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Chapter 6

External validation of the revised Baux score for the prediction of mortality in patients with acute burn injury

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ABSTRACT

Background:

Since the original Baux score was outdated and inhalation injury was recognized as an important contributor to mortality, Osler et al. developed a revised Baux score for the prediction of mortality of burn patients in an American population. The aim of this study was to validate the revised Baux score with data of patients admitted to the Rotterdam Burn Center (RBC) in the Netherlands.

Methods:

Prospectively collected data were analyzed for all patients with acute burn injury admitted to the RBC from 1987 to 2009 (n = 4,389), including sex, age, total body surface area involved, inhalation injury, mortality, and premorbid conditions. Logistic regression analysis was used to determine the relationship between mortality and possible contributing variables. The discriminative power of the revised Baux score was assessed by receiver operating characteristics curve analysis.

Results:

Overall mortality in our center was 6.5%; mortality in patients with intention to treat was 4.4%. Age, total body surface area, inhalation injury, as well as premorbid circulatory and central nervous system conditions were significant independent predictors of in-hospital mortality. Revised Baux score in the RBC population (area under the curve, 0.96; 95% confidence interval, 0.95-0.97) performed less specific and sensitive in a selected group of patients with high Baux scores (area under the curve, 0.81; 95% confidence interval, 0.76-0.84).

Conclusion:

The revised Baux score is a simple and accurate model for predicting mortality in patients with acute burn injuries in a burn center setting. (J Trauma Acute Care Surg. 2014;76:840-845. Copyright © 2014 by Lippincott Williams & Wilkins)

Level of evidence:

Prognostic study, level III.

Key words:

Burns; mortality; Baux score; revised Baux score; predictors of mortality.

1. INTRODUCTION

Traditionally, mortality is the most important outcome measure in patients with acute burn injury.¹ Serge Baux developed a simple score predicting mortality after burn injury² In this model, an additional year of age or an additional percentage of body surface area burned each increased the predicted mortality with 1%. Thus, a patient aged 73 years, with a total body surface area (TBS) of 30% has a Baux score of 103. Because of its simple applicability, the original Baux score was widely used. However, nowadays, the original Baux score seems outdated. Since the development of the Baux score in 1961, mortality rates decreased by the establishment of specialized burn centers and by therapeutic improvements including fluid resuscitation, infection prevention, wound care, and use of topical and systemic antibiotics.^{3,4} In addition, inhalation injury was recognized as an important contributor to mortality.^{5,6}

Following the Baux score, many predictive models have been developed in the past^{7,8} also looking at influencing factors other than age and TBS burned. However, since most of these formulas are very complex, their clinical applicability is limited.

Several prediction models for mortality have been developed over time. For instance, the Belgian Outcome in Burn Injury Study Group developed the Belgian Outcome in Burn Injury (BOBI) prediction model. The scoring system is also based on age, TBS burned, and inhalation injury but uses different score points.⁹

Osler et al.¹⁰ developed the revised Baux score, a rather simple and clinical applicable score, including the effect of inhalation injury. The revised Baux score is calculated as the sum of age and TBS burned plus 17 points for inhalation injury; so in case of inhalation injury, the revised Baux score is 17 points higher than the original Baux score. The revised Baux score can be included in a logistic regression model or simply imputed using a nomogram to calculate the predicted mortality.

This model was developed and internally validated using the National Burn Repository (NBR). This database contains

extensive information of burn patients admitted to American burn centers. All prediction models need to be validated to ensure accuracy and guard against potential limitations. The best way to test a prediction model is to validate it in an independent setting or data source, unrelated to the original model development settings (temporal and geographic).¹¹

The generalizability of the revised Baux score, also known as external validity, has not been tested yet. The aim of our study was to validate the revised Baux score with data of patients with acute burn injuries admitted to the Rotterdam Burn Center (RBC) to offer accurate predictions in subsequent samples of patients.

First, we described the mortality in our population, comparing survivors and nonsurvivors, and the predictive value of the revised Baux score was tested.

