age of the study sample was 30 years (25, 40), ranging from 18 to 55 years. Eighty-four were females and 79 males. The median TBSA was 40% (35, 50). One hundred fifty-nine patients sustained thermal burns, while four patients sustained scald burns. A diagnosis of inhalational injury was made in 140 patients. The observed 30-day mortality was 38.65% (63/163). The characteristics of the survivor and the non-survivor group have been summarized in ►**Table 1**. Kolmogorov–Smirnov test was applied and it was found that the data was not normally distributed.

Performance of the Models

The ABSI, rBaux and FLAMES were calculated for both the groups and compared (►**Table 2**). These scores were significantly higher in the non-survivor group.

On comparison of the ROC curves for the three models, there was no statistically significant difference in the performance of the three models (►**Fig. 1**, ►**Table 2**).

The results of the Hosmer–Lemeshow goodness of fit test for the prediction models are as shown in ►**Table 2**.

Discussion

In this study, we attempted to validate three meticulously developed burn-specific mortality prediction models in adult burn patients at a tertiary care hospital in India. It was found that ABSI, rBaux, and FLAMES were significantly higher in the non-survivor group as compared to the survivor group, implying a correlation such that mortality increases as the scores increase and vice versa (►**Table 2**).

The discriminative ability of the models was studied using the ROC curve and the AUCROC at 30 days (►**Table 2**, ►**Fig. 1**). Values of 0.5, between 0.5 and 0.7, 0.7 and 0.8, above 0.8 suggest chance relationship, poor, fair, and excellent discrimination, respectively.

These models provide a fair estimate of mortality in adult burn patients at 30 days. On comparison of the AUROC of the

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Table 1 Survivor and non-survivor group characteristics

Characteristics		Survivors ($n = 100$)	Non-survivors ($n = 63$)	p-Value
Age (years)[a]		31.50 (25,37.75)	30 (26,42)	0.549[c]
Sex	Male	49	30	0.874[d]
	Female	51	33	
Type of burns	Thermal	98	61	0.641[d]
	Scald	2	2	
TBSA (%)[a,b]		35 (30,45)	45 (40,55)	<0.001[c]
Inhalational Injury	Present	82	58	0.105[d]
	Absent	18	5	

[a]Median (IQR).
[b]Total burn surface area.
[c]Mann–Whitney *U* test.
[d]Fisher's exact test.

Table 2 Comparison of the models in survivor and non-survivor groups, comparison of AUROC for 30-day mortality and results of the Hosmer–Lemeshow goodness of fit test

	Survivors ($n = 100$)[a,b]	Non-Survivors ($n = 63$)[a,b]	AUROC[c]	SE	95% CI	C-statistic (p-Value)[d]
ABSI[e]	7.45 + 8.62	8.62 + 1.069	0.7497	0.0366	0.67796–0.82141	3.457 (0.326)
rBaux[f]	84.74 +12.981	95.71 + 11.441	0.7456	0.0383	0.67059–0.82068	5.520 (0.701)
FLAMES[g]	−3.94 + 1.192	−2.816 + 1.624	0.7119	0.0407	0.63209–0.79172	16.615 (0.034)

[a]Mean ± SD.
[b]Student's *t*-test (p-value <0.001).
[c]Area under the receiver operating characteristic curve.
[d]Hosmer–Lemeshow goodness of fit test.
[e]Abbreviated Burn Severity Index.
[f]Revised Baux score.
[g]Fatality by Longevity, APACHE II score, Measured extent of burn, and Sex score.

three models, no statistically significant difference was found (►**Table 2**, ►**Fig. 1**).

The Hosmer–Lemeshow test gives a small C-statistic and a large non-significant p-value for the ABSI and rBaux score, indicating that they are a good fit for adult burn patients. The C-statistic for the FLAMES score is large with a significant p-value, indicating that it is a poor fit for the study population (Table 2). As such, ABSI and rBaux can be used in the study population in their current form, while FLAMES requires modulation before use in the study population.

The ABSI has been extensively validated in the developed world[8–13] and two developing countries, Ghana[14] and Iran.[15] Brusselaers et al studied the performance of ABSI in the Ghanaian population and reported excellent discrimination.[14] It should be noted that the study sample was a mix of children and adults with a median age of 10.5 [2.5,2.7], median TBSA burned of 21 [11, 34], and only two patients required intubation.[14] In comparison to our study population, it consisted of younger and less severely injured patients. The adult mortality in this study was 15.4%.[14] Data about burn depth were not available; therefore, AUROC was calculated twice, once assuming partial thickness burns (ABSI-1) and then full thickness burns (ABSI-2).[14] The model retained discrimination in both the conditions, but ABSI–2 was not a good fit for the population.[14] The model significantly overestimated mortality in the sample.[14]

The study by Salehi et al concluded an excellent discriminative ability in the Iranian population.[15] The population characteristics matched the characteristics of our sample. The mortality rate reported was 69.71%.[15] The excellent discrimination might be the result of high mortality and the tendency of ABSI to overestimate mortality.[9,11,14] Furthermore, being a developing country, the facilities available in the country have similarities to what were available in the United States of America in the 1980s and therefore this might actually indicate a developmental gap.

