

The ability of GCS, FOUR, and APACHE II in predicting the outcome of patients with traumatic brain injury: A comparative study

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History

- Received: Dec 03, 2019
- Accepted: Feb 11, 2020
- Published: Feb 29, 2020

DOI : 10.15419/bmr.t.v7i2.588



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ABSTRACT

Introduction: Assessment of the neurological condition of patients admitted to intensive care units gives healthcare professionals the necessary knowledge to attempt to improve their condition and final outcome. Such an assessment cannot be done without a highly reliable and accurate instrument. This study aimed to compare the ability of GCS and FOUR scales to assess the level of consciousness and dysfunction in patients with traumatic brain injury. **Methods:** This descriptive cross-sectional study was conducted on 102 patients with traumatic brain injury who were found by convenience sampling. The condition of patients during hospitalization up until determination of the final outcome was assessed using GCS, FOUR, Karnofsky, and APACHE-II scales. In the end, the ability of these scales to predict outcome and dysfunction of these patients, and their correlation in this application, was measured using one-way ANOVA and the Pearson correlation test. **Results:** Of the 102 patients, 80 (78.4%) were male, and 22 (21.6%) were female. The mean age of patients was 32.2 ± 14.8 . There was a significant correlation between the results of FOUR and GCS in the assessment of the patients' consciousness level ($r = 0.925$), which was statistically significant ($p = 0.0001$). The mean scores of FOUR, GCS, and Karnofsky scales were significantly higher in survivors and in patients with neurological deficits than in non-surviving patients. The patients who died also had a significantly higher APACHE-II score than those who did not. FOUR and GCS showed a strong positive correlation in the assessment of outcomes, and both of them also exhibited a high correlation with APACHE II in this respect. **Conclusion:** GCS and FOUR are both suitable scales for assessing consciousness level and outcome of patients with traumatic brain injury.

Key words: FOUR, Glasgow Coma Scale, APACHE II, Traumatic Brain Injury, Karnofsky scale, Intensive care unit

INTRODUCTION

Traumatic brain injury (TBI) is one of the world's most important causes of mortality and severe disability and imposes a devastating financial burden on communities¹. This issue is exacerbated by the fact that most people suffering from TBI are young². Mortality from TBI can be reduced by improving patient assessment and management systems³. In modern evidence-based medicine, access to reliable assessment scales is essential for predicting mortality risk and the ultimate outcome of intensive care so as to allow caregivers to determine the severity and outcome of patient condition and to make important health care decisions accordingly⁴. One of the scales used for such evaluations is the Glasgow Coma Scale (GCS). This scale was first designed in 1974 to assess the level of consciousness of patients with head injury⁵. GCS can predict the primary outcome of TBI (mortality and morbidity) and help healthcare professionals devise a model for care delivery⁶⁻⁸. However, some researchers have questioned the validity of this

scale since it does not evaluate brainstem reflexes and cannot assess verbal responses in patients with intubation and tracheostomy⁹⁻¹¹. To avoid these shortcomings, researchers have developed other scales for measuring consciousness in TBI patients. One of these scales is the FOUR (Full Outline of UnResponsiveness) score, developed by researchers at Mayo Clinic (United States), which consists of four components: eye responses, motor responses, brainstem reflexes, and respiration pattern^{12,13}. Several studies have suggested that the FOUR scales can provide a better assessment of patients' final outcome than GCS^{7,8,12}. However, these studies have reached this conclusion by comparing these two scales with each other and have not assessed the consistency of these two scales with the results of APACHE II or other major scales. Therefore, this study aimed to compare the ability of GCS and FOUR, versus other scales (Karnofsky, APACHE-II, etc.), to evaluate the level of consciousness and dysfunction in TBI patients.

Cite this article : Khoshfetrat M, Arab Yaghoubi M, Khodadadi Hosseini B M, Farahmandrad R. **The ability of GCS, FOUR, and APACHE II in predicting the outcome of patients with traumatic brain injury: A comparative study.** *Biomed. Res. Ther.*; 7(2):3614-3621.