Second, we investigated if any contributing factor could possibly play an important role in fine-tuning the scoring system.

PATIENTS AND METHODS

Patient Population

All patients with acute burn injury admitted to the RBC from 1987 up to and including 2009 were included. The total population was divided into the subgroups survivors and nonsurvivors. Nonsurvivors included patients admitted with intention to treat (ITT) and patients who received tender loving care (TLC). The decision for TLC was a patient-tailored judgment made by an experienced team of burn specialists on the basis of the important criteria of age, TBS, depth, localization, inhalation injury, and premorbid conditions.

Study Design

Prospectively collected patient data included age, TBS, sex, inhalation injury, and comorbidity. The diagnosis of inhalation injury was predominantly made on clinical signs and symptoms, especially exposure to smoke or fire, or signs of airway obstruction or the presence of soot in the throat or sputum. In those cases in our opinion, bronchoscopy as a diagnostic tool is not indicated; in case of doubt, bronchoscopy was performed.

Premorbid conditions were roughly divided into circulatory, respiratory, gastrointestinal, urogenital, locomotive, endocrine, and central nervous system (CNS) disorders.

Statistical Analysis

A comparison was made between survivors and nonsurvivors. All continuous variables were presented as medians with interquartile ranges (p25Yp75); survivors and nonsurvivors were compared using the Mann-Whitney U-test. Categorical variables were calculated as frequencies with percentages, and groups were compared using X^2 analyses and Fisher's exact test when applicable.

Univariable logistic regression analysis was used to determine the relationship between mortality and possible contributing factors; odds ratios (ORs) and 95% confidence intervals (CIs) were reported. Factor analysis included patient and injury characteristics. Predicted mortality was computed with a logistic model.⁸

Predictive performance of the revised Baux score was assessed by examining measures of calibration and discrimination. Calibration refers to how close predicted mortality agrees with observed mortality and was tested with the Hosmer-Lemeshow goodness-of-fit statistic. The discriminative power of the revised Baux score refers to the ability to differentiate between patients who died and who survived their burns. This power was

assessed by receiver operating characteristic (ROC) curve analysis, which demonstrates the sensitivity and specificity of the prediction model in a graphic way. The discriminative power is maximal when the area under the curve (AUC) is 1; there is no discriminative power when this area is less than 0.5.

A test was considered significant if the *p* value was smaller than 0.05 (two sided).

Statistical analyses were performed using SPSS for Windows version 15.0 (SPSS Inc., Chicago, IL).

RESULTS

Burn Center Mortality

From 1987 to 2009, a total of 4,389 patients with acute burn injury were admitted to the RBC (Table 1).

The median age was 27.0 years (interquartile range [IQR] 4–46), the median TBS was 6% (IQR, 3–12), and 462 patients (10.5%) were diagnosed as having an inhalation injury. The overall mortality rate in our population including 96 patients who received TLC was 6.5%. The mortality of 4,293 patients with ITT was 4.4% (190 of 4,293).

Patients who survived had a significant lower age, TBS, and incidence of inhalation injury in comparison with patients who died. In survivors, the median Bauxscore was 33 (IQR, 12–53), and the median revised Baux score was 33.5 (IQR, 12–56). In nonsurvivors, the Baux score was 99 (IQR, 83–115), and the revised Baux score was 108 (IQR, 91–127).

Demographics of nonsurvivors, divided in patients with ITT and patients who received, TLC are shown in Table 2.

