Journal of Korean Academy of Nursing (2006) Vol. 36, No. 4, 621 – 629

Comparisons of the Prognostic Predictors of Traumatic Brain Injury According to Admission Glasgow Coma Scale Scores - Based on 1- and 6-month Assessments

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Purpose. The purpose of this study was to identify the clinical variables that predict functional and cognitive recovery at 1- and 6-month in both severe and moderate/mild traumatic brain injury patients.

Methods. The subjects of this study were 82 traumatically brain-injured patients who were admitted to a Neurological Intensive Care Unit at a university hospital. Potential prognostic factors included were age, motor and pupillary response, systolic blood pressure, heart rate, and the presence of intracranial hematoma at admission.

Results. The significant predictors of functional disability in severe traumatic brain injury subjects were, age, systolic blood pressure, the presence of intracranial hematoma, motor response, and heart rate at admission. In moderate/mild traumatic brain injury patients, motor response, abnormal pupil reflex, and heart rate at admission were identified as significant predictors of functional disability. On the other hand, the significant predictors of cognitive ability for severe traumatic brain injury patients were motor response and the presence of intracranial hematoma at admission, whereas those for moderate/mild patients were motor response, pupil reflex, systolic blood pressure at admission, and age.

Conclusions. The results of the present study indicate that the significant predictors of TBI differ according to TBI severity on admission, outcome type, and outcome measurement time. This can be meaningful to critical care nurses for a better understanding on the prediction of brain injury patients. On the other hand, the model used in the present study appeared to produce relatively low explicabilities for functional and cognitive recovery although a direct comparison of our results with those of others is difficult due to differences in outcome definition and validation methods. This implies that other clinical variables should be added to the model used in the present study to increase its predicting power for determining functional and cognitive outcomes.

Key Words : Traumatic brain injury, Prognostic predictors, Recovery, Glasgow coma scale

INTRODUCTION

Traumatic brain injury (TBI) can result in death or the life-long impairment of physical, cognitive, and psychosocial functioning (Das-Gupta & Turner-Stokes, 2002; Signirini, Andrews, Jones, Wardlaw, & Miller, 1999). Despite remarkable advances in the medical and

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Received March 6, 2006 ; Accepted May 22, 2006

surgical treatments, the mortality rate of TBI remains high, i.e., 29−36% in cases of severe TBI (Bahoul et al., 2004). Such high mortality and disability rates have led to intensive efforts to identify prognostic predictors in TBI. In studies, mortality and Glasgow Outcome Scale (GOS) scores have been most frequently used as measures of prognostic outcomes (Choi et al., 1999; Kilaru et al., 1996; Mamelak, Pitt, & Damron, 1996; Ono, Yamaura, Kunbota, Okimura, & Isobe, 2001; Rovlian & Kotsou, 2004; Schreiber, Aoki, Scott, & Beck, 2002; Signorini, Andrews, Jones, Wardlaw, & Miller, 1999). GOS is designed to evaluate the recovery into five levels, i.e., death, vegetative, severe disability, moderate/mild disability, and recovery. However, it has been noted that GOS is less applicable to measuring functional and cognitive recovery.

The factors previously identified to influence TBI recovery are; age, Glasgow Coma Scale (GCS) score, CT findings (the presence of hematoma and midline shift), pupil response, systolic blood pressure (sBP), intracranial pressure, heart rate, and the presence of intracranial hematoma (Kilaru et al., 1996; Schreiber et al., 2002; Signorini et al., 1999). However, the study results on prognostic values of these variables have been overall controversial. For example, there is considerable debate concerning the prognostic values of GCS. Some studies have concluded that total GCS score at admission is a significant prognostic factor (Ono, Amaura, Kubota, Okimura, & Isobe, 2001; Rovlian & Kotsou, 2004), whereas others have reported that the GCS motor response subscale score is a more significant predictor of subject recovery (Choi, Narayan, Anderson, & Ward, 1988). This apparent result divergence may have originated from the inaccurate measurements of the eye opening and verbal response for GCS score determinations, as the majority of TBI patients are intubated or have facial edema (Schreiber et al., 2002). Nevertheless, it is evident that GCS score is reliable in terms of evaluating the degree of severity. Therefore, only the GCS motor response subscale score was used as a prognostic predictor in this study.

