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Original Article

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The Effects of Glasgow Coma Scales and Bispectral Index on General Anaesthesia in Neurosurgery Patients

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Abstract

Objective: Monitorisation under anaesthesia is important for objective evaluation in intracranial surgery. We investigated general anaesthesia management performed by bispectral index (BIS) monitoring in patients who underwent surgery due to intracranial pathology with different Glasgow Coma Scales (GCS).

Methods: Forty-five patients who had been planned to undergo intracranial surgery under general anaesthesia were included in the study. Patients were divided into three groups according to GCS: Group I (n = 15) = 13-15 mildly injured; Group II (n = 15) = 9-12 moderately damaged; Group III (n = 15) = 3-8 severely damaged. Heart rate (HR), mean blood pressure, and use of anaesthetic agent were recorded.

Results: It was found that the consumption of the inhalation agent in Group III was lower than Groups I and II at all time intervals measured, and it was lower in Group II than Group I during the intervals at intraoperative 15th minute and up to 150th minute thereafter. The inhalation agent consumption rates according to the duration of anaesthesia were different between groups. The HR was significantly higher in Group III compared with Group II during the post-operative period. The mean arterial pressure was significantly lower in Group I than Group II preoperatively and at 5th, 10th, 15th, 20th, and 40th minute intra-operatively, whilst it was significantly lower in Group I than Group III preoperatively and 10th minute and 15th minute, intraoperatively.

Conclusion: We found that in patients whose GCS was severely damaged and underwent intracranial surgery under general anaesthesia with BIS monitoring, the consumption of inhalation anaesthetic agent decreased, but opioid consumption did not change.

Keywords: Bispectral index, Glasgow Coma Scale, intracranial pathology

Introduction

Clinical monitoring scales are needed for objective evaluation and grading of clinical condition in patients. Scales also detect changes in the monitoring process and provide consistency of communication amongst health professionals.

In critically ill patients, changes in the state of consciousness are very important. For this purpose, the conventional practice in unconscious patients is the use of various coma or sedation scales in assessing the state of consciousness. The most commonly used clinical scale in monitoring the level of consciousness is the Glasgow Coma Scale (GCS).[1]

It is not always possible to monitor and objectively measure the changes in the level of consciousness in clinical practice. Therefore, device-based methods have been introduced in monitoring the state of consciousness. Bispectral index (BIS) monitoring may be preferred in follow-up of the state of consciousness in critical patients such as those with acute brain injury, in terms of ease of use, ability to obtain numerical results, and continuous monitoring.[1] BIS monitoring is mostly used for the follow-up of anaesthesia depth and sedation level, whilst it can also be applied for monitoring state of consciousness following resuscitation in cases with acute brain injury and cardiac arrest.[1-3]

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It is also important to be able to perform post-operative neurological evaluation as well as providing adequate anaesthesia depth in patients who undergo neurosurgery. Consideration should be given to the method of anaesthesia in some intracranial procedures, so that it enables a reliable and rapid recovery from anaesthesia.[4]

It has been reported that the amount of anaesthetic drug consumed and hospital costs are reduced when the BIS monitor is used; the patients are recovered earlier from the anaesthesia in the post-operative period, and the discharge of waste gases to the environment occurs less.[5,6] BIS monitoring may be an advantage in terms of early recovery from the anaesthesia, especially in neurosurgical operations that require post-operative early neurological evaluation.[7]

In this study, we aimed to investigate general anaesthesia management with BIS monitorisation in terms of haemodynamic stability, drug concentrations, and drug consumption in patients who underwent surgery due to intracranial pathology and who were divided in three different GCS groups.

