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Case study

Prognostic model for patients with traumatic brain injuries and abnormal computed tomography scans

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A B S T R A C T

Traumatic brain injury (TBI) is an important cause of death and disability worldwide. The prognosis evaluation is a challenge when many variables are involved. The authors aimed to develop prognostic model for assessment of survival chances after TBI based on admission characteristics, including extracranial injuries, which would allow application of the model before in-hospital therapeutic interventions. A cohort study evaluated 1275 patients with TBI and abnormal CT scans upon admission to the emergency unit of Hospital das Clinicas of University of Sao Paulo and analyzed the final outcome on mortality. A logistic regression analysis was undertaken to determine the adjusted weigh of each independent variable in the outcome. Four variables were found to be significant in the model: age (years), Glasgow Coma Scale (3–15), Marshall Scale (MS, stratified into 2,3 or 4,5,6; according to the best group positive predictive value) and anysochoria (yes/no). The following formula is in a logistic model (*USP index to head injury*) estimates the probability of death of patients according to characteristics that influence on mortality. We consider that our mathematical probability model (*USP Index*) may be applied to clinical prognosis in patients with abnormal CT scans after severe traumatic brain injury.

1. Introduction

Traumatic brain injury (TBI) usually presents with a broad spectrum of symptoms and disabilities [1,2]. Worldwide, every year millions require treatment after TBI. The disability rates is related to the severity and mechanisms of the TBI and unfavorable outcomes (Glasgow Outcome Scale 4,5 or 6) following TBI are quite prevalent [1–5].

Creation of a prognostic model, with many variables, to stratify the risk for an individual patient is a challenge [6]. The accurate prediction of long-term outcome, after emergency neurological assessment combining individual biological predictors, tomographic findings and extracranial injuries is very complex [6–8]. Specific patient characteristics may affect the outcome in opposite directions [8,9].

The importance of baseline clinical and computed tomographic (CT) characteristics for survival probability and prediction of long-term outcome has been investigated by many studies [10–14]. Such prediction of outcome may support clinical decision-making and resources allocation. When patients are classified according to risks, the data may be useful to compare outcomes, surgical results or even, stratify patients for future clinical trials [7,8].

The majority of models was developed using small sample sizes and includes few data obtained after admission [15]. The significance of extracranial injuries has no consensus. While many studies demonstrated that outcome is related to the severity of the primary cerebral damage others emphasize the importance of extracranial injuries [6,7,9]. Besides all variables included in different models, the external validation of these are critical to clinical applicability [10].

In this paper the authors aimed to develop a prognostic model for assessment of survival chances after TBI based on admission characteristics, including extracranial injuries and, in addition, demonstrate that many variables that are included in well-

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known clinical models are not significant. The purpose of this model is to be applied before in-hospital therapeutic interventions.

2. Methods

Our cohort study evaluated 1275 patients with TBI and abnormal CT scans upon admission to the emergency unit of Hospital das Clinicas of University of Sao Paulo between September 1, 2003 and December 31, 2009. The primary objective was to analyze the final outcome on mortality. Clinical and radiographic data were prospectively collected and entered into our database. The demographic data, mechanism of cranial trauma, Glasgow Coma Scale, anisocoria, presence of thoracic lesions, abdominal injuries, upper limbs fractures, lower limbs fractures, hip fractures and neurosurgical intervention were compiled. The Marshall scale and midline deviation were documented. Sedation before neurological assessment, hemodynamic instability or CT scan without abnormalities (Marshall I patients) were excluded from our analysis.

Multivariate logistic regression analysis, chi-square test or the likelihood ratio tests were used to evaluate the effects of patients' demographics, type of TBI, and extracranial injuries in mortality. Age, ethnics, gender, etiology of trauma, spinal fractures, thoracic trauma, abdominal lesions, upper and lower extremities fractures, GCS score, fixed pupillary response on hospital admission, Marshall classification, midline shift deviation were included in our analysis.

The influence of age and Glasgow Coma Scale on mortality was estimated with the use of summary measures (mean, standard deviation, median, minimum and maximum) and Student's *t*-test.

