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# Correlation between bispectral index and FOUR score in critically ill patients with traumatic brain injury: A cross-sectional study

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**ABSTRACT**

**Introduction:** For neurological testing and monitoring of traumatic brain injury (TBI) patients whose verbal component of the Glasgow Coma Scale (GCS) cannot be assessed, the Full Outline of Unresponsiveness (FOUR) score has been established. In order to determine the degree of awareness in patients with traumatic brain injury, this study will correlate the FOUR score with the bispectral index (BIS) and global consciousness score (GCS).

**Methods:** Twenty TBI patients with traumatic brain injury who were hospitalised to the surgical ICU at Cairo University Hospital participated in our prospective observational research. An observer who was blind to the BIS values assessed each of the FOUR scores and GCS (Covidien BIS complete monitoring system, Mansfield, MA, USA). Each patient provided four sets of readings. Spearman's correlation coefficient was used to perform a correlation between the FOUR score, GCS, and BIS (r).

**Results:** There was a significant correlation between BIS and FOUR score ($r = 0.854$, 95% confidence interval: 0.780–0.904) ($P < 0.001$). There was also a significant correlation between BIS and GCS ($r = 0.864$, 95% confidence interval: 0.795–0.911) ($P < 0.001$).

**Conclusion:** There is a strong correlation between FOUR score, GCS, and BIS values in patients with traumatic brain injury. FOUR score seems a reliable alternative for GCS and BIS in the assessment of degree of consciousness, especially in intubated patients.

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Bispectral index; FOUR score; Glasgow Coma Scale; traumatic brain injury

## 1. Introduction

Traumatic brain injury (TBI) is a major global cause of mortality and disability, particularly in children and young people [1]. The need for critical care monitoring is anticipated in 22% of TBI hospitalisations [2].

The Glasgow Coma Scale is the most typical clinical grading system utilised for TBI patients [2]. However, because its verbal component cannot be assessed, GCS cannot be employed in a subgroup of TBI patients who are receiving mechanical ventilation. The Full Outline of Unresponsiveness (FOUR) score, a clinical grading system for the evaluation of patients with impaired degree of awareness, has recently been devised and may be applied to patients with or without endotracheal intubation [2]. The FOUR score also includes crucial clinical symptoms that the GCS missed, such as brainstem reflexes, respiratory drive, and a chance to locate the patient who is paralysed [3].

In operating theatres, the bispectral index (BIS) is routinely used to measure patients' degrees of consciousness. After examining the correlation between prognosis and BIS value in 56 patients with severe coma, Fàbregas et al. concluded that BIS monitoring may be utilised to evaluate brain death patients in severe coma [4]. The economic burden associated with the widespread use of the BIS electrodes, which are necessary for continuous monitoring, necessitated the construction of a simpler, more cost-effective substitute.

The aim of our work was to correlate the FOUR score with the BIS and GCS for assessment of degree of consciousness in patients with traumatic brain injury.

## 2. Patients and method

Twenty patients with traumatic brain injury who had been admitted to the surgical ICU at Cairo University Hospital were involved in this prospective observational research".

Patients were enrolled between November 2018 and March 2019. Patients who were at least 18 years old were included. A patient has to have at least one of the following trauma-related admission diagnoses in order to be given the TBI label: closed head injury (CHI), cerebral contusion, subdural hematoma, epidural hematoma, intracranial hemorrhage, intraparenchymal hemorrhage, and subarachnoid hemorrhage. Patients

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who had ocular, facial, or airway damage, spinal cord injury, limb fracture, were highly sedated, or were on neuromuscular blockers were excluded.