Methods

This single-center, prospective study was scheduled at intracranial surgery. The inclusion criteria were age between 18 and 65 years with American Society of Anaesthesiology (ASA) II-III. They should not have received intravenous sedation for at least 24 h before the evaluation. Written approvals of the local ethics committee Committee No.: 2013/127, TÜTF-GOKAEK, Trakya University, July 3, 2013 and patients were obtained (ClinicalTrials.gov Identifier: NCT03521414). Patients were divided into three groups according to the GCSs calculated before surgery: Group I (n = 15) = 13-15 mildly injured; Group II (n = 15) = 9-12 moderately damaged; Group III (n = 15) = 3-8 severely damaged. Patients with additional disease (electrolyte impairment, uremia, etc.), liver and renal failure affecting consciousness level other than intracranial pathology, pre-operative use of sedative drugs, bleeding, hypothermia, severe hypoglycaemia, or pre-operative cardiac arrest, and application of anaesthetic drug within 24 hours before operation were excluded from the study.

Main Points

- Clinical monitoring scales are needed for objective evaluation and grading of clinical condition in patients.
- The linear relationship between BIS and GCS may be a reliable method in terms of providing early neurological recovery with the reduction of consumption of inhalation agent.
- This study showed that the consumption of inhalation anaesthetic agent in patients with severely damaged GCS groups decreased compared with moderately and lightly injured group.
- There was not any statistically significant difference in the amount of opioid consumed during the operation.

When the patients were taken to the operation table, they were monitored with the heart beat, arterial blood pressure, peripheral oxygen saturation, and BIS. The patients with GSC <8 intubated and mechanically ventilated prior to arrival in the operating room. All patients received propofol of 2-3 mg kg^{-1}, fentanyl of 1 mcg kg^{-1}, and rocuronium of 0.6 mg kg^{-1} for induction. Anaesthesia was maintained with sevoflurane 2% with air+oxygen mixture, 5 I min^{-1} gas flow, and 0.25 mcg kg^{-1} min intravenous remifentanil infusion. The BIS monitoring value was kept at the level of 40-60 during the operation. A threshold of hypotension was defined as a mean arterial pressure of <70 mmHg for more than 10 minute in each group. Hypotensive episodes were treated by increasing the rate of fluid administration and/or by reducing the anaesthetic drug concentration.

Pre-operative, intraoperative, and post-operative heart rate (HR), mean blood pressure, oxygen saturation, intraoperative endtidal carbon dioxide, and BIS values were recorded. The consumption of the inhalation agents was recorded in milliliter (with the Dion's formula) every 5 minutes during the first 20 minutes, every 10 minutes until 60th minute, and every 30 minutes until 180th minute. The total amount of opioid consumed was recorded from the infusion pump.

Dion's formula: $C = P \times F \times T \times M/241 \times D$, where C is the amount of inhalation anaesthetic agent (mL), P is the concentration of anaesthetic agent (%), F is the total fresh gas flow (L min^{-1}), T is the duration at that concentration, M is the molecular weight (g) and D is the density of liquid sevoflurane (g mL^{-1}).[8]

Descriptive statistics were given as mean and standard deviation (SD). $P < .05$ was considered statistically significant. Kolmogorov–Smirnov, ANOVA, and Kruskal Wallis statistical analysis tests were used.

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences 15.0 (SPSS Inc.; Chicago, IL, USA) program. Mann–Whitney U test was used to evaluate data of ear measurements, and the Friedman and Wilcoxon tests were used for intragroup comparisons. Results were presented as mean ± SD. $P < .05$ were considered as statistically significant.

Results

Forty-five patients were included in the study (Figure 1). Demographic characteristics and anaesthesia durations of the patients participating in the study are shown in Table 1,