METHODS

This descriptive cross-sectional study was performed with the authorization of the Department of Research and Technology of Zahedan University of Medical Sciences (Iran) and the approval of the Ethics Committee of the university (with Code IR.ZAUMS.REC.1396.33). Using the reports of previous studies and the sample size formula, the sample size was calculated as 102¹⁴. Sampling was performed using the convenience sampling method according to the defined inclusion criteria.

Inclusion criteria were as follows: age of 18-65 years, hospitalization for head trauma, mechanical ventilation, and at least 24 hours of stay in the intensive care unit. Exclusion criteria were as follows: lack of consent of family members, the discovery of malignant and fatal diseases, cervical spinal cord injury, musculo-skeletal paralysis, deafness, blindness, and history of eye surgery resulting in a change in pupil size and shape.

All eligible patients were monitored using GCS, FOUR, APACHE II, and Karnofsky scales until discharge or death. For sedated patients, the infusion was stopped one hour before measurements. The scores obtained from the scales were analyzed in SPSS using descriptive statistics, one-way ANOVA, and Pearson's correlation test.

The FOUR scale consists of four components: eye responses, motor responses, brainstem reflexes, and respiration patterns (Figure 1). The validity and reliability of GCS and FOUR for Iranian patients were assessed in a 2011 study conducted in Tehran on 155 patients with 4 nurses and anesthesiology residents (including the author) in two groups of trained and untrained staff, which observed excellent inter-group agreement. In this study, the coefficient of correlation of FOUR scores in the trained and untrained groups were 0.998 and 0.993, respectively; the kappa coefficient of intra-group agreement in these groups were 0.981 and 0.986, respectively; as well, the coefficient of correlation between FOUR and GCS scores in these groups were 0.980 and 0.925, respectively¹⁵. APACHE II (Table 1) consists of 3 main dimensions: a physiological dimension, which includes GCS, temperature, mean arterial blood pressure, heart rate, respiratory rate, Pao₂, arterial blood pH, serum sodium, potassium, creatinine, hematocrit, and white blood cell count. The score of each item in the physiological dimension ranges from 0 to 4, giving this dimension a total score of 0-59. The second part of this scale is a score between 0 and 6, which is awarded based on the patient's age group. The third part involves the evaluation of chronic diseases and the failures of one or more

organs. The sum of scores obtained from these three parts is the APACHE II score, which ranges from 0 to 71. The higher the APACHE II score, the higher the patient's risk of mortality¹⁶. Karnofsky scale is used for assessing the patient's degree of dysfunction. This scale takes values between 0 (death) and 100 (no dysfunction), and reflect the patient's activity level; the lower the Karnofsky score, the more intensive care the patient requires^{17,18}.

RESULTS

Of the 102 patients, 80 (78.4%) were male, and 22 (21.6%) were female. The mean age of patients was 32.2 ± 14.8 (Figure 2).

The mean GCS score at admission was 8.6 ± 3.5 , and at the end of the study was 12.9 ± 3.5 . The mean GCS score during the hospitalization period was 10.8 ± 2.9 . The mean FOUR score at admission was 9.3 ± 4.5 and at the end of the study was 14.8 ± 4.8 . Also, the mean FOUR score during the hospitalization was 11.7 ± 3.9 . The mean Karnofsky score was 23.9 ± 5.5 , with the lowest score being 10 and the highest being 40.

The mean APACHE II score at admission was 11.5 ± 6.7 , with the lowest score being 1 and the highest being 29 (Figure 3).

There was a significant correlation between the FOUR and GCS scores for the level of consciousness ($r=0.925$), which was statistically significant ($p=0.0001$). The mean scores of FOUR, GCS and Karnofsky scales were significantly higher in survivors and patients with neurological deficits than in patients who died. Patients who died also had a significantly higher APACHE II score than those who did not (Table 2).