The external validation studies performed in the developed countries, such as the United States of America,[9,12] Switzerland,[10] Ireland,[11] Korea,[13] and Japan[8] have found excellent discrimination. These studies consisted of patients with less severe burns and a low incidence of inhalational injury.

The rBaux score has been extensively validated in the developed countries[8–13,16,17] and the Caucasian population and only two studies tested it in developing countries.[14,15] Brussealers et al[14] studied the model in the Ghanaian population and Salehi et al[15] studied the same in the Iranian population. Both these studies had an AUROC of > 0.8.

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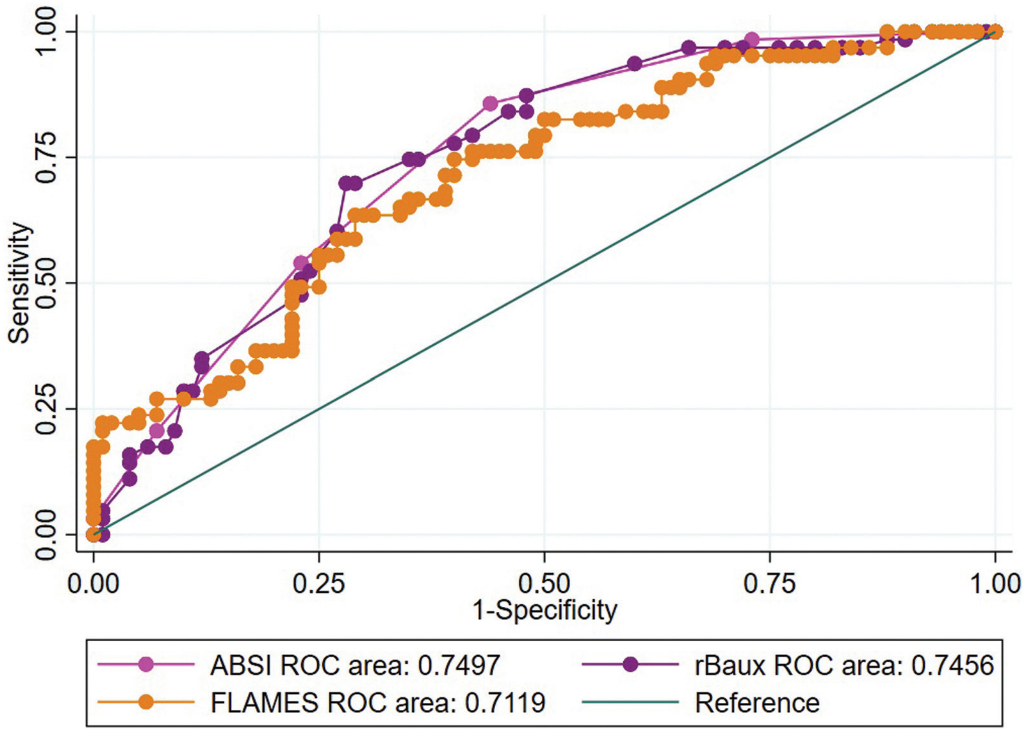

Fig. 1 Comparison of area under the ROC curve (AUROC) for Abbreviated Burn Severity Index (ABSI), revised Baux score (rBaux) and Fatality by Longevity, APACHE II, Measured extent of burn and Sex score (FLAMES) for 30-day mortality.

The FLAMES score has not been as extensively validated as ABSI and rBaux. In the studies by Moore et al,[18] Halgas et al,[12] and Kim et al,[13] the AUROC is more than 0.9. The population characteristics in these studies was similar to those of the training population.

The reason for the differences in our results when compared with the training population[5–7] and other validation populations[9–18] are explained by the differences in the population characteristics and the healthcare infrastructure of our setup. The patients in our study were more severely burnt and had a high incidence of inhalational injury. Our institution is a tertiary care referral center for burns in India, which is a developing country. On first presentation of a burn victim to the department, the patient is resuscitated and the extent of burns is calculated objectively using a burn chart. The depth of burn estimation and the diagnosis of inhalational injury are made based on history and clinical examination. Early excision and grafting is done in less severely burnt and stable patients. Delayed skin grafting is done for severely burnt and unstable patients post stabilization. There are logistic problems like limited intensive care beds and operation theater availability, which has a bearing on the treatment.

Our study highlights the importance of validation studies and we recommend subjecting externally developed models to validation before use in native population. We also recommend that more studies be performed to develop and validate indigenous burn specific mortality prediction models, such as the AT score.[3] This score was developed by the authors while studying variables, which affect mortality in adult Indian burn patients. The AT score has been validated in the training population but awaits external validation.

