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Bispectral Index Monitoring in Endoscopic Lumbar Spine Surgery: Retrospective Analysis of Central Nervous System Complications

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BACKGROUND: **Unilateral biportal endoscopic (UBE) spinal surgery involves two separate portals for viewing and working. If the outflow of irrigation fluid between portals is blocked, it can result in increased cerebrospinal fluid pressure, potentially leading to elevated intracranial pressure and related neurological complications. This sudden increase in intracranial pressure may cause transient cerebral hypoperfusion, manifesting as an isoelectric pattern on bispectral index (BIS) monitoring. This study aimed to investigate the use of BIS monitoring as an early indicator of increased intracranial pressure.**

METHODS: **BIS monitoring was conducted on patients undergoing UBE surgery to noninvasively detect sudden increases in intracranial pressure. Cases with a follow-up period of less than twelve months were excluded. Intraoperative BIS values of the patients and postoperative neurological complications were retrospectively evaluated.**

RESULTS: **As of May 2023, BIS monitoring started to be conducted on all patients undergoing UBE surgery in our clinic. Between May and December 2023, 182 levels of endoscopic spinal surgery were performed on 111 patients. The isoelectric BIS pattern was observed intraoperatively in six of these patients. Among them, 1 patient experienced left retinal vein hemorrhage due to increased intracranial pressure. No neurological complications were observed in the remaining five patients.**

CONCLUSIONS: **BIS monitoring is a noninvasive technique that can indicate cerebral hypoperfusion due to sudden increases in intracranial pressure. Thus, BIS monitoring should be considered a valuable tool in the management of patients undergoing UBE spine surgery, aiding in the early detection and appropriate treatment of central nervous system complications.**

INTRODUCTION

Parallel to the advancement of endoscopic techniques, endoscopy has become the most popular surgical approach in spine surgery and other surgical fields. Endoscopic spine surgeries are minimally invasive techniques applied as alternative methods to open surgeries for the treatment of lumbar disc herniation and spinal stenosis.[1-4] Endoscopic spinal surgical methods are known to have many advantages compared to traditional open techniques. Endoscopic techniques minimize trauma to both bone and muscle structures, resulting in minimal blood loss. Studies have shown shorter hospital stays and lower levels of postoperative pain associated with these procedures.[1,3-9]

The unilateral biportal endoscopy (UBE) technique in endoscopic spinal surgery utilizes two separate portals for viewing and working. The endoscope is advanced through the cranial portal, serving as the viewing portal, while irrigation fluid enters through this same portal. Instruments such as a radio frequency ablation probe, burr, and Kerrison punches are inserted through the caudal (working) portal. Irrigation fluid flows out from this working

Key words
- Bispectral index monitoring
- Central complications
- Complications
- Cranial complications
- Endoscopic spine surgery
- Retinal hemorrhage
- Unilateral biportal endoscopy

Abbreviations and Acronyms
ASA: American Society of Anesthesiologists
BIS: Bispectral index
BMI: Body mass index
CSF: Cerebrospinal fluid
EEG: Electroencephalography
UBE: Unilateral biportal endoscopy

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portal. The continuous flow of irrigation fluid between the two portals facilitates the creation of a working space and debris removal and provides a clear view (Figure 1).[4,5,10]

Inappropriate opening of the portal, paraspinal muscle spasms due to inadequate muscle relaxation, and soft tissue swelling due to prolonged operative duration can obstruct the working portal. If the working portal gets blocked, the outflow of irrigation fluid is obstructed, disrupting the fluid flow between the portals and reducing the flow rate. According to the law of conservation of energy, the potential energy of the fluid increases while the kinetic energy decreases.[5,11] This condition may increase the cerebrospinal fluid (CSF) pressure by increasing the pressure exerted on the subdural space (Figure 2). A sudden increase in CSF pressure can cause increased intracranial pressure and cerebral hypoperfusion. This elevated pressure may compress the central retinal vein, potentially causing retinal hemorrhage.[12,13] Although the UBE technique is a safe and effective method, complications such as postoperative retinopathy may occur if these scenarios manifest. Elevated intracranial pressure syndrome findings such as headache, altered consciousness, and vomiting cannot be noticed during UBE because the patient is usually under general anesthesia.

