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Relationship between brain computed tomography findings and bispectral index score in patients presenting with head trauma

Ozlem Kusken,[1] Tuba Cimilli Ozturk,[2] Aysel Hunuk,[3] Ebru Unal Akoglu,[2] Rohat Ak,[2] Cansu Arslan Turan,[2] Ozge Ecmel Onur[2]

[1]Department of Emergency Medicine, Istanbul Medeniyet University, Goztepe Training and Research Hospital, Istanbul, Turkey
[2]Department of Emergency Medicine, University of Health Sciences, Fatih Sultan Mehmet Training and Research Hospital, Istanbul, Turkey
[3]Department of Emergency Medicine, Kartal Yavuz Selim State Hospital, Istanbul, Turkey

ABSTRACT

OBJECTIVE: Head trauma is one of the most important emergency health problems both in the world and in our country. The objective in our study is to (i) state the correlation between the findings of bispectral index score (BIS) and computed tomography (CT), which are used to evaluate the level of consciousness of patients with isolated head trauma, and (ii) investigate objective results about the patient's level of consiousness/alertness according to the CT modality, which is used frequently.

METHODS: This prospective study was carried out between 03.01.2014 and 09.01.2014 in the emergency department of Fatih Sultan Mehmet Education and Research Hospital. The average BIS scores were correlated with the Glasgow Coma Scale (GCS) point, the Canadian CT Head Rule major and minor criteria, and the pathologic findings in CT imaging. The patients' demographic features, vital signs at admission, and arrival times at the hospital were investigated.

RESULTS: In our study, 64 (31.7%) patients were female, and 138 (68.3%) patients were male. The mean BIS scores were 84.99±11.20 (86.05) and 93.78±3.80 (95.05) in patients with and without CT pathologies, respectively. The correlation between CT pathology and BIS scores was statistically significant: BIS scores were lower in patients with CT pathologies ($p=0.001$; $p<0.01$). There was a statistically significant positive correlation between the BIS and GCS scores (45.6%) ($p<0.05$).

CONCLUSION: We showed that most head traumas occur after dangerous accidents, and according to the results, we can predict that males are more frequently affected than females.There was a statistically significant positive correlation between BIS scores and GCS points. In our study, the BIS scores were statistically significantly lower in patients with CT pathology than in patients without. We can predict that if the BIS score of the patient is low, then there will be the presence of pathology on CT imaging.

Keywords: Canadian CT criteria for head trauma; bispectral index score; brain computed tomograpy; head trauma.

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Head trauma is one of the most important emergency health problems both in the world and in our country [1]. Computed tomography (CT) is the most important imaging modality in patients with head trauma. However, CT has some disadvantages such as radiation exposure and cost [2, 3]. To date, several studies have been conducted to determine patients with head trauma who would benefit from brain CT, and a number

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Correspondence: Dr. Rohat AK. Istanbul Fatih Sultan Mehmet Egitim ve Arastirma Hastanesi, Acil Tip Klinigi, Istanbul, Turkey.
Tel: +90 0506 821 31 36 e-mail: rohatakmd@gmail.com

of clinical decision-making rules have been developed. One of these is the Canadian CT Head Rule (CCHR) [3, 4]. Within the framework of CCHR criteria, patients with head trauma who should be screened are determined, and some patients are monitored according to observation and clinical progress. One of these clinical follow-up parameters is the state of consciousness, and monitoring with the Glasgow Coma Scale (GCS) is recommended. It is not always possible to monitor and objectively measure instantaneous changes in consciousness in clinical practice. One measurable and objective parameter is the bispectral index (BIS).

A BIS monitoring device that has been developed on the basis of monitoring electroencephalography (EEG) signals is preferred when monitoring the consciousness of critical patients (e.g., patients with acute brain injury) because it is easily applicable, yields numerical results, and allows continuous monitoring [5]. No study showing (i) the relationship among severity of head trauma, underlying pathology, and BIS values and (ii) the relationship between CT scanning indications and BIS levels has been seen in the literature thus far.