Characteristics	RBC Total	Survivors	Nonsurvivors	<i>p</i>
No. patients	4,389	4,103 (93.5)	286 (6.5)	
Sex, male	2,902 (66)	2,748 (67)	154 (54)	<0.01
Age, median (IQR), y	27.0 (4–46)	25 (3–43)	62.5 (37.8–79.0)	<0.01
TBS%, median (IQR)	6 (3–12)	5 (3–10)	38 (16–62)	<0.01
Inhalation injury	462 (10.5)	296 (7.2)	166 (58.0)	<0.01
Baux score, median (IQR)		33 (12–53)	99 (83–115)	<0.01
Revised Baux score, median (IQR)		33.5 (12–56)	108 (91–127)	<0.01
Comorbidity				
Circulatory	259 (5.9)	205 (5.0)	54 (18.9)	<0.01
Respiratory	203 (4.6)	185 (4.5)	18 (6.3)	0.11
Gastrointestinal	177 (4.0)	146 (3.6)	31 (10.8)	<0.01
Urogenital	125 (2.8)	109 (2.7)	16 (5.6)	<0.01
Locomotor	224 (5.1)	191 (4.7)	33 (11.5)	<0.01
Endocrine	155 (3.5)	120 (2.9)	35 (12.2)	<0.01
CNS*	622 (14.5)	519 (12.6)	103 (36.0)	<0.01

Values are n (%) unless stated otherwise. IQR, 25th to 75th percentile.

Patients in the two groups did not differ in age, but those who received TLC had a significant higher TBS and incidence of inhalation injury, resulting in a significant higher Baux score (120.5 vs. 89) and revised Baux score (134.5 vs. 97.5).

TABLE 2. Demographics of Nonsurvivors Divided in Patients With ITT and TLC

	Nonsurvivors With ITT n = 190	Nonsurvivors With TLC n = 96	p
Sex, male, n (%)	110 (58)	44 (46)	
Age, median (IQR)	61 (38–78)	71.5 (36.3–83)	0.09
TBS, median (IQR)	24.5 (11.8–45.3)	65 (44–85)	<0.01
Inhalation, n (%)	86 (45.3)	80 (83.3)	<0.01
Baux score, median (IQR)	89 (76–101)	120.5 (110–137.5)	<0.01
Revised Baux score, median (IQR)	97.5 (83.8–110)	134.5 (123.3–153)	<0.01

Premorbid conditions were significantly more prevalent in patients who died. This applied to six of seven tracts: circulatory, gastrointestinal, urogenital, locomotor, endocrine, and CNS problems. A large number of patients with CNS problems had psychiatric disorders with more severe burn injuries because of attempted suicide. There was no significant difference in preexisting respiratory disorders between survivors and nonsurvivors (Table 1).

Predictors of Mortality

All significant predictors of mortality identified by univariable analysis are shown in Table 3. In this analysis, male sex is more related to mortality (OR, 1.7). Increasing age and more extensive TBS were significant prognostic factors as well as inhalation injury (OR, 17.8).

Premorbid conditions were also significant predictors of mortality. This applied for all seven tracts: circulatory (OR, 4.4), respiratory (OR, 1.4), gastrointestinal (OR, 3.3), urogenital (OR, 2.2), locomotor (OR, 2.7), endocrine (OR, 4.6), and CNS (OR, 3.9).

Correlation between the significant predictors was low (Pearson's <0.20), implying that all factors are additive to one another and independent predictors of outcome.

Significant factors associated with mortality were included in a multivariable logistic regression model. Multivariable analysis showed that age, TBS, inhalation injury and premorbid circulatory, and CNS problems were significant independent predictors associated with mortality. After the effects of age, TBS, inhalation injury, and the circulatory and CNS were taken into account; the other five tracts did not add to the prediction of mortality.

TABLE 3. Univariable and Multivariable Logistic Regression Analyses of Factors Related to Mortality

Characteristics	Univariable		Multivariable	
	OR	95% CI	OR	95% CI
Sex, male	1.7	1.4–2.2		
Age				
Per year	1.05	1.05–1.06	1.08	1.06–1.09
Per 10 y	1.67	1.58–1.76	2.08	1.86–2.30
TBS				
Per 1%	1.09	1.08–1.10	1.10	1.09–1.11
Per 5%	1.56	1.50–1.62	1.61	1.52–1.70
Per 10%	1.67	1.58–1.76	2.60	2.32–2.90
Inhalation injury	17.8	13.7–23.1	3.1	2.2–5.0
Comorbidity				
Circulatory	4.4	3.2–6.1	1.6	1.0–2.6
Respiratory	1.4	0.9–2.3		
Gastrointestinal	3.3	2.2–5.0		
Urogenital	2.2	1.3–3.7		
Locomotor	2.7	1.8–4.0		
Endocrine	4.6	3.1–6.9		
CNS	3.9	3.0–5.0	2.4	1.6–3.4