In addition, studies conducted on the prognostic predictors of TBI appear to be limited in terms of their generalized applicabilities due to, 1) the collection of data primarily from severely brain-damaged patients with a GCS score of 8 or less at admission, and 2) the determination of prognostic outcomes using only mortality or simplified GOS, as mentioned above. Therefore, we considered that further studies of a wide range of prognostic indices and of brain damage degree are needed. In addition, previous studies have tended to evaluate recovery status at 6−12 months after trauma, i.e., the post-acute recovery periods, and thus we needed to evaluate the relationships between acute recovery and prognostic factors.

The purpose of the present study was to identify the clinical variables that predict functional and cognitive recovery at 1- and 6-month in TBI. The factors chosen for this analysis included known prognostic predictors of brain injury that could be easily accessible by nurses in intensive care units, i.e., age, motor and pupil response, the presence of intracranial hematoma, sBP, and heart rate. In addition, we compared the prognostic predictors in TBI patients with high versus low GCS scores at admission.

METHODS

Study design and subjects

In this prospective study, we enrolled 82 traumatically brain-injured patients who were admitted to a single Neurological Intensive Care Unit (NICU) at a university hospital.

Data collection

Details concerning potential prognostic factors were collected, i.e., age, motor and pupillary response, sBP, and heart rate at admission, diagnosis, operation name, and the presence of intracranial hematoma at admission to NICU. Motor response was measured using the ‘motor response’ 6-point GCS subscale, which categorizes responses to a verbal command as: obeys command, 1; localizes, 2; withdraws, 3; abnormal flexor, 4; extensor, 5; none, 6. Pupil responses were measured using a 3-point rating scale (Choi et al., 1988; Rovlias & Kotsou, 2004; Signorini et al., 1999); bilaterally absent, 1; unilaterally absent, 2; bilaterally normal, 3. Data concerning the presence of intracranial hematoma were collected from archived CT findings. The outcome variables, 1- and 6-month functional disabilities, and cognitive abilities were measured directly or by telephone interview of patients discharged before their 6-month assessments.

Measurements

Rappaport Disability Rating Scale (DRS)

The DRS was designed to measure the degree of disability over the course of recovery after brain injury. This scale is an 8-item rating scale and consists of four main areas, 'arousability & awareness', 'ability for self-care', 'dependence on others', and 'psychosocial adaptability' (Rappaport, Hall, Hopkins, Belleza, & Cope, 1982). Each main area is further divided into sub-areas, i.e., for 'arousability & awareness'- eye open, best motor, and best verbal in area; for 'ability for self-care'- feeding, grooming, and toileting; for 'dependence on others'- level of functioning; and for 'psychosocial adaptability'- employment status. Each sub-area was 4- or 5-point rating scale. The total score ranges 0–29, and higher scores represent poorer functional ability. The DRS has been previously reported to be reliable and valid (Rappaport et al., 1982; van Baalen et al., 2003; Gouvier, Blanton, LaPorte, & Nepomuceno, 1987; Fleming & Maas, 1994). A Chronbach's α value was 0.93 in the present study.

Cognitive Ability Scale

Cognitive ability was measured using a modified Cognitive Ability Scale, which was originally developed from the Nursing Outcomes Classification (Johnson & Maas, 1997). The Cognitive Ability Scale used was an 11-item, 5-point rating scale, and was designed to measure the ability of an individual to perform multiple dimensions of cognitive function, i.e., communication, concentration, orientation, memory, information processing, and decision making. In the present study, two items were added to the original scale with the aid of a cognitive rehabilitation expert; retrospective memory and problem solving ability. We used this scale because it has the following advantages: 1) it is simple enough to be quickly implemented and minimizes time commitment, and 2) it is a multi-dimensional measurement. The reliability and clinical applicability of the Cognitive Ability Scale have been directly examined on many occasions (Johnson & Maas, 1997). The reliability coefficient of this scale was 0.98 in the present study.

Data analysis

Statistical analysis was performed using SPSS (version 12.0). Descriptive analysis was used to analyze general subject and illness-related characteristics, and multiple regression analysis was used to determine the statistical significances of the predictive accuracies of independent variables on outcome variables.