Our primary aim in this study was to determine (i) the BIS values of patients with moderate or mild head trauma who underwent brain CT and (ii) whether there was any relationship between the presence of pathology on brain CT and BIS levels. Our secondary aim was to investigate the effect of each criterion of CCHR on BIS levels.

MATERIALS AND METHODS

This study was conducted prospectively at Fatih Sultan Mehmet Training and Research Hospital Emergency Medicine Clinic between 03.01.2014 and 09.01.2014 after approval of the ethics committee. All adult patients admitted to the emergency department with isolated head trauma between the dates mentioned above were evaluated according to the study criteria, and eligible patients were included in the study.

CTs were routinely performed for all patients with GCS scores <13 who presented to the emergency department with head trauma and were aged over 18 years as recommended in the guidelines. Patients with minor head trauma (GCS scores 14 and 15) were evaluated according to CCHR criteria. All patients who were considered to be undergoing CT scans by the clinician or who planned to undergo CT scans according to CCHR criteria and who agreed to participate in the study were included.

Pregnant patients under 18 years of age, sedative drug users, patients who had been operated upon under general anesthesia within the last 72 h, cases with cerebrovascular events, known brain tumors, or cranial pathology/space-occupying lesions, patients with a previous history of epilepsy or anti-epileptic drug users, patients whose consciousness was blurred for other reasons, patients who needed resuscitation and recording procedures (which would probably delay intervention), patients with incomplete data, patients whose BIS electrodes could not be placed appropriately, and multiple trauma patients were not included. Maximum 15-min data of the patients who were followed up with BIS measurements were collected, and the brain CT images and BIS levels were compared.

For BIS monitoring, the patient was in the supine position before the BIS electrode was placed, and the temple was wiped with an alcohol swab. After the conductive gel was applied, a ring was placed in the middle of the forehead about 2–3 cm above the root of the nose. Another ring was attached between the lateral part of the eyebrow and the hair line, and two other rings were glued onto the eyebrow. Approximately 5 s of hand pressure was applied to each ring. A relationship was established between the skin and the sensor, and at least 15 min of recording was performed. The mean value was calculated. If the patient's condition was unstable or there was an urgent need to take sedatives, recordings were performed for as long as possible before the medication was administered. No change was made in patient intervention and treatment. BIS monitoring was performed with the COVIDIEN complete monitoring system PN/185-0151, which we currently use in the emergency department (Fig. 1).

After approval of the signal quality index, which is one of the pop-up windows on the monitor, BIS monitoring was provided, and the GCS and BIS values were recorded simultaneously. Arterial blood pressure, pulse rate, weight, and height were also measured.

The mean BIS values and GCS scores were compared with the CCHR major and minor criteria and the presence of pathology (if any) on CT. In addition, demographic characteristics, vital signs at admission, and duration of hospitalization were examined.

On evaluating the findings obtained in this study, the IBM SPSS Statistics 22 for statistical analysis (SPSS IBM, Turkey) program was used. While evaluating the

FIGURE 1. BIS device.

TABLE 1. Evaluation of the distributions of major and minor criteria of Canadian CT Head Rules

	n	%
Major criteria		
GCS score <15 at 2 h after trauma	1	0.5
Any sign of skull fracture	–	–
Suspected open or depressed skull fracture	1	0.5
Vomiting >2 episodes	2	1.0
Age ≥65 years	40	19.8
Minor criteria		
Amnesia before impact ≥30 min.	53	26.2
Dangerous mechanism	121	59.9

GCS: Glasgow Coma Scale.

study data, the fitness of the parameters to normal distribution was evaluated by the Shapiro–Wilks test. It was found that the parameters were not distributed normally.

Descriptive statistical methods (mean, standard deviation, and frequency) as well as quantitative data were compared with the Mann–Whitney U test. For the comparison of qualitative data, the chi-square test, Fisher's exact chi-square test, and the Yates continuity correction test were used. Spearman's rho correlation analysis was used to examine the relationships among the parameters, and statistical significance was evaluated at $p<0.05$.

RESULTS

A total of 587 patients older than 18 years with isolated head trauma were admitted to the emergency department during our study. Fifty-eight patients had severe head trauma and were excluded from the study. Cranial CT was not requested in 285 of the remaining 529 patients, and these patients were excluded from the study. The study population consisted of 244 patients. Forty-two patients whose records could not be taken due to intensity were excluded from the study, and a total of 202 patients (64 (31.7%) female and 138 (68.3%) male) were included.