Predicted Mortality

The observed mortality rate in the total population, including 96 patients who received TLC, was 6.5% (286 of 4,389 patients). The revised Baux score was used to calculate the probability of death for our population. The distribution of the survival probability estimates was divided into 10 equally sized groups (Table 4). Each patient in the RBC had an estimated probability of death. For example, in the 81st to 90th percentile, the expected number of death is 24; the observed number of death was 34 in this group.

TABLE 4. Observed and Predicted Deaths (Hosmer-Lemeshow Test)

Risk of Death*	Total Patients	Revised Baux Score	Predicted Mortality		Observed Mortality	
			Percentage	n	Percentage	n
Percentile	n	Mean	Percentage	n	Percentage	n
1–10	564	4.5	0.0	0	0.2	1
11–20	318	8.0	0.0	0	0.0	0
21–30	477	13.6	0.0	0	0.2	1
31–40	414	22.9	0.1	0	0.0	0
41–50	446	32.3	0.2	1	0.2	1
51–60	424	40.9	0.4	2	0.2	1
61–70	431	50.5	0.8	3	0.9	4
71–80	451	60.7	1.7	8	2.7	12
81–90	424	76.4	5.7	24	8.0	34
91–100	431	109.1	40.2	173	53.8	232
Total	4,380	41.4	4.8	211	6.5	286

Patients ranked according to increased probability of death. Patients in the 91st to 100th percentile groups are those with the highest predicted probability of death.

The Hosmer-Lemeshow test, which is based on an analysis of the differences between the observed and predicted number of death in each of the percentile groups, was technically not possible because of empty cells in groups with a low Baux or revised Baux index. In the high percentile groups with revised Baux scores greater than 75, predicted mortality underestimated the observed mortality.

The discriminative power of the revised Baux score was assessed by ROC curve analysis (Fig. 1).

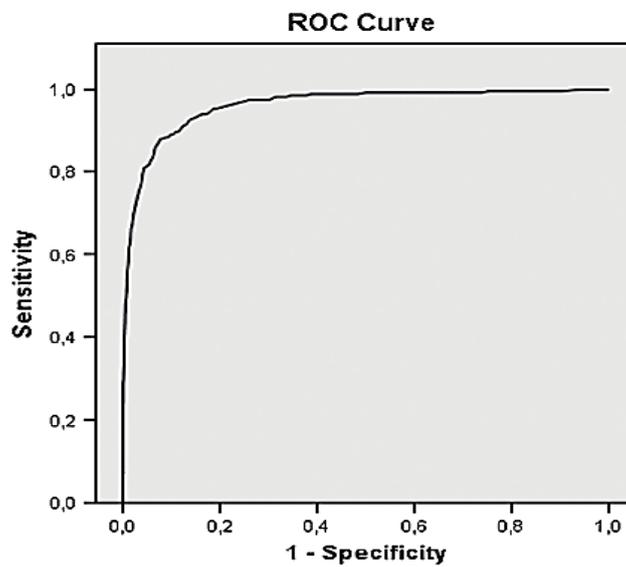


Figure 1. ROC curve of predicted mortality compared with observed mortality, based on 4,389 burn patients. AUC analysis, 0.96 (95% CI, 0.95–0.97).

The revised Baux score had a high predictive value for mortality in our patients with acute burn injury; the AUC was 0.96 (95% CI, 0.95–0.97).

An identical curve analysis was made for patients for which the model was suggested to fit the best, namely, patients between 20 and 80 years of age, with a TBS between 30% and 80%⁸ (Fig. 2). Of all patients admitted to the RBC, 247 were included in this subgroup, 109 (44.1%) of these patients died. The AUC was 0.81 (95% CI, 0.76–0.87).