RESULTS

General and illness-related characteristics

The mean age of the 82 study subjects was 50.04 (± 16.68), and this ranged from 16 to 85 years (Table 1). Sixty-nine subjects (84.1%) were male and 13 (15.9%) were female. Regarding diagnosis, 90% had intracranial hematoma, 46% subdural hemorrhage, 31.2% traumatic SAH, and 7.3% intraventricular hemorrhage (41.5% had more than one diagnosis). Of 82 subjects, 31.7% showed cerebral midline shifts after trauma, and 37.8% had received at least one surgical operation due to TBI, most commonly hematoma removal surgery or decompressive craniectomy. At admission, the mean subject GCS score was 8.01 (±3.90, range 3–15). Subjects were predominantly injured by traffic accidents or falls-down.

Table 1. General and Illness-related Characteristics

Variables	Mean(S.D.)	%	Variables	Category	%
Age	50.04 (16.68)		Diagnosis	SDH[1]	46.0
				T-SAH[2]	31.2
				IVH[3]	7.3
				Contusion	15.5
GCS score	8.01 (3.90)		Midline Shift	yes	31.7
				no	68.3
Gender			Operation	yes	37.8
Male		84.1		no	62.2
Female		15.9			

[1]: Subdural hemorrhage
[2]: Traumatic subarchnoid hemorrhage
[3]: Intraventricular hemorrhage

Significant predictors of 1- and 6-month functional disability

To identify significant predictors of TBI at 1- and 6-months, subjects were firstly divided into two groups based on GCS scores, i.e., a severe group (GCS score ≤ 8) versus moderate/mild group (GCS score ≥ 9) (Bahoul et al., 2004).

Severe TBI (GCS score ≤8)

The significant predictors of 1-month functional disability in severe TBI patients were age (β = 0.56, t = 4.06, p = 0.00, one-tailed test), the presence of intracranial hematoma (β = 0.37, t = 2.88, p = 0.00, one-tailed test), and sBP at admission (β = −0.30, t = −2.13, p = 0.02, one-tailed test). The predictability of the model that included these three significant predictors was 29% (adjusted R-square = 0.29), and this was statistically significant (F = 4.59, p = 0.00). Of these, the best predictor was age, followed by the presence of intracranial hematoma and then sBP at admission. These findings indicate that a poor functional recovery in cases of severe TBI appears to be associated with an older age, the presence of intracranial hematoma, and lower sBP at admission.

On the other hand, the significant predictors of 6-month functional disability in severe TBI patients were; sBP at admission (β = −0.50, t = −3.52, p = 0.00, one-tailed test), age(β = 0.45, t = 3.21, p = 0.00, one-tailed test), intracranial hematoma (β = 0.32, t = 2.45, p = 0.01, one-tailed test), motor response (β = 0.24, t = 1.80, p = 0.04, one-tailed test), and heart rate at admission (β = −0.23, t = −1.66, p = 0.05, one-tailed test, Table 2). The predictability of the model including these five significant factors was 27% (adjusted R-square=0.27), and this was statistically significant (F = 4.36, p = 0.00). The best predictor of 6-month functional disability was sBP, followed by age, the presence of intracranial hematoma, motor response, and heart rate. Specifically, a poor 6-month functional recovery was found to be associated with an older age, the presence of intracranial hematoma, a poorer motor response, and a lower heart rate at admission.

Moderate/mild TBI (GCS score ≥ 9)

The significant predictors of 1-month functional dis-

Table 2. Predictors of Functional Disability in the Severe Versus Moderate/mild TBI Subjects