The ages of the patients ranged from 18 to 90 years, with a mean of 45.48±19.47 years. The mean GCS was 14.92±0.548–15 (range: 8–15 pts), and BIS was 93.17±5.15 (range: 56.9–98 pts). In our study, men were found to be significantly more populous.

A little more than half of the patients (50.5%) were admitted to the hospital within the first 30 min after the trauma, and the majority (97.5%) of them presented to the emergency department within the first 90 min.

Among the vital signs of the patients at admission, the median systolic arterial blood pressure (136.85 mmHg), diastolic arterial blood pressure (78.85 mmHg), and pulse rates (81.02/min) were measured.

All patients with GCS scores <13 admitted to the emergency department with head trauma over the age of 18 years underwent a routine CT scan as recommended in the guidelines. Patients with minor head trauma (GCS scores 14 and 15) were evaluated according to CCHR criteria.

The distribution of the major criteria of CCHR gave the following results: one (0.5%) patient had a GCS score <15, one (0.5%) patient had suspected open or depressed skull fracture, and two (1%) patients had vomiting episodes (GCS score >2) at 2 h after the trauma. None of the patients had a skull base fracture. Forty patients (19.8%) were 65 years or older. The distribution of the minor criteria gave the following results: retrograde amnesia was seen in 53 (26.2%) patients and dangerous mechanism in 121 (59.9%) patients. The distribution of cases according to the CCHR criteria is shown in Table 1.

A total of 14 patients had CT pathology. Two of the 14 cases were older than 65 years.The patients had retrograde amnesia (n=1), suspected open or depressed skull fractures (n=1), and 10 of them had been exposed to dangerous traumatic mechanisms. When the BIS values of the cases and the major and minor CCHR criteria

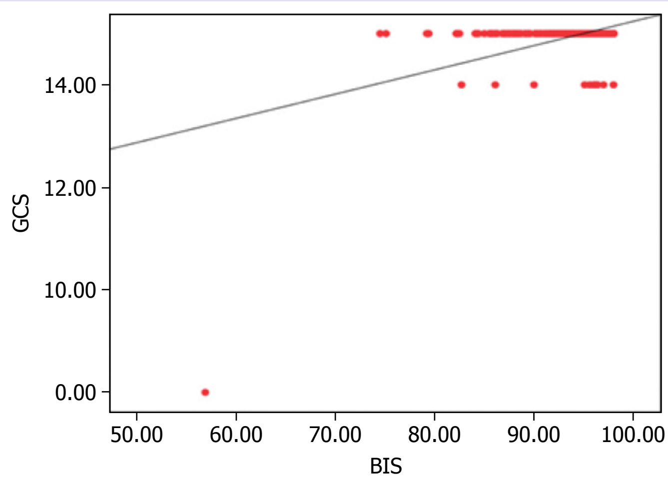

FIGURE 2. Relationship between GCS score and BIS value. GCS: Glasgow Coma Scale; BIS: Bispectral Index.

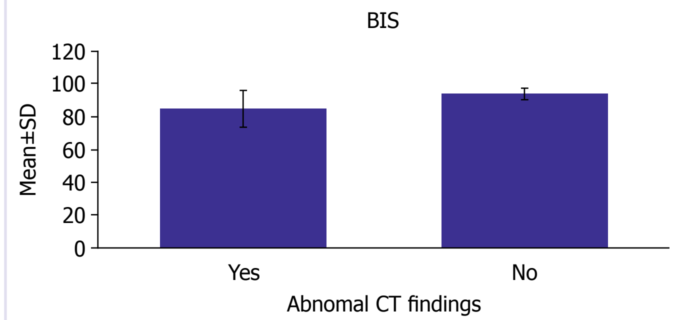

FIGURE 3. Correlation between abnomal CT findings and BIS. SD: Standard deviation; CT: Computed tomography; BIS: Bispectral Index.

were compared, it was observed that CT was performed with indications of being older than 65 years (n=40).

