



# Comparison of Two Methods of Anesthesia Using Patient State Index: Propofol Versus Sevoflurane During Interventional Neuroradiology Procedure

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Received 2018 December 14; Revised 2019 February 20; Accepted 2019 February 23.

## Abstract

**Background:** Over the past few decades, interventional neuroradiology (INR) has been a rapidly growing and evolving area of neurosurgery. Sevoflurane and propofol are both suitable anesthetics for INR procedures. While the depth of anesthesia is widely monitored, few studies have examined the patient state index (PSI) during clinical neuroanesthesia.

**Objectives:** This study aimed to investigate the differences in PSI values and in hemodynamic variables between sevoflurane anesthetic and propofol anesthetic during INR procedures.

**Methods:** We reviewed the medical charts of the patients who underwent embolization of a non-ruptured intracranial aneurysm by a single operator at a single university hospital from May 2013 to December 2014. Sixty-five patients were included and divided into two groups: S group (sevoflurane anesthesia, n = 33) vs. P group (propofol anesthesia, n = 32). The PSI values, hemodynamic variables, and use of hemodynamic drugs between two groups were analyzed.

**Results:** There were significant differences between the PSI values obtained through different perioperative stages in the two groups ( $P < 0.0001$ ). During the procedure, the PSI values were significantly lower in the P group than in the S group ( $P = 0.000$ ). The P group patients had a more prolonged extubation time ( $P = 0.005$ ) and more phenylephrine requirement than the S group patients ( $P = 0.007$ ). More anti-hypertensive drugs were administered to the patients in the S group during extubation ( $P = 0.0197$ ).

**Conclusions:** The PSI can be used to detect changes in anesthetics concentration and in the depth of anesthesia during INR procedures. Although the extubation was faster under sevoflurane anesthetic, propofol anesthetic showed rather smoother recovery.

**Keywords:** Interventional Neuroradiology, Propofol, Sevoflurane

## 1. Background

Interventional neuroradiology (INR) has been a rapidly evolving clinical field over the past few years. In this regard, the International Subarachnoid Aneurysm Trial (ISAT) reported that coil embolization showed better one-year and seven-year survival rates than clipping (1), and the coil embolization has become almost a primary therapeutic option. Although there is no clear decision concerning what type of anesthesia is superior, general anesthesia (GA) is more advantageous than sedation to preserve the intracranial pressure (ICP). Controlled ventilation during GA can provide normocapnia to control the ICP (2).

The choice of anesthetics should be guided by several considerations. Propofol and sevoflurane have been used for neurosurgery (3). Good image quality, fast recovery from GA (2), and lower disturbance of the physiologic pa-

rameters (3), as well as intraoperative neurophysiologic monitoring (IOM), are important factors should be taken into account.

The bispectral index (BIS) is a worldwide popular index to monitor the intraoperative depth of anesthesia (DOA), and numerous studies have investigated the relationship between the BIS and GA. The BIS is influenced by anesthetics such as sevoflurane and propofol (4). The SEDLine™ monitor uses a proprietary algorithm to analyze raw frontal and prefrontal EEG signals and calculate the patient state index (PSI) values (5, 6). The PSI values are adequate to expect the depth of hypnosis during GA for various anesthetic regimens (5). The BIS value for adequate GA for surgery is 40 - 60 but PSI value is 25 - 50.

SEDLine™ monitor is a four-channel processed electroencephalographic (EEG) monitor and can display bilateral EEG. Data from four-channel EEG enable the PSI algo-

rhythm to simultaneously reflect global and regional brain changes (7). Choi et al. reported that BIS was significantly increased after 5 minutes of endovascular neuro-intervention with increasing regional cerebral oxygen saturation (8). However, fewer studies have used the PSI in comparison to the BIS.

## 2. Objectives

This study aimed to investigate the differences in PSI values and hemodynamic profiles in patients undergoing propofol and sevoflurane anesthetics during INR procedures.

## 3. Methods

This study was carried out as a retrospective study at a single university hospital from May 2013 to December 2014. We reviewed the patients of ASA physical status I-III who underwent embolization of a non-ruptured intracranial aneurysm by a single operator. The study followed the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines, which were conducted according to the Declaration of Helsinki. This study was approved by the related Institutional Review Board (2015-05-005). Obtaining informed consent was waived with respect to the retrospective design of the study.