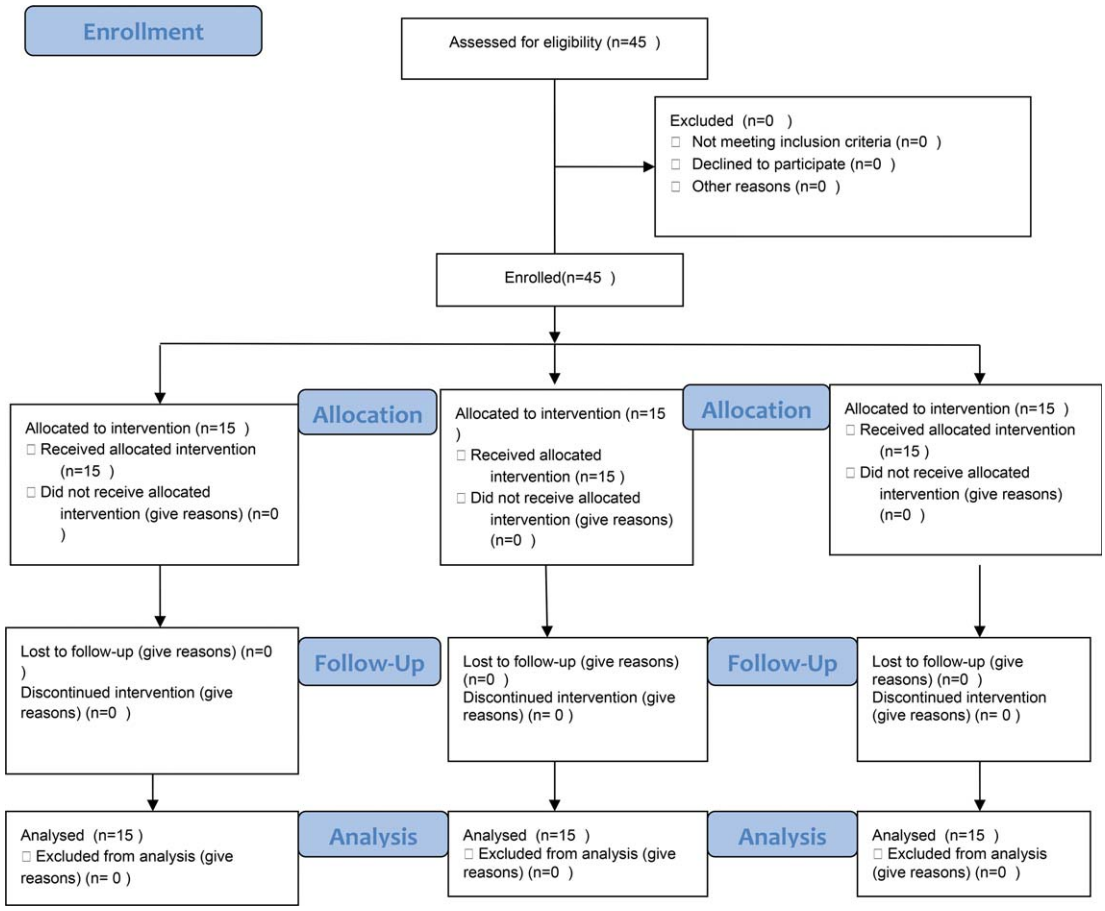

Figure 1. Flow diagram

Table 1. Demographic and Surgery Data

	Group I (n = 15)	Group II (n = 15)	Group III (n = 15)	*P*
Age (year)	43.3 ± 14.3	50.6 ± 13.3	47 ± 14.1	.370
Gender, n (M/F) (%)	10/5, 66.7/33.3	11/4, 73.3/26.7	9/6, 60/40	.740
Weight (kg)	78.8 ± 9.8	74.3 ± 12	80 ± 5.8	.247
Height (cm)	173 ± 8.2	172.7 ± 9.3	172.4 ± 8.8	.983
BMI (kg/m^2)	26.3 ± 3.2	24.8 ± 2.9	26.9 ± 1.9	.615
Duration of anaesthesia (min)	136.6 ± 46.3	150.3 ± 40.9	131 ± 44.4	.471

No significant differences were noted between the groups.
Mean ± SD, n (%).
Abbreviations: ASA, American Society of Anaesthesiology; M, male; F, female; BMI, body mass index.

and no statistically significant difference was found between the groups ($P > .05$).