In our study, the other major criteria included GCS scores <15 (n=1), head fracture findings (n=0), suspected depressed skull fracture (n=1), and more than two vomiting episodes (n=2) detected at 2 h after the trauma; however, they were not sufficient for statistical calculations. The BIS values of major criteria of being over 65 years, minor criteria of having a history of retrograde amnesia longer than 30 min (n=53), and exposure to dangerous traumatic mechanisms (n=121) were compared. However, no statistical significance was found in any of them.

The BIS values were in the range 41–65 in only 1 (0.5%) case, 66–85 in 14 (6.9%) cases, and 86–100 in 187 (92.6%) cases. The BIS values were compared according to sex, age, GCS scores, and CT findings. They did not differ significantly when compared by sex ($p>0.05$). When the BIS value and GCS scores were analyzed by Spearman's rho correlation analysis, a positive and statistically significant correlation was found at a level of 45.6% ($p<0.05$) (Fig. 2).

In our study, the mean BIS value of patients who had abnormal CT findings was 84.99±11.20 (86.05), and the mean BIS value of those without abnormal CT findings was 93.78±3.80 (95.05). A statistically significant correlation between CT pathology and BIS values was found, and those with CT pathology had lower BIS values ($p=0.001$; $p<0.01$) (Fig. 3).

Our 173 patients (85.6%) were discharged, and 29 patients (14.4%) were hospitalized.

DISCUSSION

In our study, a statistically significant correlation was found between BIS values, which can give a numerical value in the measurement of consciousness level in patients presenting to the emergency department with head trauma, and pathologic findings detected in patients with brain CT. In these patients, lower BIS values were found. Therefore, it can be concluded that patients who presented to the emergency department with head trauma and whose BIS values were low are eligible candidates for imaging by brain tomography. In our study, the GCS levels and BIS values were found to be correlated. Moreover, it was concluded that in a head trauma patient whose GCS status could not be evaluated precisely, BIS values that quantitatively and objectively assessed head trauma could be used.

Brain injury due to head trauma, which is one of the most important health problems of our time (and especially seen in young people), is a lethal, disabling pathologic condition requiring long-term treatment and care [6]. It has been reported that head trauma occurs every 15 s and a patient dies from head trauma every 12 min, and it accounts for 50% of all trauma-related deaths [7]. The early detection and proper management of this clinical condition, whose contribution to mortality is indisputable, is therefore critical.

Of 202 adult patients over 18 years, 138 (68.3%) were male and 64 (31.7%) were female. The mean age was 45.48±19.47 years. Our patient group was found to be compatible with similar studies performed in adult patients in terms of sex and age distribution [6, 8]. In most studies, young adult males have been reported to be the most traumatized age group. The higher number of traumatized men than women can be explained by the fact that men lead a more active life in our society; as a result, they are more exposed to trauma [9]. Indeed, the incidence of dangerous mechanisms was found to be statistically significantly higher in our male (65.2%) than in our female (48.4%) patients.

Early detection and intervention is of crucial importance in traumatic brain injury. When the general statistics about traffic accidents are examined, 10% of deaths occur within the first 5 min, 50% within the first 30 min, and 80% within 1 h after the accident [10]. In this sense, the arrival time at the hospital is crucial for the wounded. In this study, the arrival times of the patients were investigated. It was found that 50.5% of the cases were brought to the emergency department within the first 30 min and 37.1% within the first hour after the accident. When other studies on the subject were examined, our results were found to be acceptable and even better than the others. In the study by Işık H.S. on 954 people, 34.1% of the cases came within the first 2 h and 43.6% of them within 2–6 h after the incident.

In the study by Beyaztas et al. (Sivas), Altıntop et al., 44.52% and 24% of the patients presented to the hospital within the first hour after the incident [11, 12].This situation may be related to the fact that our hospital is easily accessible, and the ambulance services have improved considerably.

Brain CT is the most commonly used method in emergency departments to detect the severity of trauma and to make early surgical decisions. However, radiation exposure and high costs are still important factors limiting its use. Research has shown that it is not necessary to perform a brain CT scan for every patient with head trauma, and studies have focused on the development of various guidelines for imaging with the correct indications. GCS is actually the main determinant for these rules. One of the most commonly used criteria are the CCHR rules.