A high degree of positive correlation was observed between assessments by FOUR and GCS for patient outcome (healthy, neurological deficits, or death). Also, both of these scales showed very high negative correlation with APACHE II. The correlation between Karnofsky and APACHE II scores in healthy patients was $r = -0.457$; in patients with neurological deficits $r = -0.481$, and in deceased patients, was $r = -0.796$. These correlations were statistically significant in all cases except for patients with neurological deficits (Table 3).

Both GCS and FOUR were as capable as APACHE II in predicting the outcomes. The highest agreement between the scales was in the assessment of mortality rates, which was slightly higher between GCS and APACHE II.

Table 1: The APACHE II scale

Physiologic variable	High abnormal range									Low abnormal range			
	+4	+3	+2	+1	0	+1	+2	+3	+4				
Rectal temp (°C)	≥41	39-40.9			36-38.4	34-35.9	32-33.9	30-31.9					≤29.9
Mean Arterial Pressure (mmhg)	≥160	159-130	129-110		109-70		69-50						≤49
Heart Rate	≥180	179-140	139-110		109-70		69-55	54-40					≤39
Oxygenation													
a) Fio2 ≥ 0.5 record A-aDo2	≥500	499-350	349-200		<200	Pao2	-	Pao2	Pao2				Pao2
b) Fio2 < 0.5 record Pao2					Pao2 > 70	70-61		60-56	<55				
Arterial pH	≥7.7	7.69-7.6		7.59-7.5	7.49-7.33		7.32-7.25	7.24-7.15	<7.15				
HCO ₃ (mEq/l)	≥52	51.9-41		40.9-32	31.9-22		21.9-18	17.9-15	<15				
K (mEq/l)	≥7	6.9-6		5.9-5.5	5.4-3.5	3.4-3	2.9-2.5		<2.5				
Na (mEq/l)	≥180	179-160	159-155	154-150	149-130		129-120	119-111	<110				
S.Creat (mqm/dl)	≥3.5	3.4-2	1.9-1.5		1.4-0.6		<0.6						
Hematocrit (%)	≥60		59.9-50	49.9-46	45.9-30		29.9-20		<20				
WBC (10 ³ /cc)	≥40		39.9-20	19.9-15	14.9-3		2.9-1		<1				
Age-score					GCS								
< 44- 0					15 - 0 10 - 5 5 - 10								
45-54- 2					14 - 19 - 6 4 - 11								
55-64- 3					13 - 2 8 - 7 3 - 12								
65-74- 5					12 - 3 7 - 8								
≥ 75- 6					11 - 4 6 - 9								