HR was significantly higher in Group III post-operatively than in Group II ($P = .022$). There was no significant difference when Group I was compared with Groups II and III ($P = .452$, $P = .551$, respectively). There was no significant difference in HR values between the groups compared to their baseline values (Table 2). Mean arterial pressure was significantly lower in Group I than in Group II pre-operatively, and at 5th, 10th, 15th, 20th, and 40th minutes intraoperatively; it was also significantly lower in Group I than in Group III pre-operatively, and intraoperative 10th minute and 15th minute. There was not any statistically significant difference amongst the groups at other times (Table 2). There was not any clinically significant difference

Table 2. Pre-operative, Intraoperative, and Post-operative Heart Rate (HR) and Mean Arterial Pressure (MAP) in Patients

		Group I (n = 15)	Group II (n = 15)	Group III (n = 15)	*P*
Pre-operative	HR	85.5 ± 19.0	92.7 ± 14.9	96.8 ± 18.5	.218
	MAP	101.0 ± 14.7**.***	122.9 ± 12.1**	104.3 ± 27.6***	.007*
İntraoperative					
5 minutes	HR	89.4 ± 16.8	94.5 ± 17.9	98.1 ± 14.4	.359
	MAP	91.2 ± 13.6**	120.3 ± 10.7**	106.4 ± 26.9	.000*
10 minutes	HR	85.9 ± 17.6	89.3 ± 14.4	95.7 ± 14.3	.226
	MAP	84.6 ± 17.0**.***	111.3 ± 9.5**	103.2 ± 23.1***	.000*
15 minutes	HR	83.1 ± 16.3	86.3 ± 14.9	92.0 ± 11.8	.243
	MAP	82.6 ± 16.6**.***	102.6 ± 13.3**	99.0 ± 18.3***	.004*
20 minutes	HR	81.8 ± 15.6	83.1 ± 14.5	90.2 ± 10.7	.210
	MAP	82.4 ± 15.9**	99.3 ± 15.4**	96.3 ± 15.1	.011*
30 minute	HR	81.8 ± 17.0	79.6 ± 12.1	87.3 ± 9.6	.269
	MAP	83.2 ± 23.2	95.5 ± 12.2	91.1 ± 16.1	.173
40 minute	HR	78.5 ± 17.0	76.7 ± 11.5	85.2 ± 7.7	.167
	MAP	77.9 ± 18.6**	93.8 ± 14.9**	86.7 ± 16.2	.042*
50 minute	HR	77.7 ± 16.8	76.2 ± 10.8	83.0 ± 7.1	.289
	MAP	81.1 ± 25.3	90.8 ± 11.2	84.5 ± 15.0	.338
60 minute	HR	78.2 ± 14.8	75.7 ± 10.7	81.3 ± 6.6	.400
	MAP	77.9 ± 18.3	90.8 ± 16.2	87.4 ± 15.1	.102
90 minute	HR	82.7 ± 12.4	74.3 ± 10.4	78.9 ± 6.9	.111
	MAP	85.9 ± 17.9	90.7 ± 15.3	83.6 ± 13.4	.452
120 minute	HR	80.4 ± 13.1	74.1 ± 10.1	74.9 ± 9.9	.364
	MAP	80.8 ± 18.3	85.2 ± 28.4	72.1 ± 27.5	.452
150 minute	HR	79.4 ± 15.6	74.9 ± 8.7	74.6 ± 5.4	.677
	MAP	96.1 ± 24.9	100.3 ± 9.7	89.9 ± 13.2	.582
180 minute	HR	82.8 ± 16.1	70.7 ± 8.8	77.3 ± 4.6	.236
	MAP	66.7 ± 34.4	85.5 ± 6.3	78.2 ± 7.9	.361
Post-operative	HR	80.6 ± 15.3	74.5 ± 10.3**	86.2 ± 6.8**	.026*
	MAP	94.9 ± 16.7	92.2 ± 19.6	90.5 ± 14.3	.775

Data are mean ± SD.
HR: *$P < .05$, comparison of Groups I, II, and III; **$P < .05$ Groups II and III comparison.
MAP: *$P < .05$, comparison of Groups I, II, and III; **$P < .05$ Groups I and II comparison, ***$P < .05$ Groups I and III comparison.

between peripheral oxygen saturation and end tidal carbon dioxide amongst the groups. There was no significant difference in BIS value amongst the groups.