In almost all these guidelines, the processes that should be followed in head trauma, which are considered mild according to GCS criteria, are mostly based on clinical status and anamnesis, and no objective data are included in these rules. Moreover, consciousness and GCS measurements of the patients are subjective data based on the clinician's observation and examination. BIS has recently been used in emergency services as a monitoring method to determine patients' awareness and monitor patients during treatment with sedative drugs. The numerical expression of consciousness is important. However, there are not enough data about whether it can be a guide in cases of head trauma.

In our study, CTs were routinely performed for all patients over 18 years with GCS scores <13 who presented to the emergency department with head trauma as recommended in the guidelines. Patients with minor head trauma (GCS scores 14 and 15) were evaluated according to CCHR criteria. As one of the major criteria of CCHR, being 65 years or older was detected in 40 (19.8%) cases. Other criteria included more than two episodes of vomiting in 2 (1%) patients, GCS scores <15 in 1 (0.5%) patient, and suspected open or depressed skull fracture criteria in 1 (0.5%) patient within 2 h after trauma. No sign of skull base fracture was seen in any of the cases. Age is an important parameter in almost every study. In some studies, 65 years of age, and in some studies 60 years of age were taken as the limit, and the intracranial pathology rate was reported to be higher in elderly patients when compared with those under this age limit [13].

Hsiang et al. reported that headache, nausea, and vomiting were among the most common complaints after head trauma of all patients who died among mild head trauma patients with a GCS score of 15 [14]. Several studies have also examined whether these complaints make sense as a risk factor. Some studies have reported that they are insignificant, and yet there are studies showing otherwise. In some reports, intracranial lesions were found to be higher in patients with this type of complaint [13, 14]. In our study, no significant difference was found when cranial pathology was compared in patients with and without such complaints.

When the distribution of minor criteria is examined, 53 (26.2%) of the cases had amnesia and 121 (59.9%) had been the victims of dangerous accidents. Loss of consciousness after trauma has been accepted as an important parameter for several years [15]. However, although the majority of patients experience loss of consciousness, the definition of fainting, blackout, and such loss of consciousness reduces the reliability of this important parameter [13]. In this study, while taking the anamnesis, other people who were present with the patient were consulted, and thus it was possible to obtain more satisfactory data on the loss of consciousness. Boran et al. found a higher rate of intracranial pathology in patients experiencing loss of consciousness after trauma [16]. In our study, amnesia plays an important role in CT ordering rules. Although the pathology detection rate on CT was statistically insignificant, it was significant among indications for CT.

One of the most important issues in the follow-up and treatment of critical disorders that result in consciousness disorder is to closely monitor the state of consciousness. The close monitoring of changes in the brain function of these patients is very important in terms of prognosis and management of treatment. Clinical monitoring methods are frequently used to monitor the level of consciousness, and it is possible that measurements made using monitorized medical devices have been utilized more recently [5]. Although the clinical follow-up scales of the users are short and easily applicable, they may not always give real results because of the different results obtained by the practitioners. Therefore, it is generally believed that measurements with automatic devices give more accurate and reliable results in the evaluation of sedation and consciousness level, and studies are hence focused on this issue. BIS, power spectral measurement, and auditory excitable potentials are the most commonly used device-dependent methods [17].

BIS, which is a user-independent method based on objective measurement, is preferred for its practical use. BIS is a method of interpretation that quantifies the degree of the acute phase between the components of EEG signals [5]. BIS was first developed to determine the depth of anesthesia [5, 17] and is currently used in (i) the follow-up of sedation in intensive care patients, (ii) the follow-up of consciousness in critically ill patients with severe brain injury, and (iii) patients resuscitated after cardiac arrest. Moreover, research in this direction is increasing day by day. There are different results in studies investigating the relationship between GCS and BIS.