Exclusion of the TLC did not change the goodness of fit of the model.

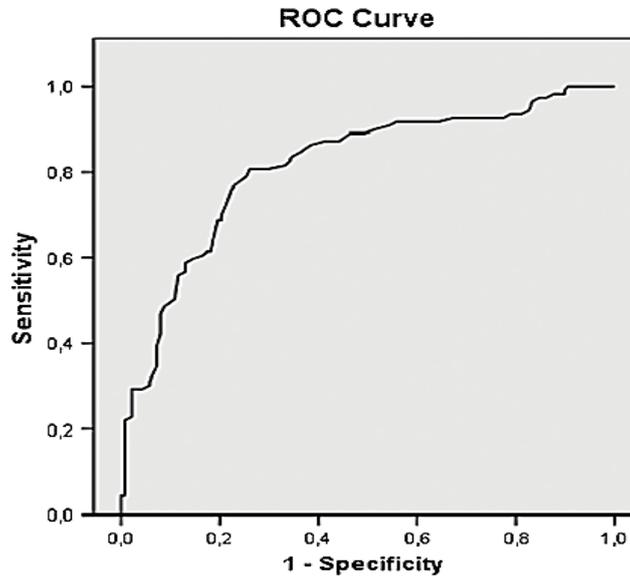


Figure 2. ROC curve of predicted mortality compared with observed mortality in a subgroup of 247 burn patients between 20 years and 80 years of age and with a TBS between 30% and 80%. AUC analysis, 0.81 (95% CI, 0.76–0.87).

DISCUSSION

In the first part of our study, we described demographics and comorbidity of patients admitted to the RBC, comparing survivors and nonsurvivors. Patients who did not survive were significantly older, had a higher TBS, more frequently had an inhalation injury, and apart from preexisting respiratory tract diseases, had more premorbid conditions, compared with survivors.

More specifically looking at factors related to mortality, contrary to the trend in trauma in general, male sex had a higher risk in univariate analysis. In univariable and multivariable analyses, increasing age, TBS involved, and the presence of inhalation injury considerably contributed to mortality: The ORs increased per age period (2.08 per 10 years of age) and percentage of burns (2.60 per 10% TBS). Inhalation injury was the strongest predictor in univariable (OR, 17.8) and multivariable analyses (OR, 3.1). Considering the impact of age, TBS, and inhalation trauma, increasing age and larger TBS at some point will have a higher impact on mortality than inhalation injury.

Concerning comorbidity groups of premorbid conditions were defined. These groups were based on tracts without distinction between complaints and severity. For example, the subgroup CNS contained patients with neurologic problems such as like neuropathy,

cerebrovascular accidents, and psychiatric problems such as depression, dementia, and suicidal attempts. Multivariable logistic regression analysis suggested that circulatory and CNS pre-morbid conditions were important contributing factors of mortality (OR, 1.6 and 2.4, respectively).

Finally, the revised Baux score was externally validated.

The revised Baux score was developed starting from patients of the American NBR but never before validated in an external population.⁸ Calibration was limited in the higher revised Baux scores, underestimating mortality in our population. ROC curve analysis revealed a good discriminative power, with an AUC of 0.96 for the total population, implying a high specificity and sensitivity of the revised Baux score in our patients.

Osler et al. assumed that the revised Baux score performed the best in predicting mortality for patients between the ages of 20 years and 80 years with TBS values between 30% and 80%.⁸ Contrary to this assumption, the AUC concerning these patients in our population was slightly lower compared with the overall population and showed a larger CI. This indicates that the revised Baux score has a higher predictive value for mortality in the total population of patients with acute burn injury than in a subgroup of patients suggested to have the best success in predicting mortality.

