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Predicting Prognosis of Isolated Head Injury: A Computer-Based Model with Simple Variables

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ABSTRACT

Objective: Over one hundred predictive models were defined in the past for head injury (HI) prognosis, but none of them have been widely used up to the present. The aim of this study is to predict the prognosis of isolated HI patients by simply using data from the first day after injury.

Materials and Methods: Data of head injury patients in Trakya University Hospital between January 1996 and December 2006 were obtained from records. The age, gender, causes of HI, basic neurologic examination findings, radiologic findings and discharge status are examined.

Results: Most of the data were simplified as absent (0) and present (1), and mortality rates for each groups were accepted weighted values. All data were processed statistically and two models were created. Model 1 with Glasgow Coma Scale (GCS) score predicted the mortality/vegetative event at a rate of 56.5%, and the conscious survival event at 98.7%. Model 2, without the GCS score, predicted the mortality/vegetative event at 55.1% rate and the conscious survival event at 99.2%.

Conclusion: Both models could be used for informing the patient and relatives and helping them to understand the severity of HI in busy working conditions of emergency departments.

Key Words: Computer-based model, head injury, outcome, prediction

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Introduction

Head injury (HI) is one of the leading causes of death and disability throughout the world. Although it affects all age groups, HI is the major cause of death and disability especially in the young population (1, 2). Assessment of severity of the injury, triage, prediction of prognosis, and family counseling are all integral parts of patient care in patients with HI. Amongst them, prediction of the prognosis plays a key role because it directly affects the selection of the treatment of choice, facilitates clinical management, and is fundamental in family counseling. Currently, prediction of the outcome of patients with HI is not easy to achieve because of the heterogeneity of the patient data, including differences of trauma causes, additional injuries, and personal variables such as age, general health condition, and existence of systemic diseases (3). Presently, the GCS is an important tool in clinical care because of its wide acceptance and ease of application (4). However, determination of the GCS score is often difficult in daily routine, because of early sedation, intubation or bilateral periorbital swelling, etc. (3).

Some recent studies have tried to determine factors affecting the outcome following HI, including demographic, epidemiological, clinical, and radiological findings such as; age, cause of injury, Glasgow Coma Scale (GCS) score, pupillary response, computerized tomography (CT) parameters etc. (1, 3-14). In the literature, more than one hundred recent studies, most of them from developed countries, were designed for predicting the prognosis after HI (15). Most of the developed models have not been used widely as yet, because of their complexity and poor reliability (16).

This study aimed to establish a novel and easy method to predict prognosis of patients with isolated HI using demographic, epidemiological, clinical and radiological parameters. Special emphasis was placed on making the method easy to apply in busy emergency settings.

Patients and Methods

Data obtained from patients who were hospitalized for HI between January 1996 and December 2006 in the neurosurgery and intensive care departments of our university hospital were reviewed. The hospitalization criteria for patients were either having a GCS point ≤14 or GCS=15 with some injury findings such as large scalp incisions or large scalp hematomas or calvarial or intracranial lesions detected on direct X-rays or cranial CT. During the investigation period, 1550 patients were hospitalized with the diagnosis of HI. Multi-traumatized

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patients were excluded from the study, in an attempt to eliminate confounding factors affecting the outcome. Also, patients who did not arrive at the emergency department (ED) on the first day after trauma were excluded. Of 978 patients having those criteria, 919 had clear GCS scores on their data chart, and they were included in the study.

Collected data included gender, age, cause of trauma, first neurological examination and radiological findings in the ED, requirement of surgical operation on the first day, and Glasgow Outcome Score (GOS) at the time of discharge.

Ten different trauma causes were identified from the patients' data. These causes were classified into four trauma groups (TG), ranked by mortality rate as depicted in Table 1.

Neurological data included GCS score, pupillary anisocoria (PA) and reactivity (PR), difference of right and left upper extremity motor responses (DUEMR) in the ED. PA was defined as more than one millimeter difference between right and left pupillary diameter, and coded as 0 (absent) and 1 (present). PR was coded as 0 (both pupil reactive to the light), 1 (one pupil responsive, other non-responsive), and 2 (both pupil non-responsive). DUEMR was coded as 0 (same muscle strength in both upper extremities) and 1 (there is difference).