1-month functional disability									
GCS score ≤8 at admission (n = 46)					GCS score ≥9 at admission (n = 36)				
Parameters[1]	β	t(p)[2]	Adj.[3] R^2	Model Test F(p)	Parameters	β	t(p)	Adj. R^2	Model Test F(p)
Age	0.56	4.06 (0.00)			Motor	0.44	2.48 (0.01)		
Hematoma[4]	0.37	2.88 (0.00)	0.29	4.59 (0.00)	Pupil	0.43	2.27 (0.02)	0.35	3.26 (0.02)
Systolic BP[5]	−0.30	−2.13 (0.02)			Heart rate	0.42	2.21 (0.02)		
6-month functional disability									
Systolic BP	−0.50	−3.52 (0.00)							
Age	0.45	3.21 (0.00)							
Hematoma	0.32	2.45 (0.01)	0.27	4.36 (0.00)	Motor	0.56	3.23 (0.00)	0.33	2.96 (0.04)
Motor	0.24	1.80 (0.04)							
Heart rate	−0.23	−1.66 (0.05)							

[1]: Parameters (age, pupil reflex, motor response, the presence of intracranial hematoma, systolic blood pressure, heart rate) were measured at the time of admission to ICU

[2]: p-value was calculated by one-tailed test

[3]: Adjusted R-square

[4]: The presence of intracranial hematoma

[5]: Blood pressure

ability in moderate/mild TBI patients were motor response (β = 0.44, t = 2.48, p = 0.01, one-tailed test), pupil reflex (β = 0.43, t = 2.27, p = 0.02, one-tailed test), and heart rate at admission (β = 0.42, t = 2.21, p = 0.02, one-tailed test, Table 2). The explicability of the model including these significant factors was 35%, and this was statistically significant (Adjusted R2 = 0.35, F = 3.26, p = 0.02). The best predictor was motor response, followed by pupil reflex and heart rate at admission although their predictabilities were similar. Our results indicate that a poor 6-month functional recovery is associated with a poorer motor response, the presence of a bilaterally abnormal pupil reflex, and a higher heart rate at admission.

The only significant predictor of 6-month functional disability in moderate/mild TBI patients was motor response at admission (β = 0.56, t = 3.23, p = 0.00, one-tailed test, Table 2), and the explicability of this model was 33% (adjusted R-square = 0.33), which was statistically significant (F = 2.96, p = 0.04). This finding suggests that a poor 6-month functional recovery in moderate/mild TBI patients is associated with a poorer motor response at admission.

Figure 1 summarizes the significant predictors of 1- and 6-month functional disability according to the TBI severity on admission. Specifically, the significant predictors of functional disability in severe TBI subjects were; age, sBP, the presence of intracranial hematoma, motor response, and heart rate at admission. In moderate/mild TBI subjects, motor response, abnormal pupil reflex, and heart rate at admission were identified as significant predictors of functional disability.

Significant predictors of 1-and 6-month cognitive ability

Severe TBI (GCS score $\leq$8)

The only significant predictor of 1-month cognitive ability in severe TBI was the presence of intracranial hematoma at admission (β = −0.38, t = −2.62, p = 0.00, one-tailed test). However, the predictability of this model was not statistically significant (F = 1.90, p = 0.12).

The significant predictors of 6-month cognitive ability in severe TBI patients were motor response (β = −0.49,

