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Prognostic Value of Clinical Variables in Moderate and Severe Head Injury

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Introduction. Craniocerebral injury is a leading cause of mortality and morbidity among predominantly young population. Outcome prediction after head injury can be useful as an aid to clinical decision making, to explore possible pathological mechanisms and as part of the clinical audit process. The aim of this study was to develop a simple, yet easy to use, model involving only variables which are rapidly and easily clinically achievable in routine practice.

Patients and methods. All consecutive patients older than 14 years with moderate or severe isolated head injury admitted to our department in period between 01.01.2007. and 30.06.2008. were enrolled in the study. Basic demographic and clinical data (Glasgow coma score, pupil size and reactivity, revised trauma score) were recorded. Outcome at 1 and 3 months after injury graded by GOS was used to construct a simple predictive model.

Results. We analyzed records 82 patients with moderate or severe head injury according to GCS. Multiple logistic regression resulted in a model containing age ($p=0.0001$), GCS ($p < 0.0001$), systolic blood pressure of the RTS ($p < 0.0001$; $t=7.388$) and pupil reactivity ($p < 0.0001$; $t=-5.605$) at admission as fair independent outcome predictors, with motor component of the GCS scale exhibiting greater predictive value over the entire GCS score ($p < 0.0001$; $t=5.732$).

Conclusion. All four variables (GCS, mGCS, SBP of RTS and pupil size and reactivity) have previously been shown to be related to survival. All variables in the model are clinically simple and easy to measure rapidly resulting in a model that is clinically useful.

Keywords. *head injury, pupilary abnormalities*

INTRODUCTION

Traumatic brain injury (TBI) with an estimated 10 million cases annually worldwide and an annual mortality rate of 100 000 in US alone [1] poses a major cause of death and disability among a predominantly young population. Accurate prediction of long term outcome soon after emergency admission to hospital and neurological assessment (with or without brain imaging) can be useful in several ways; clinically, for communication with relatives and other healthcare professionals and as an aid to decision making about whether to pursue active management; in research, to generate hypotheses about the biological mechanisms leading to poor outcome; and retrospectively, as part of a clinical audit process [2,3].

Clinicians treating patients often make therapeutic decisions based on their assessment of prognosis. According to a 2005 survey, 80% of doctors believed that an accurate assessment of prognosis was important when they made decisions about the use of specific methods of treatment such as hyperventilation, barbiturates or mannitol. A similar proportion considered that this was important in deciding whether or not to withdraw treatment. Assessment of prognosis was also deemed important for counselling patients and relatives. Only a third of doctors, however, thought that they accurately assessed prognosis [4].

Many studies have used both prospective and retrospective clinical information to derive baseline predictive models, either specific to traumatic brain injury or for patients in the intensive care unit in general [5-17]. The vast majority of these studies have encompassed variables that are either not routinely attainable or are costly. The sex and age of the patient will almost always be known, whereas an immunoassay result, even if it is a strong predictor of outcome, requires specialist input, time to get the result, and funding. In this paper we have developed a simple model for the prediction of survival after moderate or severe traumatic brain injury using clinical accessibility and cost-containment as the main considerations for selecting variables, an approach that particularly pertains to de-

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Competing interests
The authors declare no competing interests.

Table 1. Glasgow Coma Scale

Eye Opening Response	Spontaneous--open with blinking at baseline	*4 points*
	Opens to verbal command, speech, or shout	3 points
	Opens to pain, not applied to face	2 points
	None	1 point
Verbal Response	Oriented	5 points
	Confused conversation, but able to answer questions	4 points
	Inappropriate responses, words discernible	3 points
	Incomprehensible speech	2 points
	None	1 point
Motor Response	Obeys commands for movement	6 points
	Purposeful movement to painful stimulus	5 points
	Withdraws from pain	4 points
	Abnormal (spastic) flexion, decorticate posture	3 points
	Extensor (rigid) response, decerebrate posture	2 points
	None	1 point

veloping countries such as Bosnia and Herzegovina.

