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# Gait and Glasgow Coma Scale scores can predict functional recovery in patients with traumatic brain injury<sup>☆●</sup>

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## Abstract

Fifty-one patients with mild ( $n = 14$ ), moderate ( $n = 10$ ) and severe traumatic brain injury ( $n = 27$ ) received early rehabilitation. Level of consciousness was evaluated using the Glasgow Coma Score. Functional level was determined using the Glasgow Outcome Score, whilst mobility was evaluated using the Mobility Scale for Acute Stroke. Activities of daily living were assessed using the Barthel Index. Following Bobath neurodevelopmental therapy, the level of consciousness was significantly improved in patients with moderate and severe traumatic brain injury, but was not greatly influenced in patients with mild traumatic brain injury. Mobility and functional level were significantly improved in patients with mild, moderate and severe traumatic brain injury. Gait recovery was more obvious in patients with mild traumatic brain injury than in patients with moderate and severe traumatic brain injury. Activities of daily living showed an improvement but this was insignificant except for patients with severe traumatic brain injury. Nevertheless, complete recovery was not acquired at discharge. Multiple regression analysis showed that gait and Glasgow Coma Scale scores can be considered predictors of functional outcomes following traumatic brain injury.

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## Key Words

brain injury; traumatic brain injury; rehabilitation; early rehabilitation; function; prognosis; Glasgow Coma Scale; Glasgow Outcome Scale; functional level; neural regeneration

## Research Highlights

- (1) Mild, moderate or severe traumatic brain injury patients received acute rehabilitation in the Neurosurgery Department.
- (2) An acute rehabilitation program did not result in complete recovery at discharge in all patients except in one with mild traumatic brain injury.
- (3) Level of consciousness and mobility at admission to rehabilitation could be considered as predictors of functional level at discharge.

## Abbreviations

GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Score; BI: Barthel Index; LOS: length of stay; MSAS, Mobility Scale for Acute Stroke

## INTRODUCTION

Traumatic brain injury is the most common cause of death and disability amongst all neurological diseases. Impairment of an individual's physical, cognitive, and psychosocial functioning can cause permanent disability throughout life, an extreme loss of income earning potential, and a profound disruption to the family unit<sup>[1]</sup>. Hence, rehabilitation research has become a most important area of investigation. For such patients, rehabilitation aims to improve their neurological function, provide as much patient independence as possible, prevent complications, and provide an acceptable environment to the patient<sup>[2]</sup>. Rehabilitation starts in the intensive care unit and can last a lifetime in some cases. During the acute period, the purpose is to prevent complications that may cause later disability. Appropriate positioning and passive range of motion exercises can prevent complications like contracture development, pressure wounds or deep venous thrombosis. During this period, it is also important to know the outcomes at discharge for planning further management and services. Some significant factors have been reported to contribute to the outcome after traumatic brain injury. Demographic parameters such as gender, age or clinical parameters, initial Glasgow Coma Scale (GCS), duration of coma, posttraumatic amnesia, Glasgow Outcome Score (GOS) and the degree of disability at discharge, for example, are considered to be strong predictors in patients with traumatic brain injury<sup>[3]</sup>. Only a few studies have focused on the prediction of functional level at discharge in the phase of rehabilitation<sup>[4-5]</sup>. In these studies, patients were not classified according to the severity of traumatic brain injury. Therefore, this study was specifically designed to describe the functional outcomes after acute rehabilitation in patients with mild, moderate or severe traumatic brain injury, as well as to determine predictors of effectiveness of acute rehabilitation on functional outcome at discharge.

## RESULTS

### Demographic data and clinical features of patients

As shown in Tables 1 and 2, age and gender were similar among mild, moderate, and severe traumatic brain injury patients ( $P > 0.05$ ). Traffic accidents accounted for 71 % of injuries, 14 % occurred from falls and 16 % for other reasons. The percentage of traffic accidents in the severe group was higher. The average length of stay (LOS) in hospital and LOS in rehabilitation of patients with severe

traumatic brain injury were significantly longer than those of patients with moderate and mild traumatic brain injury ( $P < 0.05$ ; Table 2).