The bispectral index (BIS) is an electroencephalography (EEG) parameter that monitors the hypnotic and sedative effects of anesthetic agents. Ranging from 0 to 100, a measurement above 80 indicates wakefulness, while target values for surgical anesthesia typically fall between 40 and 60 (Table 1). BIS monitoring is applied to most patients receiving total intravenous anesthesia to monitor the sedative effect of the anesthetic agent. However, in patients receiving inhalation anesthesia, BIS monitoring is not applied to all patients since monitoring with the minimum alveolar concentration value is feasible using modern anesthesia workstations.[14-17]

A value of 0 on the EEG, known as an isoelectric EEG, indicates the absence of electrical activity in the brain (Figure 3). It is known that cerebral hypoperfusion can induce this condition by disrupting the brain's electrical activity.[18-20] Cerebral perfusion may be impaired due to a sudden increase in intracranial pressure. Consequently, transient cerebral hypoperfusion may occur, observable as an isoelectric pattern on BIS monitoring (Figure 4).

There is currently no noninvasive method available to monitor the increase in intracranial pressure during endoscopic spinal surgery. Therefore, this study aimed to investigate the use of BIS monitoring as a surrogate for increased intracranial pressure in this type of surgery.

MATERIALS AND METHODS

This retrospective study was conducted following approval from the ethics committee of our institution. Between May 2023 and December 2023, a total of 182 vertebra levels in 111 patients diagnosed with spinal stenosis or lumbar disc herniation underwent surgery using the UBE approach in the orthopedics and traumatology operating rooms. We retrospectively analyzed the records of these 111 consecutive patients who underwent UBE surgery. Cases with a follow-up period of less than twelve months were excluded.

As a standard procedure, electrocardiography, noninvasive blood pressure, peripheral oxygen saturation, core body temperature, the degree of neuromuscular blockade, and depth of anesthesia were monitored, and the relevant data were recorded for all patients. General anesthesia was induced with propofol according to the EEG spectrogram. Following the onset time of rocuronium, all patients were intubated under esmolol bolus to mitigate the hemodynamic responses to endotracheal intubation. After completing the induction period of anesthesia, all patients were positioned prone with two pillows placed under the thorax and abdomen bilaterally.

It was noticed that an isoelectric pattern was present in the BIS monitoring of some patients during UBE spinal surgery. Following the observation of postoperative temporary vision loss in one of these patients, we considered a potential relationship between the isoelectric BIS pattern and a sudden increase in intracranial pressure. We hypothesized that BIS monitoring could serve as a noninvasive method to detect sudden increases in intracranial pressure. Previously, BIS monitoring was selectively applied to

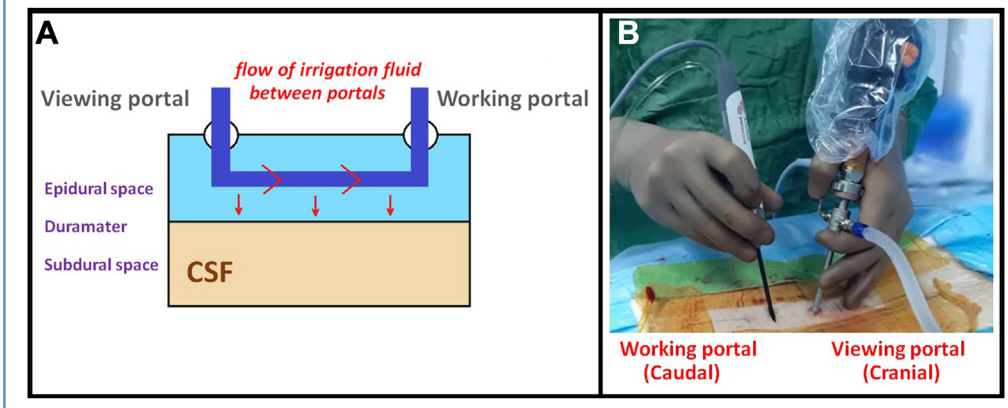


Figure 1. (**A**) Illustration of UBE. (**B**) Intraoperative view of UBE surgery and portals. CSF, cerebrospinal fluid; UBE, unilateral biportal endoscopy.

