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A nomogram for calculation of the Revised Baux Score

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ABSTRACT

Since its original publication, the revised Baux score for mortality prediction in burns patients has been widely adopted. It uses readily available measures, and it is based on regression analysis from actual data rather than a theoretical model. However, the necessary calculations are too complex to perform with anything other than a scientific calculator or dedicated software, which may create issues in a clinical setting where access to electronic devices may be limited.

We designed a nomogram capable of performing the calculation to a high degree of accuracy, and evaluated its performance on a set of randomly generated patient data to ensure that the nomogram gives accurate and repeatable results. The nomogram has a bias of −0.003 percentage points, with limits of agreement −0.3619 to 0.3550 and a repeatability coefficient of 0.29 percentage points.

We feel that the nomogram's accuracy, low cost, speed and ease of use would make it a very useful adjunct during the initial assessment of burns patients. It could also realistically be used to crosscheck calculations made by other methods.

1. Introduction

1.1. *Accurate prediction of mortality*

Objective probability estimates for the predicted mortality of patients with burns provide clinicians with information to aid decision making regarding clinical management, resource allocation and efficacy of treatment. An ideal mortality scoring system must have good predictive value (accuracy), repeatability, and generalizability to a wide range of institutions and patient demographic groups. For practical purposes, it must require relatively few and readily measurable input variables; which are combined through a simple calculation or algorithm to provide an output estimate of mortality (P) as a continuous variable on a percentage scale, rather than as a percentage range or categorical variable. The main predictor variables which determine mortality (%) following burn are: age (years), total body surface area burned (TBSA, %), and inhalation injury [1–3]. These have been used as the basis for a number of scoring systems [4–7].

The Revised Baux Score described by Osler et al. [5] has been widely adopted as it uses the above predictor variables to produce outcome estimates on a continuous scale, and is based on linear regression analysis of real patient data rather than a theoretical model. However the necessary logistic regression calculations are too complex to perform by mental calculation, and even with the aid of an electronic device

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(calculator, computer or dedicated smart phone app), data entry errors may occur. Osler et al. describe a graphic conversion scale to facilitate calculation, however their method still requires the user to perform part of the calculations by other means. We have therefore developed and evaluated a more comprehensive nomogram to rapidly calculate the Revised Baux Score, and provide a permanent record of the whole calculation which may be filed in the patients' records.

2. Method

2.1. Nomogram development

Routine techniques of analytic geometry [8] were used to convert each of the algebraic formulae for the Revised Baux Nomogram (Fig. 1a and b) into Standard Algebraic form; whereby the formulae are expressed as the sum or product of a series of functions which are equal to zero (Fig. 1c and d). These were then converted into Matrix Determinant ("Design Determinant") form (Fig. 1e and f); and multiplied by transformational matrices to adjust the size and proportions of the axes to produce the Constructional Determinant matrices. Each row of the Constructional Determinant Matrices represents a variable from the original algebraic formula (age, TBSA, mortality); and an axis in the resulting nomogram. The first and second columns define the relationship between the *x* and *y* Cartesian coordinates of the tick marks on the nomogram scales. This procedure resulted in a pair of three axis parallel scale nomograms: one for "Inhalation Injury" and one for "No Inhalation Injury". A two-dimensional nomogram cannot normally accommodate more than three variables. Further transformation matrices were therefore applied to make the two nomograms congruent, so that they could be combined in a single three-axis nomogram with shared axes and a central axis for TBSA which was calibrated for both "Inhalation Injury" and "No Inhalation Injury".

Graphic software (*PyNomo*, open-source software available from http://www.pynomo.org; *Rhinoceros*™, McNeel North America, Seattle, Washington, USA; *Illustrator*™, Adobe Systems, San Jose, CA, USA) was used to aid transformation and plotting of the resulting nomogram. The regression equations would require the axes to be of infinite length to accommodate predicted mortality scores in the range 0–100%. Axes were therefore truncated to ranges of 1–99%.

Principles of graphic and typographic design were applied to maximise legibility and ease of use. These include the use of a specialist typeface, *Tall Man* lettering, written instructions, icons to aid identification of the axes, and a thumbnail diagram illustrating method of use [9,10]. The nomogram was printed onto A4 paper in portrait format (Fig. 2).

2.2. Method of use

A straight line (isopleth) connecting the appropriate scale values for Age and TBSA (with or without inhalation injury) will indicate predicted mortality (%) at its point of intersection with the third axis. Measurements falling between scale marks of the nomogram are interpolated as appropriate for the scale graduations.

2.3. Evaluation

Although the mathematical construction of the nomogram was sound, the authors elected to evaluate its practical utility by comparison against spreadsheet calculations using simulated clinical data.

A spreadsheet (Excel™, Microsoft, Redmond, Washington, USA) was used to randomly generate 100 sets of simulated patient values for age (range 1–100 years), TBSA (range 1–99%), and presence or absence of inhalation injury. The predicted mortality (%) was then calculated independently by the authors in each case using the nomogram. Bland–Altman analysis was used to assess the accuracy and repeatability of the results [11]. No conscious bias was exercised in performing the calculations, and the authors were blinded to the results calculated by each other and by the spreadsheet until analysis was completed. It was decided a priori that the results calculated by the first author would be used for accuracy calculations, while the results calculated by the second author would be used for repeatability calculations.

3. Results

No difficulties were encountered in using the nomogram.

	No Inhalation Injury		Inhalation Injury	
Original equation	$P = \frac{e^{-8.8163 + (0.0775 * (Age + TBSA))}}{1 + e^{-8.8163 + (0.0775 * (Age + TBSA))}}$	(a)	$P = \frac{e^{-8.8163 + (0.0775 * (Age + TBSA + 17))}}{1 + e^{-8.8163 + (0.0775 * (Age + TBSA + 17))}}$	(b)
Standard form	$0 = -\log\frac{P}{1-P} - 8.8163 + 0.0775\,Age + 0.0775\,TBSA$	(c)	$0 = -\log\frac{P}{1-P} - 7.4988 + 0.0775\,Age + 0.0775\,TBSA$	(d)
Determinant form	$0 = \begin{vmatrix} 0 & 0.0775\,Age & 1 \\ \frac{1}{2} & -\frac{1}{2}(0.0775\,TBSA - 8.8163) & 1 \\ 1 & -\log\left(\frac{P}{100-P}\right) & 1 \end{vmatrix}$	(e)	$0 = \begin{vmatrix} 0 & 0.0775\,Age & 1 \\ \frac{1}{2} & -\frac{1}{2}(0.0775\,TBSA - 7.4988) & 1 \\ 1 & -\log\left(\frac{P}{100-P}\right) & 1 \end{vmatrix}$	(f)

Fig. 1 – Mathematical functions used to construct the Revised Baux Score nomogram.