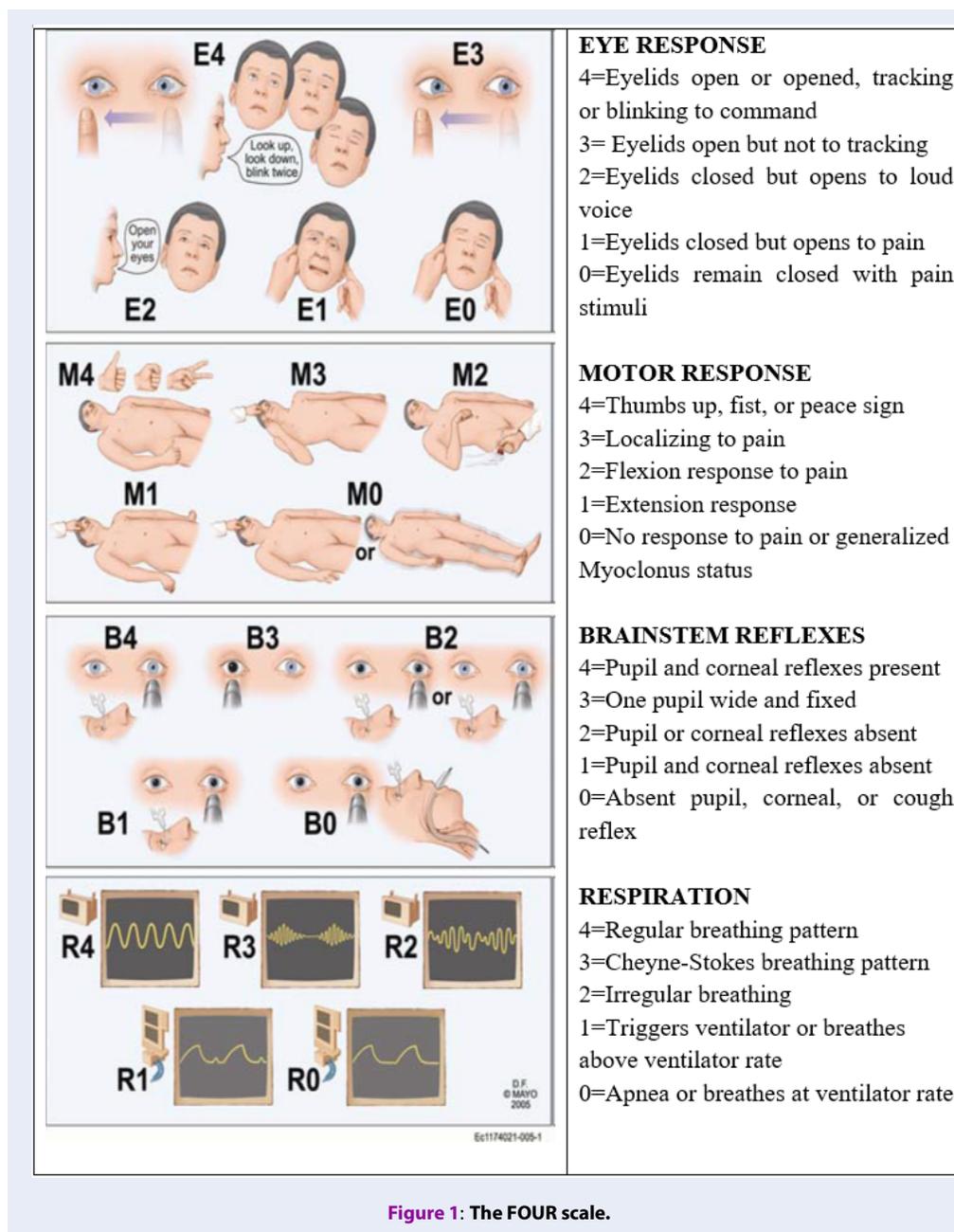


Table 2: Comparison of mean scores of the FOUR, GCS, Karnofsky, and APACHE II scales using one-way ANOVA

Variable	Outcome at discharge			P-value
	Survival n = 78	Neurological deficit n = 14	Death n = 10	
GCS	11.6 ± 1.9	9.4 ± 1.3	7.7 ± 4.7	0.0001
FOUR	12.9 ± 2.4	11.4 ± 1.2	8.8 ± 6.7	0.0001
Karnofsky	24.8 ± 5.5	21.4 ± 3.6	20 ± 4.7	0.005
APACHE II	9 ± 4.7	17.9 ± 6.1	22.1 ± 5	0.0001