Table 1 Pre-analysis of patient characteristics in relation to Barthel Index post-rehabilitation

Predictor	n (%)	Median discharge Barthel Index (IQR)	Correlation*	P value
<b>Group</b>				
Severe	27 (53)	25 (0-45)		0.000
Moderate	10 (20)	45 (38.8-56.3)		
Mild	14 (27)	80 (55-100)		
<b>Gender</b>				
Male	40 (78)	45 (6.2-82.5)		0.186
Female	11 (22)	25 (0-55)		
Age (year)	51 (100)		0.005	0.974
<b>Injury mechanism</b>				
Traffic accidents	36 (71)	40 (0-58.8)		0.155
Falling	7 (14)	45 (0-45.0)		
Others	8 (16)	80 (13.8-100)		
LOS hospital	51 (100)		-0.382	0.006
LOS rehab	51 (100)		-0.341	0.014
GCS at hospital admission	51 (100)		0.691	0.000
<b>Pre-rehabilitation</b>				
GCS	51 (100)		0.663	0.000
Sitting up from lying	51 (100)		0.859	0.000
Balanced sitting	51 (100)		0.832	0.000
Gait	51 (100)		0.800	0.000
GOS	51 (100)		0.488	0.000
BI	51 (100)		0.938	0.000

LOS hospital: Length of stay in hospital; LOS rehab: length of stay in rehabilitation; GCS: Glasgow Coma Scale; GOS: Glasgow Outcome Scale; IQR: Interquartile Range. "\*" indicates Spearman's Rank Order Correlation.

Table 2 Clinical and demographic data in patients with mild, moderate and severe TBI admitted to the rehabilitation program

Variable	Mild TBI (n = 14)	Moderate TBI (n = 10)	Severe TBI (n = 27)	P value
Age (year)	40.4 (17.1)	42.4 (15.8)	41.0 (13.5)	0.949 <sup>a</sup>
Gender (M/F, n)	12/2	8/2	20/7	0.685 <sup>b</sup>
GCS score at admission	15 (14-15)	10.5 (10-12)	7 (5-9)	< 0.001 <sup>c</sup>
LOS hospital (day)	14.5 (11.8-22.5)	25.5 (19-32.2)	36 (25-54)	< 0.001 <sup>c</sup>
LOS rehab (day)	8.5 (5-19)	15 (12.8-25.5)	23 (10-40)	0.001 <sup>c</sup>
GCS score pre-rehabilitation	14 (14-15)	10 (9.8-11.0)	6 (5-7)	0.018 <sup>c</sup>
GOS score pre-rehabilitation	3 (3-4.2)	3 (2-3)	2 (2-2)	< 0.001 <sup>c</sup>

Data are expressed as mean (SD) or median [IQR]. TBI: Traumatic brain injury; M: male; F: female; GCS: Glasgow Coma Scale; LOS hospital: length of stay in hospital; LOS rehab: length of stay in rehabilitation; GOS: Glasgow Outcome Scale. <sup>a</sup>One-way analysis of variance. <sup>b</sup>chi-square test; <sup>c</sup>Kruskal Wallis Test. Age was expressed as mean (SD).

### Outcome measures of patients

The outcome measures of mild, moderate and severe traumatic brain injury patients are shown in Table 3. The GCS scores improved drastically in the severe and moderate traumatic brain injury groups ( $P < 0.05$ ) and the improvement was more significant in the severe traumatic brain injury group than in the moderate traumatic brain injury group ( $P < 0.05$ ). There was no measurable improvement in GCS of mild traumatic brain injury patients ( $P > 0.05$ ).

Barthel Index (BI) score showed a substantial improvement in all study groups, but this was statistically important only for severe traumatic brain injury ( $P < 0.05$ ). The Mobility Scale for Acute Stroke (MSAS) subscale (sitting up from lying, balanced sitting and gait subscales) scores improved dramatically following early rehabilitation in all study groups ( $P < 0.05$ ). This recovery was similar in rolling and sitting activities among the study groups ( $P > 0.05$ ). The gait score of the mild traumatic brain injury group was significantly higher compared with the moderate and severe traumatic brain injury groups ( $P < 0.05$ ).