PATIENTS AND METHODS

In the period between January 2007. and August 2008. all consecutive patients with traumatic brain injury admitted to the regional Neurosurgical department at University Clinical Centre Tuzla were enrolled in the study if they were aged 14 or more and had Glasgow Coma Scale score (GCS) <12. Data collected on all patients on admission included age, sex, GCS, cause of injury, RTS (revised trauma score), pupil response, brain CT result, each of which have previously been suggested as important prognostic factors. The GCS was devised by Teasdale and Jennett in 1974 as a practical scale to describe the depth of coma objectively, both to aid communication between healthcare professionals and to improve reporting of head injury research [18].

It hase been suggested by some that the most significant component of GCS in terms of outcome prediction is a motor response, thus this variable is considered separately and was denoted mGSC.

Based on GCS score and other clinical variables patients with head injury can be stratified in categories [19] (Table 2).

The Revised Trauma Score is a physiological scoring system, with high inter-rater reliability and demonstrated accurracy in predictng death. It is scored from the first set of data obtained on the patient, and consists of GCS, Systolic Blood Pressure and Respiratory Rate [20] (Table 3).

The revised trauma score is calculated using the following formula:

RTS = 0.9368 GCS + 0.7326 SBP + 0.2908 RR

Values for the RTS are in the range 0 to 7.8408. The RTS is heavily weighted towards the Glasgow Coma Scale to compensate for major head injury without multisystem injury or major physiological changes. The CT findings were graded according to modfied Marshall scheme [21] which divides diffuse injury into four categories and haematomas into evacuated and non-evacuated groups. Those patients alive at discharge were followed up at 6 months from injury. Outcome measure used was Glasgow Outcome Scale (GOS) [22] (Table 3).

Logistic regression modelling was used to assess the prognostic significance of the candidate predictors. Each variable was initially fitted in a univariate model to assess the functional relation with outcome. For categorical variables (for example, pupil reactivity), all categories were fitted initially, an assessment was made of their distinguisability and, if appropriate, categories were merged to give a new, simpler variable. Multivariate modelling of the variables proceeded using the functional relations developed in the univariate models in a multivariate setting.

Table 2. Head injury severity classification

Head injury severity category	Clinical criteria
Minimal	GCS 15, no loss of consciousness
Mild	GCS 14 or 15, brief (5 minutes) loss of consciousness or amnesia, or impaired alertness or memory
Moderate	GCS 9–13, or loss of consciousness for 5 minutes, or focal neurological deficit
Severe	GCS 3–8

Table 3. Revised trauma score

Glasgow Coma Scale (GCS)	Systolic Blood Pressure (SBP)	Respiratory Rate (RR)	Coded Value
13-15	>89	10-29	**4**
9-12	76-89	>29	**3**
6-8	50-75	6-9	**2**
4-5	1-49	1-5	**1**
3	0	0	**0**

RESULTS

The study encompassed 82 patients aged over 14 years with moderate or severe head injury as graded by GCS admitted to our Department between January 2007 and August 2008. An average age at presentation was 38.5 years. 70 patients were male. Patients that have sustained moderate head injury as assessed by clinical criteria (GCS 9-13) accounted for 50% of our study population (41 patients), another 36 (43,90%) patients presented with GCS score of 3-8 and 5 patients were intubated at admission. Pupil size and reactivity is depicted in the table 6.

Tables 7- 10 reveal relationships between various clinical variables (GCS, mGSC, RTS and pupil size and reactivity) and outcome. Poor outcome was defined as GOS ≤3.

As mentioned earlier motor component of GCS (mGCS) bares particular prognostic significance. Analysis of the relationship between mGCS and outcome revealed that patients presenting with mGCS≤3 harbor greater chance of poor outcome.

Based on afore mentioned results it is evident that GCS, mGCS, SBP of RTS and pupil size and reactivity correlate fairly (significantly) with outcome, thus relative predictive value of those variables was compared by multiple regression analysis, as shown in table 11.

DISCUSSION

We have correlated commonly available clinical variables (GCS, mGCS, SBP of RTS and pupil size and reactivity) to outcome in moderately and severely head injured patients in order to determine their predictive power.