Radiological findings were classified as cranial linear fracture (CLF), craniobasal fracture (CBF), closed depression fracture (CDF), open depression fracture (ODF), epidural hematoma (EDH), subdural hematoma (SDH), traumatic subarachnoid hemorrhage (tSAH), cerebral contusion (CC), intracerebral hematoma (ICH), cerebral edema (CE) and axonal injury (AI). Each finding was coded as either absent (0) or present (1).

According to whether the patient underwent surgery, the patients were grouped as non-operated (OP0), operated without intracranial mass effect (OP1), and operated for intracranial mass effect (OP2).

All patients who had a GCS score of 8 or less were treated in the intensive care unit. The others were treated in the neurosurgery ward.

Outcome was evaluated using the GCS score at the time of discharge; where 1=dead, 2=permanent vegetative status, 3=severely disabled, 4=moderately disabled, 5=independent.

We described different weighted values for each parameters which are dependent on each group's mortality rate: TG1= 0, TG2= 4, TG3= 8, TG4= 55, PA0= 9, PA1= 43, PR0= 5, PR1= 26, PR2= 92, DUEMR0=9, DUEMR1=40, SDH0= 8, SDH1= 42, CLF0= 12, CLF1= 13, CBF0= 6, CBF1= 15, CDF0= 11, CDF1= 28, ODF0= 11, ODF1= 25, EDH0= 12, EDH1= 13, SDH0= 8, SDH1=42, tSAH0= 7, tSAH1= 34, CC0= 9, CC1= 24, ICH0= 11, ICH1= 56, CE0= 5, CE1= 32, AI0= 15, AI1= 0, OP0= 8, OP1= 2, OP2= 39.

Statistical analysis

The numeric results were expressed as mean±standard deviation (SD), and categorical results were expressed as a number (percentage). Normality distribution of the variables was tested using the one sample Kolmogorov-Smirnov test. Differences between groups were assessed using the Student's t test for normal and Mann-Whitney U test for non-normal distributed data. The chi-square test was used to compare the differences of categorical variables between the groups. The effect of the prognostic factors on outcome was assessed using backward stepwise logistic regression (LR) analysis. A p-value <0.05 was considered statistically significant. Statistica 7.0 (StatSoft Inc. Tulsa, OK, USA) statistical software was used for statistical analyses.

Logistic regression

LR is commonly used when the independent variables include both numerical and nominal measures and the outcome variable is binary or dichotomous, having only two values. LR can also be used when the outcome has more than two values. The LR model is expressed as follows, P (Event = Dead/vegetative)=$1/1+e^{-(\beta+\beta_1X_1+\beta_2X_2+......)}$ where x_1, x_2, . . . are independent variables, β_0 is the intercept, β_1, β_2, . . . are regression coefficients and e indicates that the base of the natural logarithm (exp=2.718) is taken to the power shown in square brackets (17).

Results

For this study, 919 patient data were studied (697 male/222 female). Patient characteristics which are shown in Table 2 were stratified by survival outcome [death/vegetative state (GOS 1 and 2) versus conscious survival (GOS 3, 4 and 5)]. Patient age ranged from 0 to 97 and the mean age was 27.8±21.3 year. Male gender (75.8%) was significantly dominant. Between death/vegetative state and conscious survival groups, gender did not significantly differ (p=0.097). However, mean age in death/vegetative group was significantly higher than that of the conscious survival group (42.5±24.0 vs. 26.7±20.6 years, p<0.001). The major reason for head injury was road traffic accident (RTA) injury with 429 (46.6%) patients. Subgroups of RTA were: inside motor vehicle (174 pa-