The GOS also increased significantly in all three groups ( $P < 0.05$ ). This improvement was similar in mild, moderate and severe traumatic brain injury groups ( $P > 0.05$ ). At discharge, 85% of patients with severe traumatic brain injury still had a severe disability (BI < 5;

GOS, 2–3), but the moderate disability level was found only in four patients (BI, 55–90; GOS, 4). Sixty percent of patients with moderate traumatic brain injury had a severe disability, but three patients had moderate disability (BI, 55–90; GOS, 4) and one patient had mild disability (BI > 90; GOS, 5). Seventy-one percent of the mild traumatic brain injury patients had a moderate disability (BI, 55–90; GOS, 4), but only four patients had full independence (BI, 100; GOS, 5).

### Predictors of functional level at discharge

The influences of factors identified as significant in pre-analyses (Table 1) and those analyzed by multiple regression analysis are shown in Table 4.

The results are presented as adjusted R<sup>2</sup> and  $\beta$  coefficients with 95% CI. The expected direction of the  $\beta$  coefficient was positive for GCS and gait scores pre-rehabilitation, meaning that less severe injury and higher mobility status (gait ability) equated to better functional level at discharge from rehabilitation. GCS and gait scores pre-rehabilitation explained 69% of variance of BI scores post-rehabilitation. Gait score pre-rehabilitation had the largest influence on functional level ( $\beta = 16.173$ ), followed by GCS score ( $\beta = 3.368$ ). LOS in rehabilitation ( $\beta = 0.068$ ) was included as a predictor in the model, but was not statistically significant ( $P = 0.591$ ).

Table 3 Outcome measures pre- and post-rehabilitation

Variable		Severe (n = 27)		Moderate (n = 10)		Mild (n = 14)		P value <sup>¶</sup>	
		Median	IQR	Median	IQR	Median	IQR		
GCS	Pre-rehabil	7	(5–9)	10.5	(10.00–12.00)	15.0	(14.00–15.00)	0.000 <sup>a</sup>	
	Post-rehabil	11	(9–14)	13.5	(12.00–14.25)	15.0	(14.00–15.00)		
	$\Delta$ GCS	3*	(1–6)	2.0*	(0.00–4.25)	0.0	(0.00–0.25)		
MSAS	Sitting up from lying	Pre-rehabil	1	(1–1)	3.0	(1.00–5.25)	5.0	(4.00–5.25)	0.486
		Post-rehabil	1	(1–4)	4.5	(2.75–5.25)	6.0	(5.00–6.00)	
		$\Delta$ Sitting up from lying	0*	(0–1)	1.0*	(0.00–2.00)	0.5*	(0.00–1.00)	
Balanced sitting	Pre-rehabil	1	(1–1)	2.5	(1.00–4.25)	4.0	(3.00–5.25)	0.473	
	Post-rehabil	1	(1–2)	3.5	(2.00–5.00)	5.0	(4.00–6.00)		
	$\Delta$ Balanced sitting	0*	(0–1)	1.0*	(0.00–1.00)	1.0*	(0.00–1.00)		
Gait	Pre-rehabil	1	(1–1)	1.0	(1.00–2.25)	3.0	(2.00–4.00)	0.002 <sup>b</sup>	
	Post-rehabil	1	(1–2)	2.5	(1.00–3.25)	4.0	(2.00–5.00)		
	$\Delta$ Gait	0*	(0–1)	0.5*	(0.00–1.00)	1.0*	(1.00–1.00)		
GOS	Pre-rehabil	2		2.5	(2.00–3.00)	3.0	(3.00–4.25)	0.494	
	Post-rehabil	3	(2–3)	3.0	(2.75–3.25)	4.0	(3.00–5.00)		
	$\Delta$ GOS	0*	(0–1)	0.0*	(0.00–1.25)	0.0*	(0.00–0.00)		
BI	Pre-rehabil	0	(0–25)	25.0	(25.00–45.00)	67.5	(43.75–85.00)	0.330	
	Post-rehabil	25	(0–45)	45.0	(38.75–56.25)	80.0	(55.00–100.0)		
	$\Delta$ BI	0*	(0–25)	12.5	(7.50–22.50)	15.0	(10.00–20.00)		