Haug et al. investigated the BIS and GCS values in patients who were followed up in the emergency unit due to head trauma and examined the rates of survival and neurologic sequelae according to the BIS and GCS values [18]. They reported that the BIS values obtained after the administration of sedative drugs following trauma are useful in predicting traumatic brain injury and also in evaluating the neurologic outcomes of patients at the time of discharge. Gill et al. compared the BIS and GCS values in a study on patients presenting to the emergency unit with a decrease in consciousness level and found that there was no correlation between them [19]. BIS was found to be in the ranges 47–98 and 56–98 for GCS scores 3–5 and 12–14, respectively. Gill et al. found a correlation between BIS values and GCS scores in a clinical study; however, small changes in GCS scores in assessing the impairment of consciousness corresponded to a wider range in BIS measurements. Therefore, they concluded that BIS was inadequate in assessing the deterioration in consciousness. Xifeng et al., in their study on 189 patients with severe brain injury due to head trauma, concluded that the BIS values of patients were significant in predicting the detection and follow-up of consciousness [20]. In a study conducted by Paul et al. on 29 patients with severe and moderate brain injury due to a mass-occupying lesion, a statistically significant difference was found between GCS scores and BIS values. It was concluded that there was a relationship between the BIS values and GCS scores of coma patients [21].

According to our results, when the GCS and BIS values were compared, a statistically significant positive correlation and concordance was found. Because it was known that the BIS value was especially affected by sedation and muscle relaxants, patients who were treated with these drugs were excluded. Therefore, there is no group of patients with severe head trauma in our study population. In addition, patients with low GCS on admission and requiring medication due to agitation were excluded from the study. This is also an important limitation of our study.

In our study, any pathologic condition due to trauma was not recorded on CT scans according to CCHR criteria, and the findings were retrospectively compared with the BIS values of the patients. The mean BIS values of patients with and without abnormal CT findings were 84.99±11.20 (86.5) and 93.78±3.80 (95.05), respectively. When the two groups were compared, the BIS values of patients without CT were found to be statistically significantly higher. According to this result, it can be predicted that patients with low BIS values may have pathology on brain CT. However, to determine the limit value for this finding, it is necessary to conduct studies in large patient groups.

One of the most important limitations of our study is that the number of patients was not sufficient to arrive at a conclusion, because the BIS values could not be determined. BIS requires at least 15 min of recording; however, patients in a critical condition cannot wait and should be sedated for early intubation. Therefore, our study does not provide sufficient information about the values in severe head trauma. Another limitation of our study is that indications of CT scans in our patient group were not evenly distributed; therefore, all the CCHR major and minor criteria could not be compared with BIS. We believe that each criterion can be evaluated separately in larger patient groups. In our study, the BIS values of patients with CT pathology were found to be low; however, the clinical significance of this could not be evaluated owing to the small number of pathologic CTs obtained.

Conclusion

From the results of our study, it is possible to say that head traumas are often caused by dangerous accidents and affect men more severely. It was observed that patients arrived at our hospital relatively quickly and were evaluated in an earlier stage. In comparisons made with the measured BIS values, a statistically significant positive correlation was found between the GCS and BIS values. However, no statistically significant difference was found between the sex of the patients and significantly, and frequently observed CCHR criteria as being <65 or >65 years of age the presence of dangerous mechanism and history of amnesia. Another important result of our study was that the BIS values of patients with traumatic pathology on CT were significantly lower than those with normal CT. Although low BIS values cannot be determined precisely owing to the limited number of subjects in our study, we believe that low values indicate that it is appropriate to perform CT. In continuation of this study, we will increase the number of subjects, and numerically more important cutoff values of BIS will be determined.

Ethics Committee Approval: This study was conducted prospectively at Fatih Sultan Mehmet Training and Research Hospital Emergency Medicine Clinic between 03.01.2014 and 09.01.2014 after approval of the ethics committee (Date: 3.03.2014, number: FSMEAH-KAEK 2014/11)

Conflict of Interest: No conflict of interest was declared by the authors.

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Authorship Contributions: Concept – OK, OEO; Design – TCO, OEO; Supervision – TCO, OEO; Materials – CAT, RA, OK; Data collection and/or processing – OK, CAT, RA; Analysis and/or interpretation – OK, AH, EUA; Writing – OK, RA, OEO; Critical review – TCO, RA, EUA, AH.

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