Table 1. Classification of trauma groups

TG1:	(Include bicycle accident and struck by/against; no mortality)
TG2:	(Include fall, assault) mortality rates= 4% (4.7%, 3.1%)
TG3:	(Include high fall, road traffic accident (RTA) (include; motor vehicle in or out, motorcycle, tractor) mortality rates= 7.9%, (7.4%, 9.2%, 6.9%, 7.4%)
TG4:	(Include penetran injury (PI); mortality rate= 55%)

Table 2. Patients' characteristics stratified by survival outcome

	Total (n=919)	Conscious survival (n=850)	Dead/ vegetative (n=69)	p
Age, years	27.8±21.3	26.7±20.6	42.5±24.0	<0.001
Sex, male	697	639	58	0.097
Cause of injury				
TG1	56	56	0	<0.001
TG 2	199	191	8	
TG 3	644	594	50	
TG 4	20	9	11	

tients; 18.9%) or outside motor vehicle (141 patients; 15.3%), motorcycle (87 patients; 9.5%), tractor (27 patients; 2.9%). The other causes were high fall (215 patients; 23.4%), fall (105 patients; 11.4%), assault (94 patients; 10.2%), struck by/against (37 patients; 4.0%), penetrating injury (PI) (20 patients; 2.2%) and bicycle accident (19 patients; 2.1%). Death/vegetative state rate was significantly differ amongst TG (p<0.001). This difference was arose from that the death rate was significantly lower in fall injury than those of PI, RTA, and high fall injuries. Additionally, the death rate of the penetrating injury was significantly higher than those of RTA and high fall injuries.

Clinical characteristics of the patients are shown in Table 2, stratified by survival outcome. The mean GCS score was 12.7±2.8.115 patients had a GCS score 8 or less (12.5%). 50 of those patients (43.5%) had GOS 1 or 2 score. 155 patients had GCS score 9- 12 (16.9%), and 17 of them had GOS 1 or 2 score (11.0%). 314 patients had GCS score 13 or 14 (34.2%) and 2 of them had GOS 1 and 2 score (0.6%). 335 patients had GCS score 15 (36.5%) and no patient had GOS 1 and 2 score in this group.

69 patients (7.5% of total) had anisocoria, and 19 of them (27.5%) had poor outcome (i.e., GOS 1 or 2). 850 patient (92.5% of total) were isocoric and only 50 of them (5.9%) had poor outcome. At the ED, 835 patients (90.9% of total) had normal bilateral PR and 35 of them (4.2%) had poor outcome. 57 patients (6.2% of total) had unilateral non-reactive pupil and 10 of them (17.5%) had poor outcome. 27 patients (2.9% of total) had bilateral non-reactive pupil and 24 of them (88.9%) had poor outcome. 825 patients (89.8% of total) had same upper extremity response, and 36 of them (4.4%) had poor outcome. 94 patients (10.2% of total) had upper extremity motor response difference, and 33 of them (35.1%) had poor outcome.

131 patients (14.3% of total) had any radiological abnormality. Totally 178 patients (19.4% of the total) were diagnosed axonal injury and none of those patients had poor outcome. 249 patients (27.1% of total) had only one radiological finding and the others had two or more. No patients had poor outcome, if the patient had only one of the following lesions: CLF (87, 9.5% of total), CBF (33, 3.6% of total), CDF (15, 1.6% of total), ODF (17, 1.8% of total), CC (22, 2.4% of total), ICH (2, 0.2% of total). In patients having only EDH (17, 1.8% of total), only one patient (5.9%) had poor outcome. In patients having only tSAH (8, 0.9% of total), one patient (12.5%) had poor outcome. In patients having only cerebral edema (33, 3.6% of total), two (6.1%) had poor outcome.

174 (18.9%) patients underwent surgery in the first day after trauma. 50 of them were operated without any IME lesions; 12 for CDF, and 38 for ODF, two patients (4%) who had severe cerebral injury findings without mass effect (GCS scores 4 and 7) ended with poor outcome. 124 patients were operated for IME lesions. EDH was the most common lesion in this group (65 patients) and 42 of them were diagnosed as having only EDH as the mass lesion. The second common lesion in this group was contusion but only one patient underwent surgery with the mass effect of this lesion. The third common lesion in this group was CE and only one patient was operated with the mass effect of this lesion, too. SDH was the fourth common lesion in this group, and only nine of them were diagnosed isolated SDH as a space-occupying lesion. 35 patients (28.2%) of this group had poor outcome.