The awareness degree of each patient was assessed via FOUR score and bispectral index (Covidien BIS complete monitoring system, Mansfield, MA, USA) by a blinded observer who also noted the patient's GCS. BIS was assessed utilizing two sensors that were positioned on the patient's forehead to obtain the raw EEG data. The device translates the signal into an absolute BIS value between 0 and 100 (0 = no brain electrical activity) (100 = wide awake). At four different time periods, measurements for APACHE II, hemodynamics (including heart rate, blood pressure, and temperature), and brain monitoring (including FOUR Score, GCS, and BIS values) were gathered. At the time of admission (T0), two sets of readings were taken at (T0 a) 8 a.m. and (T0b) 8 p.m., and 3 days later (T1), another two sets of readings were taken at (T1a) 8 a.m. and (T1b) 8 p.m.

"According to the GCS level, these patients were divided into 2 groups: Patients with GCS of ≥ 8 were considered as patients with mild to moderate TBI group (Group M), and patients with GCS < 8 were considered i.e., patients with severe TBI group (Group S)."

## 3. Outcomes

### 3.1. Primary

The correlation between the FOUR score and the BIS.

### 3.2. Secondary

- Correlations between the GCS and the FOUR score and the BIS.
- The BIS's sensitivity and specificity in determining the severity of traumatic brain injury
- Patient characteristics and demographics:
  Age, gender, the APACHE II score, the reason for artificial breathing, and surgical intervention.
- Hemodynamic factors (Heart rate, blood pressure, temperature).

## 4. Sample size

We took the cautious premise that we could discover an association between the FOUR score and the BIS of 0.7. Using the MedCalc software version 14 for a study power of 95% and an alpha error of 0.05, a minimum of 20 pairs of measurements were calculated (Med Calc software bvba, Ostend, Belgium).

## 5. Statistical analysis

Data were provided as means (with standard deviation) unless otherwise noted, and the Mann-Whitney U-test for continuous variables and the 2 test for categorical data were used to compare them. To ascertain the relationship between the BIS, FOUR score, and GCS, Spearman's rho correlation coefficient was applied. To evaluate how well BIS predicts the severity of TBI, the area under the curve (AUC) and receiver operating characteristic (ROC) curves were developed. MedCalc version 12.1.4.0 (MedCalc Software bvba, Mariakerke, Belgium). The level of significance for two-tailed testing was set at P 0.05.

## 6. Results

The patients' demographics and baseline characteristics collected at T0 are represented in Table (1).

A significant correlation was noted between BIS and FOUR score ($r = 0.854$, 95% confidence interval: 0.780–0.904, $P < 0.001$). Also, a significant correlation was noted between BIS and GCS ($r = 0.864$, 95% confidence interval: 0.795–0.911, $P < 0.001$).

A significant correlation between FOUR score values and GCS for the assessment of degree of consciousness (r = 0.958) (P < 0.001) (Figures 1,2) (Table 2).

Sensitivity of BIS to detect the severity of TBI was 100%, while its specificity was 80.4% at a cut-off value of 68 with AUROC (95% CI) 0.948 (0.874–0.985) (Figure 3).

## 7. Discussion

We found a strong correlation between BIS and FOUR score values ($r = 0.854$) and between GCS and FOUR scores ($r = 0.958$) in patients with TBI, denoting the condition's worsening and improvement, as a method to assess and record the degree of consciousness in traumatic brain injury patients in intensive care unit settings.

Prior research suggested ways to validate simple ratings and evaluation instruments to help GCS indicate the worsening and improvement of the TBI condition. In a research, 97 individuals over the age of 16 participated in a prospective study conducted by Khanal et al. Within 24 hours of admission to the intensive care unit, they assessed the GCS and FOUR score. In comparison to survivors, non-survivors had lower mean GCS and FOUR scores, and there was a statistically significant association between the two [5].