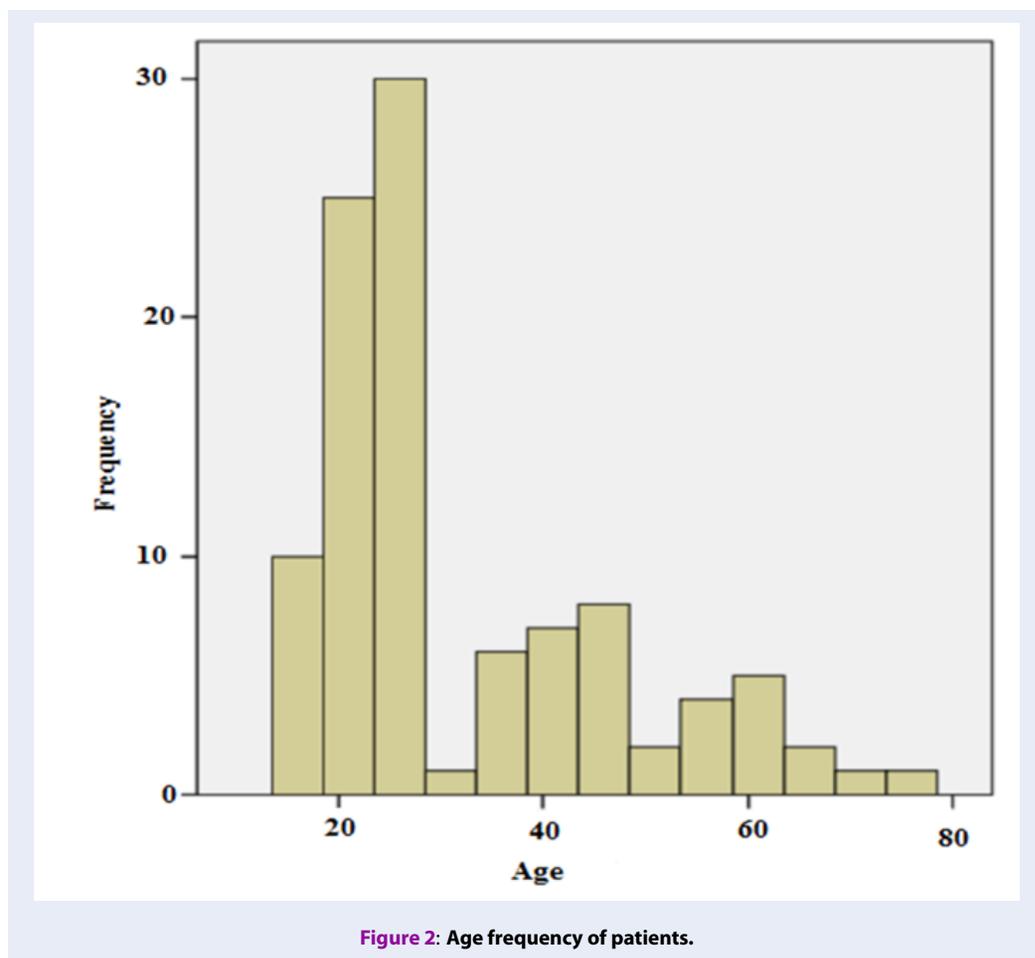
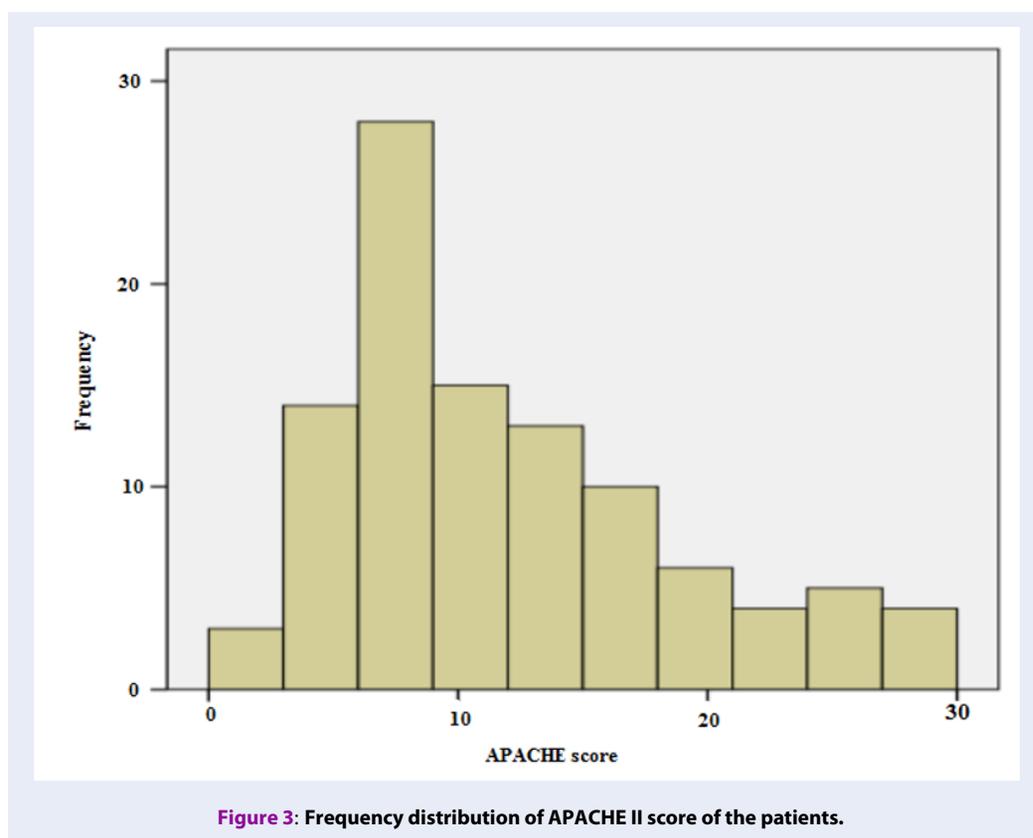