Of the 919 patients, 67 died in the hospital and 2 were in vegetative state at discharge. As a result 69, (7.51%) patients had poor outcome.

The possible factors affecting the outcome are shown in Table 3. Primarily, we assessed them between death/vegetative state and conscious survival groups independently. When we compared prognostic factors, GCS score in death/vegetative group (the poor outcome group) was significantly lower. In addition, anisocoria, pupil reaction, hemiparesis, close depression fracture, open depression fracture, SDH, tSAH, contusion, ICH, cerebral edema rates, and operation for IME were significantly higher in the poor outcome group than that of conscious survival group (p<0.001 for all variables). In addition, operation without IME was significantly higher in conscious survival group than the poor outcome group (p<0.001). There were no significant difference in linear fracture, basal fracture, and EDH rates between the outcome groups (p>0.05 for all of them).

Table 3. Clinical characteristics of the patients, stratified by survival outcome

	Total (n=919)	Conscious survival (n=850)	Dead/ vegetative (n=69)	p
Glasgow Coma Score	12.7±2.8	13.2±2.3	7.3±2.7	<0.001
Anisocoria, yes	69 (7.5)	50 (5.9)	19 (27.5)	<0.001
Pupil reaction				
Unilateral (+)	57 (6.2)	47 (5.5)	10 (14.5)	<0.001
Bilateral (-)	27 (2.9)	3 (0.4)	24 (34.8)	
DUEMR, yes	94 (10.2)	61 (7.2)	33 (47.8)	<0.001
Cranial Linear fracture, yes	424 (46.1)	396 (46.6)	28 (40.6)	0.335
Cranial Basal fracture, yes	210 (22.9)	196 (23.1)	14 (20.3)	0.598
Close depletion fracture, yes	57 (6.2)	46 (5.4)	11 (15.9)	<0.001
Open depletion fracture, yes	73 (7.9)	59 (6.9)	14 (20.3)	<0.001
EDH, yes	123 (13.4)	114 (13.4)	9 (13.0)	0.931
SDH, yes	97 (10.6)	69 (8.1)	28 (40.6)	<0.001
tSAH, yes	164 (17.8)	129 (15.2)	35 (50.7)	<0.001
CC, yes	212 (23.1)	180 (21.2)	32 (46.4)	<0.001
ICH, yes	31 (3.4)	15 (1.8)	16 (23.2)	<0.001
CE, yes	231 (25.1)	185 (21.8)	46 (66.7)	<0.001
DAI, yes	178 (19.4)	178 (20.9)	0 (0.0)	<0.001
Operation				
Yes, not mass effect	50 (5.4)	48 (5.6)	2 (2.9)	<0.001
Yes, mass effect	124 (13.5)	89 (10.5)	35 (50.7)	

Mean±SD, n (%)

Then, prognostic variables that were found to be significant in the univariate analysis were used to construct multivariate logistic regression model. Results of the multiple logistic regression models with backward stepwise method are shown in Table 4. We constructed the models based on GOS score that was categorized as death/vegetative state versus conscious survival.

The result showed that seven variables (age, TG, GCS, PR, CDF, tSAH, and CE) that were entered to the backward logistic regression model were found to be significant factors on outcome. Predictive accuracies of this model were found as 56.5% for sensitivity, 98.7% for specificity, and 95.5% for accuracy.

After that, we made another model without GCS score and the result of second model showed that nine variables (age, TG, PR, CDF, SDH, tSAH, ICH, CE, and OP) that were entered to the backward logistic regression model were found as significant factors on outcome. Predictive accuracies of this model were found as 55.1% for sensitivity, 99.2% for specificity, and 96.0% for accuracy.