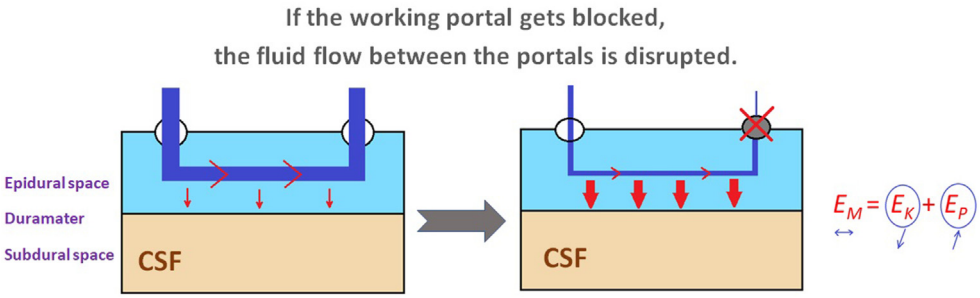


Figure 2. Schematic demonstrating fluid flow changes in case of possible blockage in the working portal during UBE surgery. If the working portal gets blocked, the fluid flow rate decreases. The kinetic energy of the fluid decreases while the potential energy increases. This condition may increase the CSF pressure by increasing the pressure exerted on the subdural space. CSF, cerebrospinal fluid; UBE, unilateral biportal endoscopy; E_m, mechanical energy; E_k, kinetic energy; E_p, potential energy.

patients as deemed necessary by the anesthesia team. However, as of May 2023, we started to routinely implement BIS monitoring for all patients undergoing UBE surgery.

We collected data about anesthesia types, intraoperative hypertension occurrences, BIS patterns, and surgery durations by reviewing anesthesia observation forms. Additionally, we retrieved information on patients' age, body mass index (BMI), and American Society of Anesthesiologists (ASA) scores from the hospital's digital archive. The intraoperative BIS values of patients and any postoperative neurological complications were evaluated retrospectively.

For statistical analysis, SPSS v.22.0 (SPSS Inc., Chicago, IL, USA) was used. Descriptive statistics were employed to characterize patients' demographic variables, with mean, median, and standard deviation values utilized for this purpose. Patients were divided into two groups based on the presence or absence of an isoelectric pattern observed in BIS monitoring, and these groups were compared in terms of postoperative retinopathy and intraoperative hypertension using Fisher's exact test, with P values <0.05 considered significant. Additionally, comparisons were made regarding age, BMI, ASA score, duration of anesthesia, and level of surgery between the two groups using the Mann-Whitney U test, with P values <0.05 deemed statistically significant.

Table 1. Correlation Between BIS and Sedation Level*

BIS	Levels of Sedation
86–100	Awake
66–85	Response to loud verbal command
41–66	Minimal response to stimulus, low probability of recall
20–40	Deep sedation unresponsive to painful stimulus
<20	Suppression in EEG
0	No electrical brain activity (isoelectric EEG pattern)

EEG, electroencephalography; BIS, bispectral index.
*Akinci SB, Çelebioglu B. Bispektral Index Monitoring J Turk Soc Intens Care 2006;4(2).[14]