Logistic regression analysis was used to analyze the adjusted weigh of each independent variable in the outcome. According to our results in the multivariate analysis and adjusted weight, four variables were found to be significant in the model: age (years), Glasgow Coma Scale (3–15), Marshall Scale (MS, stratified into 2,3 or 4,5,6; according to the best group positive predictive value) and anysochoria (yes/no).

After interpretation of the adjusted weight of significant variables a mortality probability calculator was developed using as input the logit (p) obtained from the analysis applying those four independent variables. The tests were performed at a significance level of 5%.

3. Results

3.1. General characteristics

Baseline data is presented in Table 1. Most patients were men (81%). More than half (75%) of participants were caucasians. Road traffic crashes represented the most common cause of injury (54%). Young people (less than 30 years) were involved in 39% of hospital admission. The general mortality was 19.1%. The mortality increases with increasing age of the patient ($p < 0.001$). Ethnics were statistically associated with mortality, 26% of Caucasian people died versus 16% of others ($p = 0.03$).

3.2. Extracranial injuries and mortality

The presence of spinal fracture was associated with lower mortality in the univariate analysis. Of 169 spinal fractures in this series only 8 patients (5%) died, while 21% of patients without spinal fractures died ($p < 0.001$). Spinal fractures were detected in 20% of patients classified as Marshall 4, 5 or 6 and 6% of patients classified as Marshall 2 or 3 ($p < 0.001$). Thoracic, abdominal, pelvic lesions and upper or lower limbs fractures were not associated with higher mortality in these patients (Table 2).

3.3. Computed tomography findings

Marshall degree is statistically associated with mortality ($p < 0.001$). Midline deviation is a significant factor in increasing mortality ($p < 0.001$). Despite exclusion of analysis Marshall I patients, any category above Marshall II increases the risk of death. This was especially observed in Marshall VI when compared with Marshall V patients (Table 2). When grouped the overall mortality of Marshall II and III was 12% and Marshall IV, V and VI was 26% ($p < 0.001$).

3.4. Glasgow Coma Scale and anisocoria

The average Glasgow Coma Scale of patients who die is statistically lower than the patients who survived ($p < 0.001$) (table 3). The 1-point increase in Glasgow scale causes a 19% reduction in the chance of mortality of the patient. Pupillary abnormalities were associated with higher mortality ($p < 0.001$). The mortality of anisocoric patients was 38% and 16% for isocoric patients ($p < 0.001$). Patients with anisocoria have 67% higher chance of mortality (Table 2).

3.5. Neurosurgical intervention

Patients ($n = 601$) were operated on following current literature recommendations for the neurosurgical management of patients with traumatic brain injury. For lesions with more than 50 cm^3, the decision were easier, and usually in favor of surgery. For lesions with volume less than 25 cm^3 the conservative management were prefered. When the lesion volume was between 25 and 50 cm^3 associated factors, as midline shift, cisterns aspects, and Glasgow Coma Scale were considered for surgical indication.

3.6. Multivariate analysis

A logistic regression analysis was undertaken to define the adjusted weigh of each independent variable in the outcome. Four variables were found to be significant in the model: age (years), Glasgow Coma Scale (3–15), Marshall Scale (MS, stratified into 2,3 or 4,5,6; according to the best group positive predictive value) and anysochoria (yes/no). Data from the regression analysis, odds ratio with IC 95%, beta-coefficients and p-values from the four independent variables included in the model are presented in Table 4.

The following formula is in a logistic model (we call it *USP index to head injury*) estimates the probability of death of patients according to characteristics that influence on mortality:

Logistic regression equation: logit (p) = -1.36 + (age * 0.03) + (GCS * -0.2) + (MS 4,6 or 6 * 0.72) + (anysochoria * 0.58). Probability = 1/1 + e–logit (p).

Constant: -2.04. Hosmer and Lemeshow test: $p = 0.24$, area under the curve (AUC): 0.77 (-0.74–0.79).

Based on this logistic equation, a mortality probability calculator (Supplementary material) was developed using as input the logit (p) obtained from the analysis applying those four independent variables. As shown in the example (Fig. 1), the death probability of a patient aged 65, with a GCS of 7, a MS of 4, with no anysochoria is estimated to be around 47.7%. The significance level of 5% was considered.

4. Discussion

Neurotrauma is an expressive public health problem. It is a heterogeneous disease and outcomes for individual patients are very difficult to predict. There are many variables as mechanism