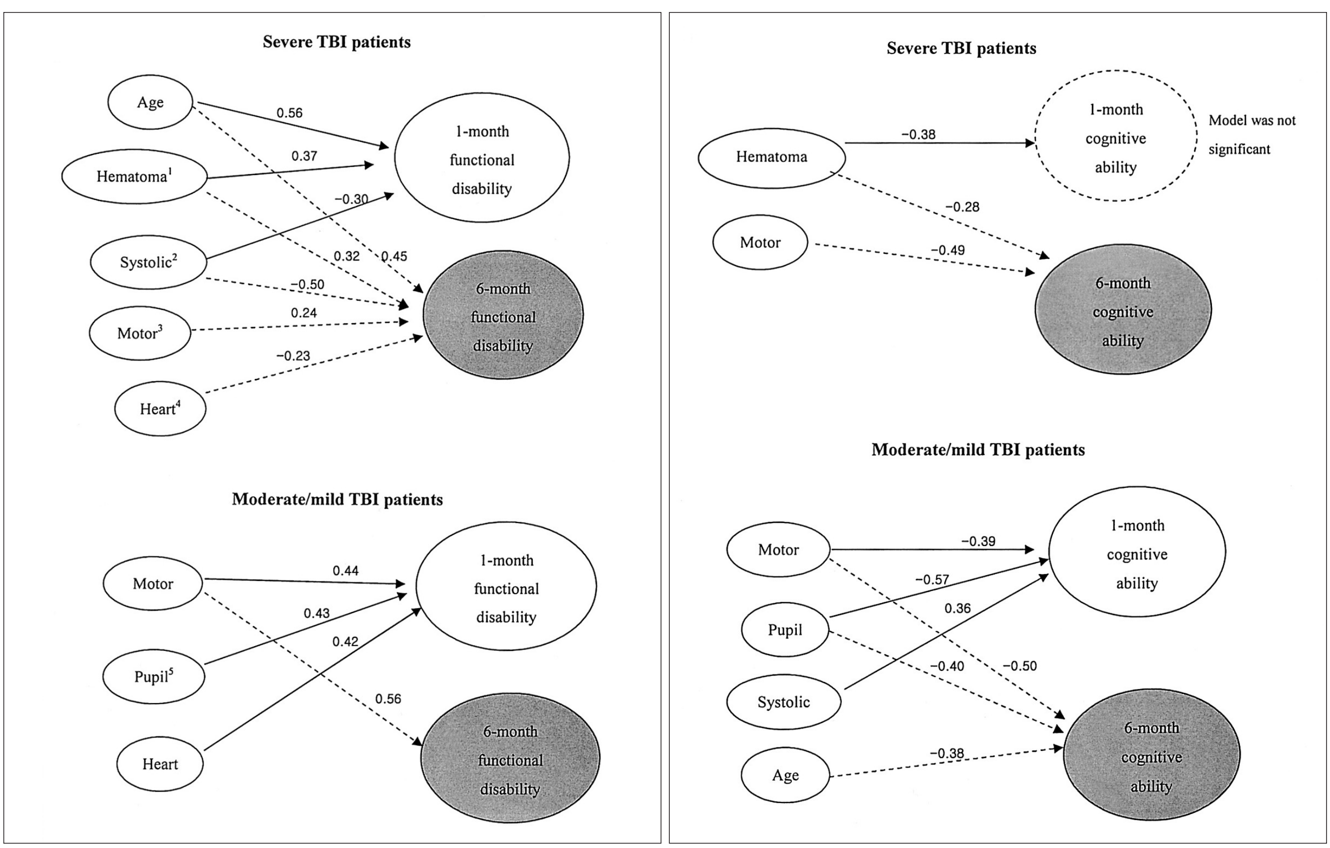

Figure 1. A. Significant predictors of functional disability. **B.** Significant predictors of cognitive ability.
[1]: The presence of intracranial hematoma, [2]: Systolic blood pressure, [3]: Motor response, [4]: Heart rate, [5]: Pupil response

Table 3. Predictors of Cognitive Ability in the Severe Versus Moderate/Mild TBI Subjects

1-month cognitive ability									
GCS score ≤8 at admission (n = 46)					GCS score ≥9 at admission (n = 36)				
Parameters[1]	β	t(p)[2]	Adj.[3] R^2	Model Test F(p)	Parameters	β	t(p)	Adj. R^2	Model Test F(p)
Hematoma[4]	−0.38	−2.62 (0.00)	0.09	1.90 (0.12)	Pupil	−0.57	−2.73 (0.01)	0.34	3.05 (0.03)
					Motor	−0.39	−2.15 (0.03)		
					Systolic BP[5]	0.36	1.86 (0.04)		
6-month cognitive ability									
Motor	−0.49	−3.30 (0.00)	0.19	2.89 (0.02)	Motor	−0.50	−2.84 (0.01)	0.32	2.89 (0.04)
Hematoma	−0.28	−1.89 (0.02)			Pupil	−0.40	−1.93 (0.04)		
					Age	−0.38	−1.76 (0.05)		

[1]: Parameters(age, motor response, pupil reflex, the presence of intracranial hematoma, systolic blood pressure, heart rate) were measured on admission to ICU
[2]: p-value calculated by one-tailed test
[3]: Adjusted R-square
[4]: The presence of intracranial hematoma
[5]: Blood pressure

t = −3.30, p = 0.00, one-tailed test) and the presence of intracranial hematoma at admission (β = −0.28, t = −1.89, p = 0.02, one-tailed test) (Table 3). The model including these two significant factors was statistically significant (Adjusted R^2 = 0.19, F = 2.89, p = 0.02) with an explicability of 19%. These results signify that a poor 6-month cognitive recovery is associated with a poorer motor response and the presence of intracranial hematoma at admission.