RESULTS

Between July 2017 and December 2023, a total of 2330 levels of endoscopic spinal surgery were performed on 1505 patients diagnosed with spinal stenosis or lumbar disc herniation at our clinic. Among these patients, postoperative visual impairment due to intraocular hemorrhage was observed in two cases. Fortunately, retinal hemorrhage was resolved in both patients, and permanent visual impairment did not occur. Notably, BIS monitoring was not universally implemented among these 1505 patients initially. However, beginning in May 2023, we initiated routine BIS monitoring for all UBE surgeries. From May 2023 to December 2023, 111 patients who underwent endoscopic spinal surgery were included in our study, with 182 levels of surgery performed in total. Of the 111 patients included in the study, 54 (48.6%) patients were male, and 57 (51.4%) were female, resulting in a male-to-female ratio of 0.95. The mean age of the cohort was 58.66 years. Among them, 43 (38.7%) patients were operated on with a diagnosis of lumbar disc herniation, while 68 (61.3%) patients underwent surgery due to spinal stenosis. The mean duration of surgery was 106.5 minutes, with an average surgical duration per level of 64.9 minutes (Table 2).

An isoelectric BIS pattern was observed intraoperatively in six patients (5.4%). The mean age of these six patients was 66.33, the mean BMI was 29.38, and the mean ASA score was 1.83. Notably, postoperative vision loss developed in only 1 of these 6 patients (Table 3). Following surgery, this patient was consulted by ophthalmology, where a diagnosis of bilateral retinal hemorrhage was confirmed via fundus examination. Fortunately, with the resolution of retinal hemorrhage, the visual loss gradually improved over time, with no residual sequelae.

The patients were divided into two groups based on the presence or absence of isoelectric EEG activity in BIS monitoring. Notably, the only patient who developed postoperative retinopathy was in the "isoelectric BIS pattern" group. Postoperative retinopathy was absent in five of six patients (83.3%) with an isoelectric BIS pattern, while none of the 105 patients (100%) with a normal BIS pattern developed postoperative retinopathy (Table 4).

Blood pressure values during surgery were examined, with patients exhibiting values above 140/90 mm Hg considered to have

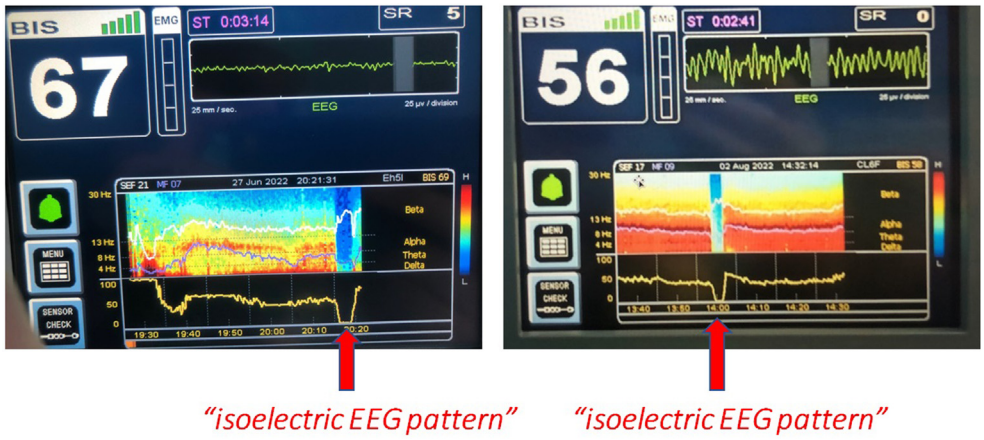


Figure 3. BIS monitoring. Examples of isoelectric EEG patterns in two different patients in which the intraoperative BIS value was measured as zero temporarily. BIS, bispectral index; EEG, electroencephalography.

intraoperative hypertension. Intraoperative hypertension was observed in five of six patients (83.3%) with an isoelectric BIS pattern, compared to 40 out of 105 patients (38.1%) in the normal BIS pattern group. The incidence of intraoperative hypertension was significantly higher in the group of patients with an isoelectric BIS pattern ($P = 0.04$) (Table 4). The observation suggests that