Statistically significant differences were found between the groups at all times in terms of amounts of the inhalation agent consumed ($P < .05$). The Group III inhalation agent consumption was found to be statistically significantly lower than Groups I and II at all measured time intervals, whilst Group II was statistically significantly lower than Group I during intraoperative 15th minute and at the intervals until 150 minutes (Table 3 and Figure 2). Amongst the groups, the inhalation agent consumption rates according to the duration of anaesthesia were found to be significantly higher in Group I compared with Groups II and III, and in Group II compared with Group III (Table 4, $P = .001$).

It was found that the amount of remifentanil used during the operation of the patients participating in the study was not different amongst the groups (Group I: 42.8 ± 20.3, Group II: 50.3 ± 15.8, Group III: 48.8 ± 33.7; $P = .674$).

Discussion

In our study, we found that the consumption of inhalation anaesthetic agent in patients with moderately and severely damaged GCS groups decreased compared to the lightly

Table 3. The Patients' Consumption of Inhalation Agent

Amount of intraoperative consumed inhalation agents (mL)	Group I (n = 15)	Group II (n = 15)	Group III (n = 15)	*P*
5 minute	2.41 ± 0.55	2.15 ± 0.20	1.51 ± 0.50	.000*
10 minute	4.81 ± 1.09	4.12 ± 0.50	2.85 ± 0.95	.000*
15 minute	7.19 ± 1.65	5.93 ± 0.72	4.12 ± 1.41	.000*
20 minute	11.94 ± 2.88	9.35 ± 1.35	6.51 ± 2.15	.000*
30 minute	16.64 ± 4.01	12.61 ± 1.86	8.77 ± 2.94	.000*
40 minute	21.41 ± 4.95	15.78 ± 2.37	10.83 ± 3.61	.000*
50 minute	25.90 ± 5.59	18.84 ± 2.90	12.83 ± 4.24	.000*
60 minute	30.32 ± 6.39	21.94 ± 3.57	14.79 ± 4.88	.000*
90 minute	41.27 ± 10.41	31.07 ± 5.65	20.20 ± 6.95	.000*
120 minute	50.20 ± 15.48	38.53 ± 7.18	23.93 ± 9.01	.000*
150 minute	56.68 ± 21.22	44.08 ± 9.07	25.89 ± 10.25	.000*
180 minute	61.94 ± 27.98	48.16 ± 10.19	27.36 ± 11.64	.000*

*$P < .05$, comparison of Groups I, II, and III.

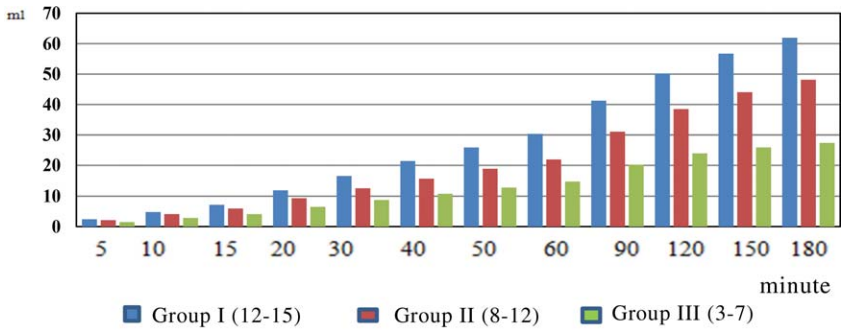

Figure 2. Group III inhalation agent consumption was found to be statistically significantly lower than Groups I and II at all measured time intervals

injured group. Study patients were divided into three different groups according to GCS and underwent intracranial surgery under general anaesthesia with BIS monitoring. In addition, there was not any statistically significant difference in the amount of opioid consumed during the operation and the clinically intraoperative haemodynamic amongst the groups.