The differences between our data and the data of Osler et al. can be the consequences of differences in study period, geography, methodology, and patient population.¹¹

Data used in the NBR included the time frame 2000 to 2008. Our data from 1987 to 2009 therefore also contained less recent information. Although mortality rates in acute burn injuries were higher in the past, the trend of mortality rates was constant for this entire period in the RBC.

Geographic transportability should not interfere with the results. Our burn center is one of three burn centers in the Netherlands. The data from the NBR were collected from burn centers in America, both continents having a comparable standard of burn care.

Methodological transportability of this study may be suspect. First of all, the number of 39,888 patients studied in the NBR differs from the total of 4,389 patients evaluated in our review. Furthermore, there may be a difference in diagnosing inhalation injury. In the RBC, inhalation injury predominantly is a clinical diagnosis. Osler et al. did not report on which basis the diagnosis inhalation injury was made.

The 6.5% total mortality rate in this study was higher than the 3.7% mortality rate of the NBR. This could be the result of the inclusion of patients who received TLC in the subgroup of nonsurvivors. In our study, 286 patients did not survive, from which 96 received TLC (33.6%). When these patients were excluded, the mortality rate would be 4.3%.

The populations of the RBC and the NBR both include patient with burns admitted to a burn center setting. The population of the RBC contains patients admitted with acute burn injuries; no patients were excluded. In the NBR database, patients with missing data or survival status were excluded.

The mean age of the patients in the RBC was 29.1 years, comparable with the mean age of the patients in the NBR (30.6 years), as was the mean TBS (RBC, 10.5%; NBR, 9.7%). We suggest that the minor difference in mortality rate of patients with an ITT of 4.3% (RBC) versus 3.7% (NBR) may be caused by the difference in incidence of inhalation injury and premorbid conditions. In the RBC patients, 10.5% had an inhalation injury versus 7.4% of the patients in the NBR. In our population, premorbid circulatory and CNS problems were a significant contributing factor of mortality. In the NBR analysis of Osler et al.,⁸ data on patients' comorbid conditions were absent.

The absence of the patients' comorbid conditions is an important limitation of the revised Baux score. As stated by Osler et al.,¹⁰ clinicians know that a patient's death is sometimes more of the result of a preexisting condition.

One could presume that the discriminative power of the revised Baux logistic was not maximal, owing to the absence of preexisting circulatory and CNS conditions in the model. Although our results do indicate that inclusion of premorbid conditions could improve the model, we refrained from extension of the formula. Frequently, at the time of admission to a burn center, the patient's history is unknown. Premorbid conditions are limited, available at admission to a burn center, and therefore limit its inclusion in the revised Baux score. Furthermore, the greater is the complexity of the model, the less is its clinical applicability.⁹

The revised Baux score alone does not determine whether to treat a patient with extensive burns. There are obviously more factors involved. The revised Baux score may help the clinician in his or her decision to choose for ITT or TLC.

Lastly, our study contains data of one burn center. We recommend additional external validation studies including data from other burn centers or from different countries.

A recent review by Hussain et al.¹² on the methodology of composite prediction models of burns concluded that the revised Baux score has been constructed using appropriate methodological standards, except for one point (in case of missing data, cases were excluded). In our burn center, we continue to use the revised Baux score because of its simplicity, taking its limitations into account. The score is as easy to calculate as the original Baux score. For a precise prediction of mortality, a nomogram or calculator can be used.

In a recent systematic review, Hussain et al.¹² concluded that although a variety of complex models for predicting mortality in thermal injury have been devised, only a limited number of models have been constructed using appropriate methodological standards. So, progress has been made, but further evaluation in independent patient populations and data sets is necessary to identify the ones best suited for outcome prediction and performance monitoring.¹²

CONCLUSION

The revised Baux score reveals a high specificity and sensitivity in patients with acute burn injuries in our hospital. The score less adequately predicts survival in case of higher revised Baux scores. Premorbid cardiovascular and CNS disorders could be factors related to mortality, but to gain full insight in the merits of the revised Baux score and its external validation, larger sample sizes, including data from other hospitals, would be required.

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