Despite being a prospective study, there are certain limitations to this study. Due to the small number of cases, we are unable to provide population-specific cut-offs for these models as at least 100 events of the outcome of interest should occur in a sample to be able to justify the provision of population-specific cut-offs. The strict inclusion criteria limits extrapolation of the results to the pediatric and geriatric populations. The development and validation populations for ABSI had 80.8% and 93.1% of the patients with less than 30% burns, respectively.[5] The rBaux score training population had a mean TBSA of 9.7%[6] and the parent population for FLAMES had a mean TBSA of 48.2% $\pm$ 21.5% for non-survivors and 15.5% $\pm$ 13.9% for the survivors.[7] To minimize the differences between the study and training populations, we studied patients with only 30 to 60% TBSA, limiting its use in the less and more severely burnt. We did not study the effect of comorbid illnesses on burn mortality, separate well-controlled studies are required for the pursuance of this subject.

Conclusion

In light of the findings of our study, we conclude that the Abbreviated Burn Severity Index (ABSI) and the revised Baux score (rBaux) are a good fit for adult burn patients with 30 to 60% thermal and scald burns and can be used as such with fair predictive value. The Fatality by Longevity, APACHE II score, Measured extent of burn, and Sex score (FLAMES), in contrast, retains discriminative value but is not a good fit for our patients and should be used after population-specific modification of this model.

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Authors' Contributions

Both the authors were involved in the conception of the work, data collection, analysis, and interpretation and throughout the process of the drafting and revision of the manuscript.

Note

Informed consents were taken from all the participants.

Ethical Approval

Ethical committee approval was obtained from the institutional ethics committee.

Conflict of Interest

None declared.

References

1 Gupta JL, Makhija LK, Bajaj SP. National programme for prevention of burn injuries. Indian J Plast Surg 2010;43(Suppl):S6–S10

2 Coste J, Wasserman D, Venot A. Predicting mortality in adult burned patients: methodological aspects of the construction and validation of a composite ratio scale. J Clin Epidemiol 1996;49 (10):1125–1131

3 Sharma S, Tandon R. Predicting burn mortality using a simple novel prediction model. Indian J Plast Surg 2021;54(01):46–52. Doi: 10.1055/s-0040-1721867

4 Hussain A, Choukairi F, Dunn K. Predicting survival in thermal injury: a systematic review of methodology of composite prediction models. Burns 2013;39(05):835–850

5 Tobiasen J, Hiebert JM, Edlich RF. The abbreviated burn severity index. Ann Emerg Med 1982;11(05):260–262

6 Osler T, Glance LG, Hosmer DW. Simplified estimates of the probability of death after burn injuries: extending and updating the baux score. J Trauma 2010;68(03):690–697

7 Gomez M, Wong DT, Stewart TE, Redelmeier DA, Fish JS. The FLAMES score accurately predicts mortality risk in burn patients. J Trauma 2008;65(03):636–645

8 Kaita Y, Tarui T, Tanaka Y, Suzuki J, Yoshikawa K, Yamaguchi Y. Reevaluation for prognostic value of prognostic burn index in severe burn patients. Acute Med Surg 2020;7(01): e499

9 Tsurumi A, Que YA, Yan S, Tompkins RG, Rahme LG, Ryan CM. Do standard burn mortality formulae work on a population of severely burned children and adults? Burns 2015;41(05): 935–945

10 Pantet O, Faouzi M, Brusselaers N, Vernay A, Berger MM. Comparison of mortality prediction models and validation of SAPS II in critically ill burns patients. Ann Burns Fire Disasters 2016;29(02): 123–129

11 Woods JFC, Quinlan CS, Shelley OP. Predicting mortality in severe burns-what is the score?: evaluation and comparison of 4 mortality prediction scores in an Irish population Plast Reconstr Surg Glob Open 2016;4(01):e606

12 Halgas B, Bay C, Foster K. A comparison of injury scoring systems in predicting burn mortality. Ann Burns Fire Disasters 2018;31 (02):89–93

13 Kim Y, Kym D, Hur J, et al. Development of a risk prediction model (Hangang) and comparison with clinical severity scores in burn patients. PLoS One 2019;14(02):e0211075

14 Brusselaers N, Agbenorku P, Hoyte-Williams PE. Assessment of mortality prediction models in a Ghanaian burn population. Burns 2013;39(05):997–1003

15 Salehi SH, As'adi K, Abbaszadeh-Kasbi A, Isfeedvajani MS, Khodaei N. Comparison of six outcome prediction models in an adult burn population in a developing country. Ann Burns Fire Disasters 2017;30(01):13–17

16 Douglas HE, Ratcliffe A, Sandhu R, Anwar U. Comparison of mortality prediction models in burns ICU patients in Pinderfields Hospital over 3 years. Burns 2015;41(01):49–52

17 Dokter J, Meijs J, Oen IMMH, van Baar ME, van der Vlies CH, Boxma H. External validation of the revised Baux score for the prediction of mortality in patients with acute burn injury. J Trauma Acute Care Surg 2014;76(03):840–845

18 Moore EC, Pilcher DV, Bailey MJ, Stephens H, Cleland H. The Burns Evaluation and Mortality Study (BEAMS): predicting deaths in Australian and New Zealand burn patients admitted to intensive care with burns. J Trauma Acute Care Surg 2013;75 (02):298–303

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