Moderate/Mild TBI (GCS score ≥ 9)

The significant predictors of 1-month cognitive ability in moderate/mild TBI patients were; pupil response (β = −0.57, t = −2.73, p = 0.01, one-tailed test), motor response (β = −0.39, t = −2.15, p = 0.03, one-tailed test), and sBP at admission (β = 0.36, t = 1.86, p = 0.04, one-tailed test, Table 3). The explicability of the model containing all three significant predictors was 34% (adjusted R-square=0.34), which was statistically significant (F = 3.05, p = 0.03). Of these, the best predictor of 1-month cognitive ability was pupil reflex, followed by motor response, and sBP at admission. These findings imply that a poor 1-month cognitive recovery in moderate/mild TBI patients is associated with a bilaterally abnormal pupil reflex, a poorer motor response, and a lower sBP at admission.

The significant predictors of 6-month cognitive ability in moderate/mild TBI patients were; motor response (β = −0.50, t = −2.84, p = 0.01, one-tailed test), pupil reflex at admission (β = −0.40, t = −1.93, p = 0.04, one-tailed test), and age (β = −0.38, t = −1.76, p = 0.05, one-tailed test, Table 3). The explicability of the model that included all three factors was 32% (adjusted R-square = 0.32), which was statistically significant (F = 2.89, p = 0.04). The best of these predictors was motor response, followed by pupil reflex and age. Our results indicate that a poor 6-month cognitive recovery in moderate/mild TBI patients is associated with a poorer motor response, a bilaterally abnormal pupil reflex at admission, and an advanced age.

Figure 2 summarizes the significant predictors of 1- and 6-month cognitive recovery according to the TBI severity on admission. Specifically, the significant predictors of cognitive ability for severe TBI patients were motor response and the presence of intracranial hematoma at admission, whereas those for moderate/mild TBI patients were motor response, pupil reflex, sBP at admission, and age.

DISCUSSION

Many researchers have examined the prognostic values of acute clinical variables in TBI. However, these studies evaluated outcomes using only mortality or a dichotomized recovery status (good or poor recovery), and in the main collected data from severe TBI patients. Therefore, in the present study, we aimed at identifying the significant predictors of the functional and cognitive aspects of recovery at one and six months after trauma, and examined whether these significant predictors might differ according to the TBI severity on admission.

The results obtained show that the significant predictors of 1-month functional disability in severe TBI subjects are; age, the presence of intracranial hematoma, and sBP at admission; whereas in moderate/mild TBI subjects these were motor response, pupil reflex, and heart rate at admission. Many other studies have reported that age is the most important predictor of recovery in brain injury patients (Choi et al., 1988; Ono et al., 2001; Rovlian & Kotsou, 2004; Schreiber et al., 2002; Signorini et al., 1999). Kilaru and collegues (1996) found that the relationship between age and recovery in brain injury patients was nonlinear, because their associations were significant only in the octogenarians and nonagenarian subjects. However, in the present study, we found a linear relationship between age and recovery, although our subjects were predominantly young or middle-aged patients (70.7% were between 20 and 50 years old). Taken together, these findings indicate that elderly TBI are more prone to experience a poor functional recovery.

In addition to age, the presence of intracranial hematoma and a low sBP at admission also found to be significant predictors of 1-month functional disability. This result is in accord with the findings of others (Schreiber et al., 2002; Signorini et al., 1999). i.e., that TBI patients with intracranial hematoma and a low sBP at admission are more likely to have a poor functional recovery.

The effect of sBP on recovery from brain injury is controversial, for example, Bhalla et al. (2003) reported that high blood pressure may be associated with either poor or good outcome. Nevertheless, there is a general agreement that sBP be maintained within the ranges 120 – 150 mmHg in acute brain injury patients in clinics. From this point of view, our results may provide clinical evidence for the beneficial effect of avoiding hypotension during critical periods.