Table 3: Comparison of correlation between FOUR and GCS, Karnofsky and APACHE II scores for the assessment of patient outcomes using Pearson correlation test

Outcome at discharge	Compared variable	r	P-value	
Survival	Healthy	GCS-FOUR	0.826	0.0001
	neurological deficit	GCS-FOUR	0.746	0.002
Death	GCS-FOUR	0.871	0.001	
Survival	Healthy	Karnofsky-APACHE II	-0.457	0.0001
	neurological deficit	Karnofsky-APACHE II	-0.481	0.082
Death	Karnofsky-APACHE II	-0.796	0.006	
Survival	Healthy	GCS-APACHE II	-0.737	0.000
	neurological deficit	GCS-APACHE II	-0.7	0.01
Death	GCS-APACHE II	-0.911	0.000	
Survival	Healthy	FOUR-APACHE II	-0.699	0.0001
	neurological deficit	FOUR-APACHE II	-0.646	0.00
Death	FOUR-APACHE II	-0.891	0.000	



DISCUSSION

Access to reliable and uniform scales for assessing a patient's level of consciousness can help caregivers provide a better assessment of patient condition⁸. The results of this study showed that GCS and FOUR are perfectly consistent in the assessment of patients' level of consciousness. Most of the previous studies have reported the better ability of the FOUR scale in assessing consciousness and have suggested that GCS is unable to measure brainstem reflexes, is inconsistent in measuring verbal reflexes in confused patients without consciousness disorder, and is unable to give reliable results for patients with intubation and tracheostomy^{1,7,8,19}. However, the results of this study showed no significant difference between the initial score obtained from these two scales. There was also no significant difference between the two scales in the assessment of consciousness and outcome. In other words, GCS was as capable as FOUR in predicting patient outcomes. Considering the ease of use of GCS and the fact that it can be used by all healthcare team members and does not need any special measurement equipment, GCS can still serve as a good scale for measuring consciousness and outcome.