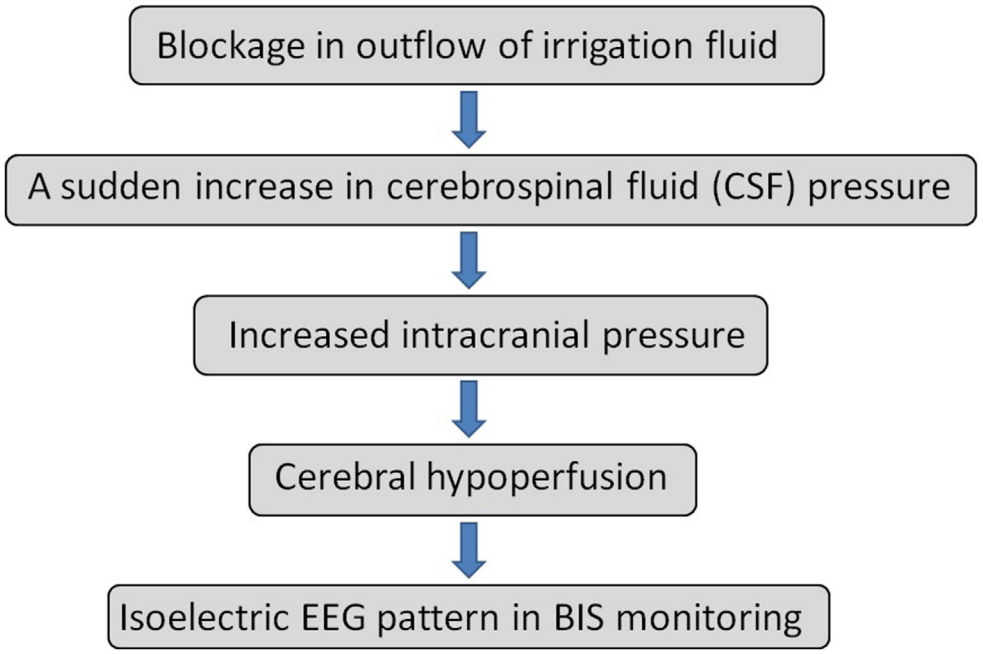


Figure 4. Schematic demonstrating the possible consequences of blockage in the fluid outflow and its reflection in BIS monitoring. BIS, bispectral index; EEG, electroencephalography.

Table 2. General Information of Patients

Total Numbers	
Total number of patients	111
Total number of endoscopic spinal surgery levels	182
Age	
Mean	58.66
Median	60
Standard deviation (SD)	15.59
Sex (n, %)	
Male	54 (48.6%)
Female	57 (51.4%)
M/F	0.95
Etiology (n, %)	
Lumbar disc herniation	43 (38.7%)
Spinal stenosis (central or foraminal)	68 (61.3%)
Duration of surgical intervention (minutes)	
Mean duration of anesthesia	146.6
Mean duration of surgery	106.5
Mean surgical duration per level of surgery	64.9
BIS pattern (n, %)	
Isoelectric BIS pattern	6 (5.4%)
Normal BIS pattern	105 (94.6%)

BIS, bispectral index.

during endoscopic spinal surgery in hypertensive patients, increasing the pressure of irrigation fluid to manage bleeding and maintain image quality may contribute to a higher likelihood of observing isoelectric EEG activity.

Furthermore, no significant differences were observed between patient groups concerning ASA score, duration of anesthesia, number of surgical levels, age, and BMI (Table 5).