For moderate/mild status TBI patients, motor response, pupil reflex, and heart rate at admission were identified as significant predictors of 1-month functional disability, and their influences on outcome variable were almost identical. Of these, motor response and pupil reflex have been the focus of previous prediction studies, and finally became accepted as major prognostic indicators of severe brain injury (Choi et al., 1988; Choi et al., 1991; Mamelak et al., 1996; Rovlias & Kotsou, 2004). According to the Prediction Tree Model developed by Choi and colleagues (1991), the most significant predictor of outcome in severe TBI is pupil reflex followed by age and motor response. Interestingly, in the present study, motor response and pupil reflex were found to more strongly predict 1-month functional disability in moderate/mild injury. This implies that the predictabilities of motor response and pupil reflex may differ according to outcome definition.

Age, the presence of intracranial hematoma, motor response, and heart rate at admission were all found to significantly predict 6-month functional disability in severe TBI. On the other hand, motor response at admission was the only significant predictor of 6-month functional disability in moderate/mild TBI patients. These findings signify that the predictors included in the present study are more predictive of 6-month functional disability in severe TBI. Notably, the predictability of motor response alone (33%) in moderate/mild TBI was higher than that of all five significant predictors combined (27%) in severe TBI.

Unexpectedly, severe TBI 1-month cognitive recovery could not be predicted significantly using the variables included in the present study. However, 6-month cognitive recovery in the same group was significantly predicted by motor response and the presence of intracranial hematoma at admission. Moreover, these two factors were also found to significantly predict 6-month functional disability, as discussed above.

In moderate/mild TBI patients, motor response and pupil reflex at admission were found to significantly predict both 1- and 6-month cognitive ability. Additionally, sBP and age were found to significantly predict 1- and 6-month cognitive abilities, respectively. One notable feature of our results is that the explicabilities of functional (0.33 – 0.35) and cognitive (0.32 – 0.34) recovery were almost the same in moderate/mild TBI, whereas the explicability of cognitive recovery was markedly poorer than that of functional recovery in severe TBI.

It is difficult to directly compare our results with those of others, because previous studies investigated TBI outcomes using mortality or dichotomized GOS scores, and because they validated prediction models by calculating accurate prediction rates (Choi et al., 1988; Choi et al., 1991; Ono et al., 2001; Rovlias & Kotsou, 2004). Nevertheless, the predictive accuracies of previously described prediction models fall in the range 78–90%, which is higher than the 50% expected by chance. In contrast to this high predictability, the model used in the present study produced relatively low explicabilities for functional and cognitive recovery. This result implies that other clinical variables should be added to the model used in the present study to increase its predicting power for determining functional and cognitive outcomes. Further studies on this matter are needed. Our findings are probably not generalizable because this study was conducted specifically on traumatic brain injury patients with a small number, and because predictors known to affect TBI recovery were not comprehensively included.

CONCLUSION

The results obtained show that the significant predictors of 1-month functional disability in severe TBI subjects are; age, the presence of intracranial hematoma, and sBP at admission; whereas in moderate/mild TBI subjects these are motor response, pupil reflex, and heart rate at admission. For 6-month functional disability, age, the presence of intracranial hematoma, motor response, and heart rate at admission are found to be significantly predictors in severe TBI. On the other hand, motor response at admission is the only significant predictor of 6-month functional disability in moderate/mild TBI patients.

Our results also show that the only significant predictor of 1-month cognitive ability in severe TBI is the presence of intracranial hematoma at admission, but the predictability of this model was not statistically significant. The significant predictors of 1-month cognitive ability in moderate/mild TBI patients are; pupil response, motor response, and sBP at admission. On the other hand, the significant predictors of 6-month cognitive ability in severe TBI patients are motor response and the presence of intracranial hematoma at admission; whereas in moderate/mild TBI subjects these are motor response, pupil reflex at admission, and age.

The relationships between prognostic predictors and recovery status are highly complex, as is adequately demonstrated by the results of studies performed to date. Evidently, our results indicate that the significant predictors of TBI differ according to TBI severity on admission, outcome type, and outcome measurement time. This point can be meaningful to critical care nurses for a better understanding on the prediction of brain injury patients.

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