Among other variables GCS score was correlated to outcome and it has been shown that patients with GCS scores 3-8 bare a poorer outcome. Other authors have reached similar conclusions. A large cohort study of more than 12 000 patients from the USA found that field GCS and arrival GCS correlated with each other (unsurprisingly), and both were predictive of survival [23]. Field GCS is associated with early, but not late, outcome in children [24]. However, the relationship between field GCS and survival is non-linear, with a steep relationship between GCS 3 and 7, followed by a shallower decline in mortality between GCS 8 and 15. The relationship between field GCS and functional outcome appears to be approximately linear [25]. Numerous studies have assessed the relationship between post-resuscitation GCS and mortality and functional outcome in generalized TBI [26, 27] and specific subgroups [28-29]. In general, as with field GCS, these studies show a quasi-exponential relationship, with a sharp decrease in mortality as GCS increases from 3 to 8, with a shallower decrease between 8 and 15. Of note, one centre has postulated that this link between GCS and outcome may have been eroded by improvements in care of patients with severe TBI [30]. The change in GCS may also be prognostic, with deterioration in GCS predicting the need for evacuation of traumatic subdural hematoma [31].

Our study found pupil size and reactivity to be fair outcome predictor, which is in accordance with earlier papers. Pupil size and reactivity can be affected by a variety of mechanisms associated with head injury: eye and optic nerve trauma, third nerve injury at any point in its course, mid-brain, and pontine dysfunction, and drug an administration. If direct trauma to the eye is excluded, then pupillary signs may provide prognostic information. Pupillary constriction is mediated via a parasympathetic pathway, which requires integrity of the third nerve and its nuclei in the brain, which lie close to areas involved in consciousness. Third nerve palsy initially causes mydriasis followed by loss of reactivity to light. Classically, ipsilateral third nerve palsy has been attributed to compression of the nerve on the free edge of the tentorium. It may also occur because of kinking of the nerve over the clivus or 'buckling' of the brainstem as a result of an increase in supratentorial pressure. In the presence of unilateral third nerve palsy, the consensual light reflex (opposite eye constricting in response to bright light) should still be present. Optic nerve injury (more common with frontal injuries) will impair both the direct and indirect responses and may lead to fixed or sluggish pupils, which may display

Table 4. Glasgow Outcome Scale

GOS score	Meaning
5	Good Recovery
4	Moderate Disability (Disabled but independent)
3	Severe Disability (Conscious but disabled; depends upon others)
2	Persistent vegetative state (unresponsive)
1	Death
0	Unknown

Table 5. Motor component of GCS in head injured patients

GCS/Motor response	M-1	M-2	M-3	M-4	M-5	M-6	Total
9-13	0	0	0	4	26	11	41
3-8	8	8	11	8	1		36
Intubated patients							5

Table 6. Pupil size and reactivity

Pupil size and reactivity	No of patients
Symetrical, responsive	64
Dilatated, fixed	4
Left midryasis	7
Right mydriasis	6
Undetermined	1

spontaneous fluctuations (hippus) [32]. Bilaterally fixed pupils occur in around 20–30% of patients with severe head injury (GCS 8) after resuscitation: 70–90% of these patients will have poor outcome (vegetative or dead) when compared with around 30% with bilaterally reactive pupils. Unresponsive pupils are associated with the presence of hypotension, lower GCS, and closed basal cisterns on CT. The underlying pathology influences the prognostic value of unresponsive pupils: patients with epidural haematoma fare better than those with subdural haematoma [33, 34]. Unilaterally unresponsive pupils have an outcome intermediate between bilaterally reactive and unresponsive pupils. Pupil asymmetry is associated with an operable mass lesion in around 30% of patients.

Our study revealed that systemic hypotension is one of clinically significant outcome predictors. Numerous observational studies have confirmed the association between systemic hypotension occurring at any point after injury and poor outcome [35]. The largest study [36] a prospective review of more than 700 patients from the American TCDB, found that a single episode of hypotension during the period from injury through resuscitation was associated with an approximate doubling of mortality and a parallel increase in morbidity in survivors. This association persists when age and the presence or absence of hypoxia and extra-cranial injuries are taken into account. The duration and number of episodes of hypotension are correlated with mortality. The precise mechanism for the enhanced susceptibility of the injured brain to hypotension is not clear, but up to 90% of head-injured patients have been found to have evidence of ischemic damage at autopsy.