GCS: Glasgow Coma Scale; MSAS: Mobility Scale for Acute Stroke; GOS: Glasgow Outcome Scale; BI: Barthel Index; IQR: Interquartile Range;  $\Delta$  indicates absolute amount of change between pre-rehabilitation and post-rehabilitation; \* indicates that amount of change is significant ( $P < 0.05$ ) within the group. Wilcoxon Signed Rank Test was used. The superscript "a" indicates significant difference between mild, moderate and severe traumatic brain injury; the superscript "b" indicates significant difference between severe and mild traumatic brain injury; ¶ indicates Kruskal-Wallis test.

Table 4 Result of multiple regression analysis (n = 51)

Variable	$\beta$ coefficient (95% CI)	P value
Constant	-21.196 (-42.123 to -0.268)	0.047
GCS pre-rehabilitation	3.368 (1.600– 5.136)	< 0.001
Gait score pre-rehabilitation	16.173 (11.404–20.941)	< 0.001
LOS rehabilitation	0.068 (-0.184–0.320)	0.591

Adjusted  $R^2$  for the model: 0.687. GCS: Glasgow Coma Scale; GOS: Glasgow Outcome Score; BI: Barthel Index; LOS: length of stay.

## DISCUSSION

This study includes analyses of demographics, injury characteristics, functional outcomes and predictors of 51 patients with mild, moderate and severe traumatic brain injury admitted to an acute rehabilitation program. In this study, 71% of traumatic brain injury resulted from traffic accidents. The majority of patients were old and male, and most of them had severe traumatic brain injury. These findings are consistent with recent studies that report a rise in the mean/median age of the traumatic brain injury population due to increased frequency of injury related to traffic accidents<sup>[6-7]</sup>. Scholars agree that early rehabilitation intervention for traumatic brain injury patients generally produces a positive outcome<sup>[8-10]</sup>. In the present study, mild, moderate and severe traumatic brain injury patients showed an improvement in functional outcomes at the end of primary treatment (surgery and medical) combined with an acute rehabilitation program, but the expected recovery level was not reached due to a shortened rehabilitation. The majority of severe and moderate traumatic brain injury patients were severely disabled at admission to rehabilitation. At discharge, severe disability still continued. No obvious response was observed in patients with mild traumatic brain injury. Only one patient showed a complete recovery. A similar trend in functional improvement at discharge has been reported<sup>[8]</sup>. This study examined acute outcomes of patients with severe traumatic brain injury admitted to acute inpatient rehabilitation. Patients showed a gradual functional improvement, but they were still severely disabled at discharge. Sandhaug *et al*<sup>[11]</sup> also described the functional level of severe and moderate traumatic brain injury patients after acute rehabilitation. But they reported that more than half the severe traumatic brain injury and 95% moderate traumatic brain injury patients were discharged with a mild disability. This higher functional level than in the

Nakase-Richardson and our study may be explained by longer LOS in rehabilitation (32 days) and higher cognitive level at admission. Longer LOS in rehabilitation provides time for functional gains<sup>[12]</sup>. Cognitive function is an important determinant of clinical recovery. Less cognitive impairment provides better functional level.

In the present study, the predictors of recovery following traumatic brain injury rehabilitation were also investigated. After traumatic brain injury, cognitive and behavioral impairments have an impact on independence, particularly, when the subject turned his/her back to his/her social environment. By contrast, mobility status is a good predictor soon after injury. Therefore, in the regression model, total BI score at discharge was used as the figure of merit<sup>[13]</sup>. The strongest predictor, as evidenced by  $\beta$  coefficient, was the level of consciousness (GCS) and mobility (gait score) pre-rehabilitation. LOS in rehabilitation ( $\beta = 0.068$ ) was also analyzed as a predictor, but weak correlation was found in the model. A longer LOS in rehabilitation was associated with a better functional level at discharge. These findings are consistent with reports from Cowen *et al*<sup>[14]</sup> and Sandhaug *et al*<sup>[11]</sup> who found that a longer LOS in rehabilitation was associated with significantly higher gains.