In a similar manner, Wijdick et al. found 51 TBI patients who were admitted to their Neuro-ICU. Scores for the GCS and FOUR were developed. The results included in-hospital mortality and poor neurologic outcomes (mRS scores of 3–6 and Glasgow Outcome Scale (GOS) scores of 1–3) at 3–6 months. Both the FOUR score and GCS have extremely good internal consistency [1]

Results from the BIS and GCS were strongly associated in our research. This outcome was comparable to Senapathi et al. [6]'s ($r = 0.744$, p0.01) and Ebtehaj et al. [7]'s ($r = 0.88$, $p = 0.03$) findings. Similar findings were suggested by Paul and colleagues, who

**Table 1.** Demographics and baseline characteristics.

| Characteristics | |
|---|---|
| Age (18-82 years) | 41.3 ± 18.6 |
| APACHE II score | 13.25 ± 5.97 |
| GCS | 10.04 ± 4.59 |
| FOUR | 11.34 ± 4.60 |
| BIS | 68.36 ± 16.09 |
| Heart rate (Bpm) | 92.06 ± 16.44 |
| Systolic Blood pressure (mmHg) | 126.38 ± 15.69 |
| Diastolic blood pressure (mmHg) | 74.00 ± 9.08 |
| Mean arterial blood pressure(mmHg) | 87.73 ± 12.95 |
| Temperature ($^{o}$ C) | 37.34 ± 0.48 |
| Type of Pathology [N(%)] | |
| Compound depressed fracture | n = 6 (30%) |
| Extradural hemorrhage | n = 4(20%) |
| Chronic subdural hemorrhage | n = 3(15%) |
| Brain contusion | n = 2(10%) |
| Intracerebral hemorrhage | n = 2(10%) |
| Acute subdural hemorrhage | n = 1(5%) |
| Fissure fracture | n = 1(5%) |
| Concussion | n = 1(5%) |

Data presented as Mean (± SD). FOUR score: Full outline of unresponsiveness score, GCS: Glasgow Coma Scale, BIS: Bispectral index, *n*= The whole number of the patients in the present study, N(%)= The number and percent of each pathology in the patients of the present study,APACHE score=The Acute Physiology and Chronic Health Evaluation.