Contrary to this finding, Keykha *et al.* reported that the FOUR scale is a better measure of consciousness level and should be used instead of GCS when measuring consciousness in ICU patients⁸. This difference in the results can be attributed to the fact that the above study was performed on patients receiving continuous sedation infusion, whereas sedation of the patients in this study was stopped one hour before measurements. Stopping the sedation infusion before consciousness measurements have the benefit of ensuring that the patient's level of consciousness is not physically reduced. To avoid high levels of reduced consciousness, it is best to use on-off infusions, because sedative drugs may accumulate in the fat tissue, and their sedative effects can remain for as long as 24 hours after stopping infusion²⁰. In cases where continuous sedation is absolutely needed for pain control or tolerance of mechanical ventilation, although the scores of both scales would drop, the FOUR scale appears to be more suitable for consciousness assessment. In a study by Jalali, it was reported that the FOUR scale was better in assessing consciousness and predicting mortality than GCS, but the low score of neither scale was associated with mortality because deceased patients had a higher mean score in both

scales¹.

In terms of the scales' ability to measure consciousness, these results are consistent with previous findings but are inconsistent with the findings of the present study. In terms of predicting mortality, these results are inconsistent with all other reports because all previous studies have shown that patients with a low admission score, in either scale, have a mortality outcome. Unlike the present study, Phuping *et al.* recognized the FOUR scale as a reliable predictor of recovery and mortality and reported that most of the recoveries occurred in patients who earned a FOUR score of more than 10. They argued that since the lower scores of the FOUR scale could provide a better assessment of patient condition (compared to GCS), this scale is recommended for measuring changes in the level of consciousness in neurosurgery and similar patients. It should be noted that there are etiological differences between these two studies, as subjects of that study included patients with tumors, aneurysms, hydrocephalus, and brain infections. Yet, this study was conducted only on patients with head trauma²¹. Consistent with the results of the present study, Bruno *et al.* reported that GCS and FOUR are well-correlated in predicting mortality and recovery¹⁴. But in intensive care units, these scales must not only measure prognosis and consciousness but also meet other requirements, one of which is the distinction between coma, vegetative state and locked-in syndrome (LIS). According to the GCS scoring criteria in the eye response dimension, open eyes earn a complete score. Meanwhile, vegetative patients cannot close their eyes or follow a target, and LIS patients only have vertical eye movements. In the eye response component of the FOUR scale, a complete score is awarded only when the patient can blink on-demand or follow a target, which helps make a distinction between the aforementioned states^{12,22}. Despite all these shortcomings of GCS, Hosseini *et al.* reported that this scale was even better than APACHE II in predicting patient mortality²³. Cho *et al.* stated that although GCS is suitable for assessing early mortality, it is not a good replacement for APACHE, as APACHE II is a better predictor of late mortality²⁴.

CONCLUSIONS

The results of this study showed that GCS and FOUR are both very good scales for measuring the consciousness level and outcome of TBI patients and that neither scale can be considered preferable over the other in measuring the consciousness level. Since many healthcare professionals with varying degrees of expertise participate in the treatment process, the instruments used to evaluate patients' condition should

be able to provide a uniform assessment of consciousness level and outcomes when applied by different people. Therefore, it is best to choose the right instrument according to the type of department and the skill of healthcare professionals who are going to employ it.

LIMITATIONS

The limitations of this study included the absence of any measurement during sedation and the small size of the sample. The authors recommend conducting a similar study with a greater number of subjects to confirm the findings.

COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

AUTHORS' CONTRIBUTIONS

Masoum Khoshfetrat: Participation in implementation of research and supervision over data collection and revising this paper. Mostafa Arab Yaghoubi: Participation in implementation of research and data collection. Bibi Mahdie Khodadadi Hosseini: Compilation of the paper. Reza Farahmandrad: Analyzing the data and editing this paper carefully. All authors reviewed, commented and approved the final version.

FUNDING

The present study was financially supported by Zahedan University of Medical Sciences, Zahedan, Iran.

ACKNOWLEDGMENT

This article has been adopted from the Thesis written by Resident of Anesthesiology and Critical Care, approved and funded by Research and Technology Deputy of Zahedan University of Medical Sciences. The researcher would like to express own gratitude to the Research and Technology Deputy of the University and the staff and ICU ward at the Khatam-ol-Anbia Hospital of Zahedan.

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