However, lower motor and cognitive scores (slow-to-recover patients) at admission were associated with extended LOS in rehabilitation. Eames *et al*<sup>[15]</sup> found that prolonged (11 months) rehabilitation time was associated with a significant increase in functional independence. Willer *et al*<sup>[16]</sup> showed that a rehabilitation program of 8 months was associated with improved function. In this study, patients achieved a lower functional level, possibly because rehabilitation time for a functional recovery was not sufficient enough.

The GCS at admission to hospital was not a predictor of outcome in this study. This result correlates well with previous literature. Marion *et al*<sup>[17]</sup> showed that in the first 24 hours after trauma, aggressive treatments, involving early sedation and intubation, were factors of preventing real GCS assessment. This problem may have affected the relevance of the GCS on results. Zafonte *et al*<sup>[18]</sup> concluded that GCS may be a valuable tool in the prediction of mortality, but suggested that its usefulness in predicting functional and cognitive level in traumatic brain injury patients who were admitted to an inpatient rehabilitation setting is limited. Balestreri *et al*<sup>[19]</sup> suggested that the predictive value of acute GCS should be carefully reconsidered when building prognostic models. Similarly, Sandhaug *et al*<sup>[11]</sup> found



that the GCS at admission to hospital was a weaker predictor of outcome. The GOS, before rehabilitation, was not a significant predictor of the functional outcome in this study. This result is consistent with Miller *et al*<sup>[20]</sup>. They examined whether an early GOS assessment provides a reliable indicator of later outcome in patients with traumatic brain injury. They indicated that baseline (within 3 months of injury) GOS score was a reliable predictor of outcome in patients with an initial score of 5 (no disability) or 4 (mild disability), but not in patients with an initial score of 3 (severe disability). An updated evaluation conducted after the early phase of treatment is needed to provide a realistic prognosis of severe traumatic brain injury. In the present study, the mean GOS score was 3 before rehabilitation and therefore GOS score did not seem to be a significant predictor. The present results suggest that the predictive value of the GOS should be carefully reconsidered. Age and gender were not significant predictors of the functional outcome in this study. As suggested by Zafonte *et al*<sup>[21]</sup>, neurological status may have a more profound impact on functional level in earlier phases after injury, while pre-injury variables may have greater influence in the later recovery phases. Schönberger *et al*<sup>[22]</sup> also predicted the functional and employment outcome 1 year after traumatic brain injury. In their study, age predicted post-injury 1 year employment. Since age was not related to post-traumatic amnesia and reported cognitive change, poorer recovery in older individuals is likely not the reason for this age effect. Felmingham *et al*<sup>[23]</sup> also found that age significantly predicted work status at 2 years after traumatic brain injury. Prediction of outcome after traumatic brain injury is a problem for all health professionals working in this area. The most frequently asked questions by patients and/or families within the first days after a traumatic event surround mortality, morbidity, and prospects for short- and long-term recovery. Most health care professionals are unable to predict prognosis accurately since patient recovery is quite variable. These results may be used to evaluate the chance of recovery and to guide an appropriate care plan. The small sample size and the lack of a control group (due to ethical reasons) are major limitations in this study. In conclusion, results from this study demonstrate that acute rehabilitation did not provide a complete recovery at discharge in all patients except in one with mild traumatic brain injury. Level of consciousness and mobility at admission to rehabilitation can be taken as predictors of functional level at discharge.

## SUBJECTS AND METHODS

### Design

A retrospective review of medical records.

### Time and setting

This study was performed at the Department of Neurosurgery, Hacettepe University, Ankara, Turkey from January 2008 to November 2010.