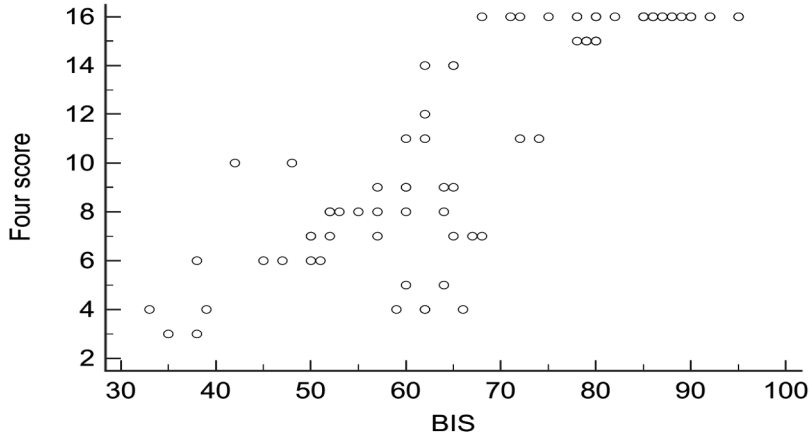


**Figure 1.** Scatter plot for correlation between FOUR score and BIS for the assessment of degree of consciousness.

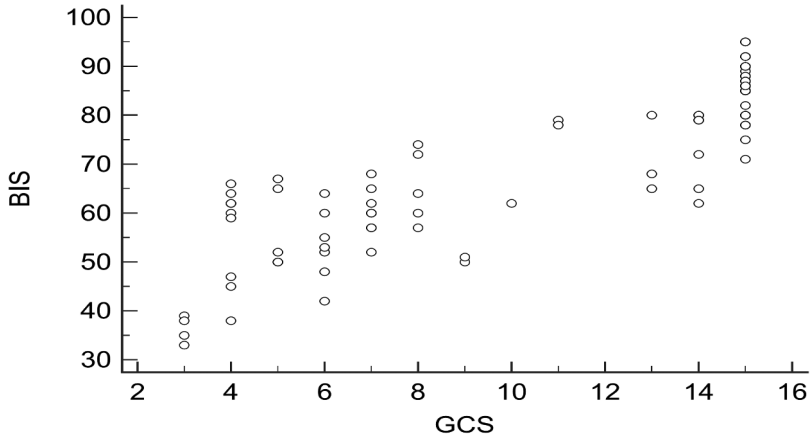


**Figure 2.** Scatter plot for correlation between GCS and BIS for the assessment of degree of consciousness.

measured the GCS and BIS of 29 patients who underwent craniotomies and had mild (GCS 13–15) or moderate (GCS 9–12) head injuries. These assessments were made before the surgery, right after it, and once a day during the first 10 days. There was a strong correlation between GCS and BIS in the data sets from all the patients ($r = 0.67$; p 0.001). As GCS scores grew, the mean BIS values increased [8]

**Table 2.** Correlation between BIS values and different scores for assessment of degree of consciousness and FOUR score and GCS in patients with traumatic brain injury.

| | r value (95% confidence interval) | P value |
|---|---|---|
| BIS and Four score | 0.854 (0.780–0.904) | *<0.001 |
| BIS and GCS | 0.864 (0.795–0.911) | *<0.001 |
| Four score and GCS | 0.958 | *<0.001 |

FOUR score: Full outline of unresponsiveness score, GCS: Glasgow Coma Scale, BIS: Bispectral index, *$P$ value significant < 0.05.

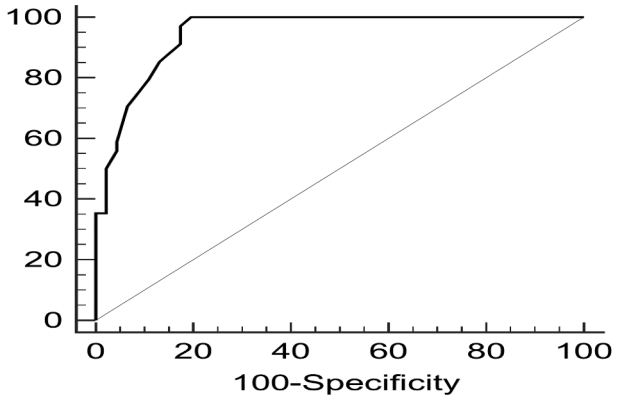


**Figure 3.** Receiver operating characteristic curve for BIS to detect severe TBI.

It is justified to use the FOUR score as a standard method for measuring the level of consciousness by pointing out that it incorporates significant clinical markers that the GCS missed, such as brainstem reflexes, respiratory drive, and the capacity to recognize paralyzed individuals.

The relationship between the FOUR score and BIS in TBI patients is the subject of our investigation.

It is important to note that the FOUR score has been shown to be a reliable and accurate assessment for usage with TBI patients in a critical situation [5].

Our findings that the sensitivity of BIS to detect the severity of TBI was 100% and its specificity was 80.4% at a cut-off value of 68 enhanced the role of BIS in monitoring the degree of consciousness of traumatic brain injury patients and the significant correlation between FOUR score values and GCS in our study for the evaluation of degree of consciousness. ($r = 0.958$) (P 0.001), supporting the validity of the FOUR score as a measure that may be used in tandem with the GCS to evaluate the neurological state of TBI patients.

The relevance of these methods for identifying the state of consciousness in patients with traumatic brain injury is shown by the fact that there is a strong correlation between the BIS and FOUR scores ($r = 0.854$, 95% CI: 0.780–0.904, P 0.001), which should be noted.

## 8. Limitations

Being a single-center study and the financial burden for the BIS probes limited the recruitment process.

## 9. Conclusion

In individuals with traumatic brain injury, there is a significant correlation between the FOUR score, GCS, and BIS values. As a trustworthy, understandable, free of charge, and readily available instrument, the FOUR score appears to be a good replacement for the GCS and BIS in the assessment of degree of consciousness, particularly in intubated patients.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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