After these results, we created two spreadsheet tables for predicting outcome of isolated head injured patient to use mortality rate of each groups as a weighted value put it on the web (http://norosirurji.trakya.edu.tr/kafa-travmasi-prognoz.php.htm). Each model gives the possibility of mortality/vegetative status for patients.

Discussion

Prediction of outcome (especially mortality risk) is an integral part of care of patient with HI. Outcome prediction is not an easy task to achieve after HI, because of complexity of affecting the factors. We described two new predicting models with well described parameter by recent studies for affecting the prognosis of head injured patient (1, 3-12). In differently, the most of these parameters used in our models were simplified present or absent for easy using.

The main finding of this study is that two computerized models with good discriminative accuracy rates: 98.7% for the model 1 and 99.2% for the model 2. Model 1 constructed based on GCS, and model 2 constructed without GCS that included co-variates (Age, TG, PR, CDF, SDH, tSAH, CE, OP). The model 1 includes GCS score and makes more powerful predicting than the model 2. However, GCS score has some drawbacks such as early intubation, sedation, etc in the current medical management (3). As a result, the model 1 may be more useful for moderate and mild isolated HI, and the model 2 may be more suitable for severe isolated HI. Thus, the two models can be placed in the same spreadsheet file any computer, and can be used simultaneously.

In additional to, we think that the predictor models have to be used only informing to patients and their relationships, understanding of HI severity and never make a negative effect on patients' treatment (20).

Mortality rate was the most important factor when designing our models. We think that it will be helpful to adaptation of our model for the other medical center. They can adapt their series data in our models and create more objective results for their patient.

Our study has some limitations. It has been conducted retrospectively in patients with isolated head injury. Thus, the results here cannot be extrapolated to multiple-system injured patients. Internal or external validation is more important for predicting models (15, 18, 19), but our models have not been

Tablo 4. Results of the multiple logistic regression analysis by GOS outcome (Dead/vegetative vs. conscious survival)

	Model 1 Dead/vegetative vs. conscious survival			Model 2 Dead/vegetative vs. conscious survival		
	β	p	OR (95% CI)	β	p	OR (95% CI)
Age	0.053	<0.000	1.054 (1.033-1.075)	0.040	<0.001	1.041 (1.022-1.060)
TG	0.054	0.001	1.056 (1.022-1.091)	0.043	0.003	1.044 (1.014-1.074)
GCS	-0.535	<0.000	0.586 (0.497-0.690)	-	-	-
PR	0.026	0.005	1.026 (1.008-1.045)	0.050	<0.001	1.051 (1.034-1.068)
CDF	0.118	0.003	1.125 (1.042-1.215)	0.123	<0.001	1.131 (1.060-1.206)
SDH	-	-	-	0.024	0.043	1.024 (1.001-1.048)
tSAH	0.039	0.007	1.040 (1.010-1.070)	0.037	0.014	1.037 (1.007-1.068)
ICH	-	-	-	0.032	0.023	1.032 (1.004-1.061)
CE	0.033	0.039	1.034 (1.002-1.066)	0.065	<0.001	1.068 (1.037-1.100)
OP	-	-	-	0.039	0.003	1.040 (1.014-1.066)
Constant	-2.589	0.038	-	-9.904	<0.001	-
C statistics		0.967			0.950	

OR: Odds ratios, CI: Confidence interval
Model 1. Correctly predicted the mortality/vegetative event at a rate of 56.5% (Positive Predictive Value), and the conscious survival event at 98.7% (Negative Predictive Value)
Model 2. Correctly predicted to the mortality/vegetative event at 55.1% rate and to the conscious survival event at 99.2%

validated yet. Some predicting models have some difficulties for external validation, because of complex variables (18). On the other hand our models have simple variables, and its validation by the other centers may be easier.

We obtained two computer based models to predict outcome of patient with isolated head injury. They work by entering simplified data variables such as age, trauma etiology, GCS, etc into a spreadsheet file, and give an estimation regarding the outcome in a busy emergency setting. It can be used as an extra tool for a better triage, to direct treatment, and to inform patients or their relatives regarding the severity of the injury.

Conflict of Interest

No conflict of interest was declared by the authors.

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