### Subjects

Fifty-one patients with mild ( $n = 14$ ), moderate ( $n = 10$ ) and severe ( $n = 27$ ) traumatic brain injury who received treatment at the Department of Neurosurgery, Hacettepe University were included in this study. Patients with traumatic brain injury confirmed on brain CT scans were included in the study whilst subjects younger than 16 years of age or in a vegetative state at admission were excluded. The mechanisms of injury (traffic accident, falls and others) were recorded. The severity of injury at admission was determined based on the GCS<sup>[24]</sup>. Patients with GCS score of 13 or higher were classified as mild, GCS of 9 to 12 were classified as moderate and those with GCS of 8 or lower were classified as severe head injury. Forty (78%) of fifty-one patients were male and eleven (22%) were female, with a mean age of  $40.4 \pm 15.3$  years.

### Methods

#### Acute rehabilitation

The Bobath Neurodevelopmental Therapy approach<sup>[25]</sup> was performed in all patients by an experienced physiotherapist who had at least 10 years of professional experience in treating patients with traumatic brain injury. The exercise program was applied for at least 30 minutes a day, 5 days a week until hospital discharge. This program was composed of passive stretching, static weight-bearing, muscle strengthening, functional exercises and electrical stimulation.

#### Evaluation of outcome measures

The measurements used at the beginning and the end of rehabilitation program were the GCS, GOS, MSAS sitting up from lying, balanced sitting and gait subscales, BI and LOS hospital and LOS rehabilitation. GCS was used to evaluate the level of consciousness and degree of brain injury<sup>[24]</sup>. This score evaluates visual, motor and verbal responses to stimuli. GCS scores range from 3 to 15, with a lower score indicating more severe damage and a poorer prognosis.

The GOS is a commonly used scale to assess the

outcome in traumatic brain injury patients. This scale ranks the outcome from 1 (dead) to 5 (good recovery)<sup>[26]</sup>. Mobility was assessed using the MSAS. This scale consists of six activities (bridging, sitting from supine, sitting balance, getting up from a chair, standing balance and gait) and rates performance from 1 (patient makes no contribution to the activity) to 6 (unassisted) with a maximum total score of 36<sup>[27-28]</sup>.

The BI is a 10-item instrument measuring functional independence in personal activities of daily life. Higher scores indicate functional performance and more independence<sup>[29]</sup>.

At discharge, the range of outcomes was described by classifying the patients as having minimal or no disability (BI score, > 90; GOS, 5), moderate disability (BI, 55–90; GOS, 4), or severe disability (BI, < 55; GOS, 3 or 2), according to the criteria proposed by National Institute of Neurological Disease and Stroke<sup>[30-31]</sup>.

### Statistical analysis

Data were presented as medians with inter-quartile ranges for non-normally distributed variables and means with standard deviation for normally distributed continuous variables. Continuous variables in patients with mild, moderate and severe traumatic brain injury patients were compared statistically using one-way analysis of variance or Kruskal-Wallis test. Wilcoxon Signed Rank Test was used for comparison of individual changes within mild, moderate and severe traumatic brain injury patients between pre-rehabilitation and post-rehabilitation. The chi-square test was used to determine whether or not there was any association between the categorical variables. Correlations were studied using Spearman's Rank Order Correlation. The dependent variable in the regression analysis was BI at discharge from the rehabilitation unit. Independent variables with *P* values < 0.05 in pre-analyses were then entered into a backward stepwise multiple linear regression model to quantify their predictive impact on BI at discharge. Variables that were strongly correlated to another one ( $r > 0.7$ ) were excluded from the analyses in the regression model. All data were analyzed using SPSS version 15.0 (SPSS, Chicago, IL, USA) and results with *P* values < 0.05 were considered statistically significant.

**Author contributions:** All authors participated in the study design, conduction, and evaluation. All authors contributed to preparation of the manuscript.

**Conflicts of interest:** No authors of the above manuscript have any conflicts of interest, within the last three years, which may arise from being named as an author on the manuscript.

**Ethical approval:** The study protocol was approved by Hacettepe University Ethics Committee.

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