For monitoring the consciousness level of the patient, clinical follow-up methods and monitoring, in other words, device-based modalities are used. GCS is the most commonly used clinical method. Clinical follow-up scales performed by the practitioner are easy to implement but cannot always deliver actual results because of the different results obtained by different practitioners. Therefore, it is generally accepted that instrument-based measurements give more accurate and reliable results in evaluating the sedation and consciousness level. BIS is a method of interpretation that quantifies the degree of acute phase coupling between the components of EEG signals.[9] It is independent from the practitioner, based on objective measurement. It is used for monitoring the level of consciousness. BIS was first developed to determine the depth of anaesthesia.[10] Today, it is used in intensive care patients for monitoring the level of sedation[7] and for monitoring the level of consciousness in severe brain-damaged, critically ill patients,[3,6] and in patients who were resuscitated after cardiac arrest,[1,7] and the research done in this field is increasing day by day.

The relationship between the GCS and the BIS has been investigated in various studies.[11-15] Ebtehaj et al.[11] compared GCS and BIS values in 61 patients aged between 20 and

Table 4. The Inhalation Agent Consumption Rates According to the Duration of Anaesthesia				
	Group I (n = 15)	**Group II (n = 15)**	**Group III (n = 15)**	***P***
Ml/minute	0.478 ± 0.086	0.338 ± 0.062	0.230 ± 0.021	.001*

50 years who were admitted to intensive care unit due to head trauma and did not have sedation in the last 24 hours. The patients were evaluated using GCS and divided into three groups as mild, moderate, and severe trauma. They performed the BIS instrument measurements for 3 minutes in the intensive care patients and recorded the average value. They found a correlation of 0.88 between BIS and GCS. Paul et al.,[12] on the other hand, performed a similar study on the 29 patients with an intracranial mass lesion, subdural hematomas, epidural hematomas, or cerebral contusion due to traffic accidents and falls. These patients were between the ages of 18 and 65 and were evaluated and divided as mild (GCS 13-15) and moderate (GCS 9-12) head trauma. BIS and GCS were evaluated before operation, post-operative 3 hours, and once a day for the next 10 days, and a correlation of 0.67 between GCS and BIS was found ($P < .001$). Unlike these studies, Michelle et al.[13] compared the BIS and GCS in a study, and they conducted on 38 patients who admitted to the emergency unit with a decrease in consciousness level and found no correlation between them. They found BIS 47-98 for GCS 3-5 and BIS 56-98 for GCS 12-14. According to our literature review, our study was the first to evaluate the BIS correlation using GCS and the consumption of anaesthetic agent intraoperatively.

Vivien et al.[14] investigated that they could use BIS in the diagnosis of brain death in their study. They assessed 56 intensive care patients with severe coma (GCS < 6) due to cerebral hypoxia, intracranial haemorrhage, and head trauma with BIS device. BIS measurements were made when patients were taken into the intensive care unit, and the brain death was diagnosed at the time of discharge from the intensive care unit. BIS values were measured as 0 in 12 patients who were clinically diagnosed with brain death at the time of intensive care unit admission. Then, the brain death in 12 patients was confirmed by EEG or cerebral angiography. The BIS values of 44 patients without brain death were between 20 and 79. A few hours later, the BIS value of 27 patients who were clinically diagnosed with brain death was measured as 0, and the brain death was confirmed by angiography or EEG. Patients who had relatively stable clinical condition but slow and gradual decline in BIS values were diagnosed with brain death after days; therefore, the decline in BIS was considered significantly. As a result, it was thought that the decrease in BIS value down to zero in the comatose patients could save time compared to cerebral angiography and EEG in diagnosis of brain death. In our study, we as well investigated the effect of these measurements on the management of general anaesthesia and anaesthetic agent consumption, concluding that the correlation between GCS and BIS could not be ignored in the light of literature.[11-15]

