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A model of British in-hospital mortality among burns patients☆

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ABSTRACT

Introduction: Mortality among patients treated in hospital for burn is routinely examined, but none of the many models in use in the UK was developed using nationwide data. The aim of this research was to develop a prediction model using national data, representative of the British population.

Methods: Data were gathered from the international Burns Injury Database (iBID) and included 66,611 patients from England and Wales from 2003 to 2011. Core variables were selected following systematic review of the literature, expert consultation and then supplemented with variables selected through logistic regression. Discrimination and calibration of the model were assessed using the area under the receiver operating characteristic curve and the Hosmer–Lemeshow χ^2 test respectively.

Results: Overall mortality for the years of the study in England and Wales was 1.27%. Mortality was predicted by age (and quadratic term) total burn surface area, presence of inhalation injury, presence of existing disorders and category of injury. The model gave a discrimination area under the curve of 0.97 in both internal and external validation. The calibration of the model gave a Hosmer–Lemeshow χ^2 of 11.9 ($p = 0.3$).

Conclusion: We have reported a strongly predictive and theoretically well-founded model of in-patient mortality using nine years of data from all burn care services in England and Wales. We recommend this model for British burn service development and for international consideration of the variables to use in developing similar models with other data sources.

1. Introduction

Mortality among burn patients has fallen substantially over recent decades [1–3]. Severe burns, however, continue to occur, for which mortality is still common. A number of outcomes may be used in burn prognosis but mortality is the commonest – death being a universally important statistic that is recorded accurately. Other outcomes include length of stay (LOS) in hospital [4], but due to the nature of burns LOS does not always reflect the severity of the injury. Even minor burns can result in long stays for psychological reasons or reconstructive surgery. Quality of life is an important metric of

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the long term consequences of burns [5,6], but this measure is not consistent and not standardised across age, socioeconomic and ethnic groups.

In recent years, the UK's Departments of Health have changed how performance is measured. They have moved from process-based indicators to measuring clinical outcomes [7]. Inpatient mortality and LOS are important clinical outcomes that may be used in measuring the performance of, and allocating resources to, burn services.

Mortality prediction of burns has been used since 1902 when the first model was developed by Wiendenfeld. This model used total burn surface area (TBSA) and age as the sole predictors of in-patient death [8]. Since then many models have been developed, with most having similar predictors. It was not until 1982 that Tobiasen etal. developed a model, based on multivariate logistic regression [9], the Abbreviated Burn Severity Index (ABSI), which included wider factors, notably the presence of inhalation injury.

With the increased provision of data there has been an increased number of prediction models in the literature. To date there are approximately 45 models published that attempt to predict mortality in burn patients [10]. The majority of these models were developed in regional burn centres with a small sample size. There is a concern about the performance of those models some of which can be attributed to the development methodology of the older models, for example categorising continuous variables, and to a lack of regular calibration checks [11–15].

The aim of this study was to develop a model that accurately and reliably predicts in-hospital mortality in the UK and can be used as soon as the patient is admitted to the burn service using a developmental methodology that can be used to re-calibrate and test the model in the future.

2. Methods

2.1. Data

This was a retrospective population based study which took data from all of the burn services in England and Wales for the years 2003–2011. Data were collected from the international Burn Injury Database (iBID), which has routinely captured the data from all English and Welsh burn services since 2003. The database was established primarily for service monitoring. All UK burn services have adopted the iBID system. The data are prospectively collected locally then uploaded monthly to a national server after removing patient-identifiable information [16].

Our iBID data extract included all patients admitted to a specialised burn service in the years 2003–2011. In the specialised burn services many variables are recorded on admission, not just TBSA, existing disorders, and type of injury. More than 500 variables are recorded in iBID. In-hospital mortality is routinely captured in iBID and audited.

2.2. Model development

The model was developed based on expert opinion from clinicians involved in UK audits of burn services and from the literature. This led to a long-list of variables to consider as predictors of death in the hospital admission following burn. From the literature it was noted that all burn mortality prediction models include age and TBSA [10]. Logistic regression with backward selection was used to refine the choice of predictors and adjustments for possible confounding. A significance cut off level of 0.05 was used for the selection. Model fits were assessed using the Akaike Information Criterion (AIC). A temporal validation split was performed for development and validation purposes. The dataset was split into 54,822 patients for deriving the model and 11,789 for validating it. The data was split based upon the year of the records. The dataset selected for development of the model consisted of the years 2003–2010 thus year 2011 was retained for validation. The model's discrimination and calibration were assessed using the area under the receiver operating characteristic (ROC) curve and the Hosmer–Lemeshow χ^2 test respectively. All data cleaning and analysis was performed with Stata Version 12 (StataCorp LP, College Station, TX).

3. Results

More than 84,747 patients were assessed by the specialised burn services in England and Wales for the period of 2003–2011. Scholastic data cleaning was performed: 6832 patients were excluded due to missing outcome data and 11,304 due to other missing variables. Missingness was investigated by simple techniques such as missing value to get the basic statistical values such as the mean, median or mode as well as more computationally challenging, multiple imputations. These techniques did not change the model therefore complete case analysis was used for the modelling. After data cleaning 66,611 (78.6%) complete patient records were available for analysis. The mean (SD) age of the patients was 25.5 (23.5), ranging from 0 to 110 years. The mean (SD) TBSA was 3.96 (8.3). Inhalation injury was present in 776 (1.2%) patients – defined as the attending clinician's note of moderate or severe inhalation injury and if the patient underwent intubation and mechanical ventilation. 847 (1.3%) out of 66,611 patients died during their hospital stay following burn (Table 1). Mortality rates, average age, TBSA and percentage inhalation injury were approximately the same in the derivation and validation data sets.

3.1. Development of the model

Mortality in the derivation dataset was 1.35%. The mean (median, IQR) TBSA was 4.17 (1.50, 3.50). Mean (SD) age was 25.14 (22.13) years. Inhalation injury was present in 1.22% of patients. The relative frequency of patients with more than 3 existing disorders was 3.63%. The relative frequencies of injury types were 17.85% for flame, 7.92% for flash, 21.97% contact, 40.36% scalds, 6.60% chemical and 5.31% others (this category included electrical, radiation, friction, cold and non-skin burns). The summary statistics of the development dataset by gender and overall can be found in Table 1. Univariate analysis showed that age, TBSA, inhalation injury, more than three existing disorders and the type of injury wereeach significantly correlated with mortality. Age plus aquadratic term to account for some non-linearity in age