DISCUSSION

The intraocular hemorrhage associated with subarachnoid hemorrhage was first described by Terson in 1912.[12] Over time, the definition of "Terson syndrome" has been extended to encompass intraocular hemorrhages occurring due to various factors that lead to sudden increases in intracranial pressure.[12,21] The primary triggering event leading to Terson syndrome is believed to be the sudden rise in intracranial pressure. The optic nerve sheath is continuous with the submeningeal spaces within the cranial cavity, allowing the transmission of intracranial pressure through this pathway, ultimately compressing the central retinal vein. This elevated venous pressure in the retinal venous system is thought to cause intraocular hemorrhages by rupturing the superficial retinal vessels.[13]

Additionally, there are documented cases in the literature detailing visual impairment following epidural fluid injections and epiduroscopy. In the review published by Gill and Heavner, 12 cases reporting visual loss after epidural injection were examined.[22] Bolus fluid injection is typically identified as the triggering event. During epiduroscopy, saline is commonly injected to facilitate epidural space opening, which may result in CSF displacement and a transient rise in CSF pressure. Guidelines recommend maintaining injection rates below 1 mL per 1–2 seconds to minimize this risk.[22] Increased CSF pressure can compress the optic nerve sheath, leading to venous retinal hemorrhage. While retinal venous hemorrhages may regress spontaneously, those involving the vitreous region may necessitate vitrectomy.[22,23]

In our cohort of 1505 patients who underwent UBE for lumbar spinal stenosis or lumbar disc herniation between July 2017 and December 2023, postoperative visual impairment occurred in only two cases. Both patients were referred to ophthalmology for fundus examination during the postoperative period. In 1 case, the retinal hemorrhage spontaneously resolved, while in the other case, vitrectomy was required due to subhyaloid hemorrhage. Both patients experienced temporary visual impairment and recovered without residual sequelae. We believe that the retinopathy observed in these cases may be attributed to a sudden increase in intracranial pressure during UBE, supported by the presence of an isoelectric EEG pattern in BIS monitoring. Although theoretical

Table 3. Patients with Intraoperative Isoelectric BIS Pattern

		Level of					Intraoperative		Postoperative
Number	Diagnosis	Surgery	Age	BMI	ASA	Types of Anesthesia	Hypertension	BIS Pattern	Retinopathy
1	L3-L5 Stenosis	2	78	29.4	2	General anesthesia	Present	Isoelectric pattern	Absent
2	L4-L5 Stenosis	1	60	29.1	1	General anesthesia	Present	Isoelectric pattern	Absent
3	L4-L5 LDH	1	55	27.7	2	General anesthesia	Present	Isoelectric pattern	Present
4	L3-L5 Stenosis	2	80	24.6	2	General anesthesia	Present	Isoelectric pattern	Absent
5	L5-S1 LDH	1	67	33.3	2	General anesthesia	Absent	Isoelectric pattern	Absent
6	L4-L5 Stenosis	1	58	32.2	2	General anesthesia	Present	Isoelectric pattern	Absent

BIS, bispectral index; BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 4. Comparison of Patient Groups in Terms of Postoperative Retinopathy and Intraoperative Hypertension

	Isoelectric BIS Pattern	Normal BIS Pattern	*P* Value*
Postoperative retinopathy			
Present	1 (16.7%)	0	0.05
Absent	5 (83.3%)	105 (100%)	
Intraoperative hypertension			
Present	5 (83.3%)	40 (38.1%)	0.04
Absent	1 (16.7%)	65 (61.9%)	

BIS, bispectral index.
*Fisher's exact test was used. Differences were considered statistically significant for P value < 0.05.

knowledge suggests that retinopathy can develop as a result of increased intracranial pressure during UBE, no published cases of retinopathy have been found in the literature.[4,5,24]

Currently, there is no noninvasive method in the literature to monitor the increase in intracranial pressure during endoscopic spinal surgery. Ventricular catheterization is the gold standard for measuring intracranial pressure in clinical practice.[25] In some biomechanical studies in the literature, invasive methods such as cervical epidural catheterization have been applied.[4,5] For example, Kang et al.[4] aimed to evaluate the effect of biportal endoscopic lumbar discectomy on intracranial pressure in their study. The authors performed a single-level UBE lumbar discectomy on 20 patients and measured changes in cervical epidural pressure during different phases of UBE using cervical catheterization. It was observed that as the fluid inflow pressure increased, the cervical epidural pressure also increased. However, when the fluid inflow pressure exceeded 50 mm Hg, the cervical epidural pressure reached a plateau and remained constant. The authors noted that if the fluid outflow was blocked due to an obstruction in the working portal, different outcomes were observed. In cases of fluid outflow obstruction, the cervical epidural pressure increased linearly with increasing fluid inlet pressure, and no plateau value was observed. The authors concluded that UBE could be safely performed as long as there was no blockage in fluid outflow. However, they cautioned that in case of blockage in the outflow, an increase in intracranial pressure may occur.[4]