Boztuğ et al.[16] investigated the role of BIS in the anaesthesia recovery and change of medication use in craniotomy patients. Fifty patients were randomised into two groups, and all patients received standard induction medications. In the case of anaesthesia maintenance in which BIS monitoring was applied, the concentration of sevoflurane was titrated from 0.8 to 1.5%, so that the BIS would be kept between 40 and 60. In the control group, the concentration of sevoflurane was adjusted according to the haemodynamic changes of the patient. As a result, the concentration of anaesthetic agent, the use of narcotic drugs, and the recovery time from general anaesthesia decreased in the BIS group. In the same study, haemodynamic values of patients were lower during the maintenance of anaesthesia compared to pre-operative values in both groups. We also found that the consumption of analgesic agent did not change, whereas the consumption of inhalation agent decreased with decreased level of GCS in our study ($P < .05$). Although the agent consumption rate differs between groups according to the duration of anaesthesia, it was significantly higher in Group I compared with Groups II and III, and it was also significantly higher in Group II than in Group III. In the haemodynamic evaluation of the patients, there was not any significant difference in HR amongst groups except post-operative period; however, we found a statistically significant difference amongst pre-operative, intra-operative 5th, 10th, 15th, 20th, and 40th minute mean arterial pressure (MAP) values.

Most investigators have reported that BIS monitoring has led to considerable reductions in anaesthetic agent consumption in anaesthetic applications.[17-19] The correct decision to use an anaesthetic agent with a good intraoperative monitoring (such as BIS) may be important in terms of post-operative anaesthesia recovery, rapid neurological recovery, and reducing the side effects of medications.[20] Haug et al.[21] recorded the BIS and GCS values in cases who were monitored for head trauma in the emergency unit and did not receive any sedation. They investigated survival and neurological sequelae rates of cases according to BIS and GCS values. They reported that the value of BIS obtained without sedative drugs after trauma is useful in predicting traumatic brain injury and also in evaluating the neurological outcome

at the time of hospital discharge. Unlike other studies, in our study, we found that the BIS value showed a significant decrease along with a decrease in GCS as intra-operative anaesthesia was performed in patients who were operated due to intracranial pathology, and a concomitant decrease in anaesthetic agent consumption occurred.

This study has some limitations. Recovery from anaesthesia and neurological evaluations were not included in the study because the GCS of the patients was taken into account at the time of transfer to the post-operative recovery room and intensive care unit. A higher sample size of the study would be better in terms of the value of the study results.

In conclusion, the patients who underwent intracranial surgery under general anaesthesia with BIS monitoring were subdivided into three separate groups according to the GCS. We found that the consumption of inhalation anaesthetic agent in patients with moderately and severely damaged GCS groups decreased compared with the mildly damaged GCS group, but the opioid consumption did not differ in moderate, severe, and mildly damaged group. We believe that more extensive series of studies should be conducted to decide whether the linear relationship between BIS and GCS is a reliable method in terms of providing early neurological recovery with the reduction of consumption of inhalation agent and reducing side effects of anaesthetic medications.

Ethics Committee Approval: Ethical committee approval was received from the Trakya University School of Medicine (No: 2013/127, TÜTF-GOKAEK).

Informed Consent: A written informed consent was obtained from patients and/or their relatives who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - S.H.Ş.; Design - S.H.Ş. and T.Ç.; Supervision - S.H.Ş., T.Ç., and N.S.; Resources - T.Ç. and S.H.Ş.; Materials - S.H.Ş.; Data Collection and/or Processing - T.Ç. and N.S.; Analysis and/or Interpretation - S.H.Ş., T.Ç., and N.S.; Literature Search - T.Ç. and S.H.Ş.; Writing - T.Ç. and S.H.Ş.; Critical Review - S.H.Ş., T.Ç., and N.S.; Other - S.H.Ş., T.Ç., and N.S.

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