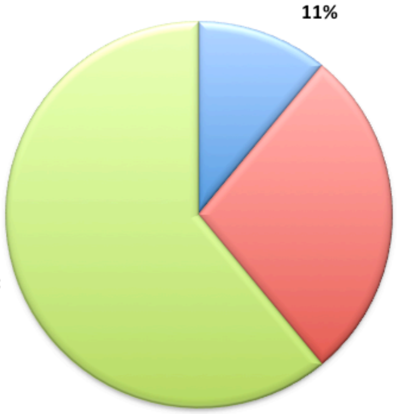

Figure 1. RTS values in moderately and severely head injured patients

CONCLUSIONS

Our study resulted in a model containing age, GCS, systolic blood pressure of the RTS and pupil reactivity at admission as fair independent outcome predictors in patients with severe head injury, with motor component of the GCS scale exhibiting greater predictive value over the entire GCS score. All four variables have previously been shown to be related to survival. All variables in the model are clinically simple and easy to measure rapidly resulting in a model that is clinically useful and cost-effective which is of paramount importance to medical facilities in developing countries such as Bosnia and Herzegovina.

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Table 7. Relationship between GCS and outcome

GOS	after n	GCS 1 mo %	9- after n	13 3 mo %	GCS after n	3 - 1 mo %	8 after n	3mo %
GOS1	1	1.22	3	3.66	17	20.73	20	24.39
GOS 2	0	0.00	0	0.00	0	0.00	0	0.00
GOS 3	3	2.44	2	2.44	5	6.10	3	3.66
GOS 4	1	0.00	0	0.00	2	2.44	1	1.22
GOS 5	36	43.90	36	43.90	12	14.63	12	14.63
Total	41	50.00	41	50.00	36	43.90	36	43.90

Table 8. Relationship between mGCS and outcome

mGCS	GOS 1m	1 3m	GOS 1 m	2 3mo	GOS 1m	3 3m	GOS 1m	4 3m	GOS 1m	5 3m
M 1	0	3	0	0	5	3	1	0	2	2
M 2	3	5	0	0	2	1	1	0	2	2
M 3	3	3	0	0	1	1	0	0	7	7
M 4	0	0	0	0	0	0	0	0	12	12
M 5	12	12	0	0	0	0	0	0	14	14
M 6	0	0	0	0	0	0	1	1	11	11
Unknown	0	1	0	0	1	0	0	1	4	3
Total	18	24	0	0	9	5	3	2	52	51

Table 9. Relationship between pupil size and reactivity and outcome

Pupillary Size and response	**GOS 1** N	%	**GOS 2** N	%	**GOS 3** N	%	**GOS 4** N	%	**GOS 5** N	%	**Total** N	%
Reactive	5	6.10	0	0.00	4	4.88	3	3.66	50	60.87	62	75.61
Unilateral dilatation	6	7.32	0	0.00	3	3.66	0	0.00	2	2.44	11	13.41
Dilated, unresponsive	4	4.88	0	0.00	0	0.00	0	0.00	0	0.00	4	4.88
Undetermined	3	3.66	0	0.00	2	2.44	0	0.00	0	0.00	5	6.10
Total	18	21.95	0	0.00	9	10.98	3	3.66	52	63.41	82	100.00

Table 11. Multiple regression analysis encompassing statistically significant outcome predictors

Variable	**p**	**Correlation coiffitient**	**Std err**
GCS	0,0047	**0,520**	0,05149
SBP	0,005	**0,527**	0,32425
Pupils	0,0405	**0,398**	0,23183

Table 10. Correlation between RTS and outcome

RTS	**GOS 1** N	%	**GOS 2** N	%	**GOS 3** N	%	**GOS 4** N	%	**GOS 5** N	%	**Total** N	%
4 - 6	6	7.31	0	0.00	2	2.44	0	0.00	1	1.22	9	10.98
7 - 9	9	10.98	0	0.00	4	4.88	2	2.44	8	9.76	23	28.05
10 - 12	3	3.66	0	0.00	1	1.22	3	3.66	43	52.44	50	60.97
Total	18	21.95	0	0.00	7	8.54	5	6.10	52	63.41	82	100.00

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