Table 5. Comparison of Patient Groups According to BIS Patterns

	Isoelectric BIS Pattern	Normal BIS Pattern	*P* Value*
ASA score	1.83 (±0.41)	1.76 (±0.51)	0.69
Age	66.33 (±10.59)	58.22 (±15.75)	0.22
BMI	29.38 (±3.14)	29.28 (±7.82)	0.63
Level of surgery	1.33 (±0.52)	1.66 (±0.88)	0.46
Duration of anesthesia	148.33 (±53.16)	146.57 (±50.35)	0.92

BMI, body mass index; ASA, American Society of Anesthesiologists; BIS, bispectral index.
*Mann-Whitney U-test was used. Differences were considered statistically insignificant for a P value > 0.05.

While methods such as ventricular catheterization or cervical epidural catheterization are preferred in biomechanical studies, they are not routinely applicable to every patient due to their invasive nature. We argue that BIS monitoring can be used as a noninvasive method to monitor sudden increases in intracranial pressure during UBE surgery. The use of BIS monitoring for this purpose is defined for the first time, significantly increasing the importance of our study.

BIS is a processed EEG parameter commonly utilized to monitor the depth of anesthesia during surgical procedures. Factors such as hypothermia, hypoglycemia, cardiac arrest, or cerebral hypoperfusion are recognized to cause sharp decreases in BIS value.[18] During surgery, core body temperature was continuously monitored in all patients using esophageal probes, and the anesthesia team implemented appropriate warming measures to prevent hypothermia. Additionally, glucose-containing electrolyte-balanced intravenous solutions were administered to prevent hypoglycemia, and blood glucose levels were monitored intraoperatively via both glucometry and blood gas analyses. These routine monitoring procedures were performed for all patients, and those showing isoelectric EEG activity on the BIS monitor were re-evaluated in detail by the anesthesia team to rule out other possible causes such as hypoglycemia and hypothermia. In our study, all six patients with isoelectric EEG activity had normal body temperatures and glucose levels. None of them had underlying causes such as hypoglycemia or hypothermia. In all six cases, the surgical team was alerted intraoperatively by the anesthesia team regarding the risk of cerebral hypoperfusion.

The major limitation of our study was the limited number of patients and the retrospective design of the research. Although we had a large case series of 1505 patients with UBE, we only included 111 patients who received routine BIS monitoring in the study. A prospective study with a larger number of participants would provide more comprehensive insights. Additionally, animal studies could be designed in the future to demonstrate the relationship between BIS monitoring and increased intracranial pressure.

CONCLUSION

BIS monitoring emerges as a noninvasive technique that can monitor cerebral hypoperfusion associated with sudden increases in intracranial pressure during UBE. The detection of an isoelectric pattern in BIS monitoring serves as a warning sign of increased intracranial pressure. Upon observing isoelectric EEG activity, it is imperative to assess fluid outflow and ensure that the working portal is unobstructed. If necessary, fluid flow should be stopped, and the operation should be paused. BIS monitoring should be incorporated into the standard practice for all patients undergoing UBE surgery to mitigate neurologic complications.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Abdullah Merter: Writing — review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization.

Mustafa Özyıldıran: Writing — original draft, Methodology, Investigation, Formal analysis, Data curation. **Fatih Kurt:** Methodology, Investigation, Formal analysis, Data curation. **Menekşe Özçelik:** Writing — review & editing, Supervision, Project administration.

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