The patient was monitored for electrocardiogram, invasive arterial blood pressure (BP), pulse oximetry, SEDLine™, and capnography. No premedication was administered to the patients. The invasive BP was monitored through the right or left radial artery. In Group S, GA was induced by the administering intravenous (IV) propofol (2-3 mg/kg), remifentanyl (0.1 µg/kg/hr), and rocuronium (0.6 mg/kg). The general anesthesia was maintained with sevoflurane 2-3 vol% and remifentanyl (0.05-0.1 µg/kg/hr) with 50% FiO<sub>2</sub>. In the P group, GA was induced with a 3-4 µg/mL target effect-site concentration (Ce) of 2% propofol (Fresofol® MCT 2% Inj.; Fresenius Kabi Austria GmbH, Graz, Austria) using the Schnider model (9), and a target Ce of 3-4 ng/mL of remifentanyl using the Minto model (10). The concentration of the maintaining anesthetic agents was adjusted to maintain the mean arterial pressure within 20% of the baseline levels in both groups. A bolus IV injection of ephedrine or phenylephrine was administered to the patients according to the anesthesiologist's judgment. When the patients showed movement or the operator wanted more neuromuscular relaxation, IV rocuronium 10 mg was injected. The patients were maintained in normocapnia (end-tidal CO<sub>2</sub> values of 30-35 mmHg) during the procedure.

At the end of the procedure, the anesthetics were discontinued and the neuromuscular blockade was reversed. The patients were extubated after confirming the full recovery of their spontaneous breathing. The time to extubation (between the cessation of anesthetic agents to the removal of the endotracheal tube) and the incidence of nicardipine administration were recorded. We recorded the PSI values at five stages (baseline awake, during the induction, during the procedure, during the extubation, and after the extubation).

We did not conduct a powerful analysis as we studied the entire sample of the patients. We presented the data as the mean ± standard deviation (SD) and the number of the patients. The statistical analyses were performed with a chi-squared test and an independent *t*-test using the MedCalc (MedCalc Software, Ostend, Belgium). A *P* < 0.05 was considered statistically significant.

## 4. Results

A total of seventy-seven patients were included, and sixty-five patients were ultimately analyzed. Nine patients in the P group were excluded due to an unexpectedly prolonged anesthesia time for a complex procedure, and one patient in the S group and two patients in the P group were excluded because of insufficient anesthetic records.

The patients' baseline and anesthetic characteristics were not significantly different between the two groups except for the time to extubation (Table 1). The P group patients showed a more prolonged time to extubation (16.2 ± 7.5 min) than those in the S group (11.7 ± 4.3 min) (*P* = 0.005).

There were significant differences between the PSI values obtained through different perioperative stages in the two groups (*P* < 0.0001). In particular, the PSI values during the procedure were lower in the P group than in the S group; 26.4 ± 9.2 and 42.1 ± 10.1, respectively (Table 2).

The perioperative usage of hemodynamic drugs (phenylephrine, ephedrine, and nicardipine) is described in table 3. The incidence of intraoperative phenylephrine infusion was higher in the P group (66.7%) than in S the group (21.9%) (*P* = 0.0007). More anti-hypertensive drug (nicardipine) was administered to the patients in the S group during extubation (*P* < 0.05).

## 5. Discussion

In this study, the PSI values were significantly co-varied with the changes in state under GA. Sevoflurane anesthetic

**Table 1.** Patients' Baseline and Anesthetic Characteristics<sup>a</sup>

Variables	S Group (N = 32)	P Group (N = 33)	P Value
Sex, male/female	7/25 (21.9/78.1)	3/30 (9.1/90.9)	0.278
Age, y	60.2 ± 12.3	58.7 ± 12.0	0.630
Height, cm	157.9 ± 8.4	157.7 ± 7.3	0.914
Weight, kg	58.7 ± 9.8	60.2 ± 9.3	0.515
ASA classification, 1/2/3	7/23/2 (21.9/71.9/6.2)	7/25/1 (21.2/75.8/3.0)	0.818
<b>Main symptoms</b>			
Dizziness	3 (9.4)	4 (12.1)	0.6773
Visual disturbance	1 (3.1)	1 (3.0)	
Headache	12 (37.5)	18 (54.5)	
Syncope	1 (3.1)	1 (3.0)	
Gait disturbance	2 (6.2)	0 (0.0)	
No symptom	10 (31.2)	7 (21.2)	
Aphasia	1 (3.1)	0 (0.0)	
Hemiparesis	2 (6.2)	2 (6.1)	
<b>Total amount of rocuronium, mg</b>	46.9 ± 11.2	45.0 ± 10.9	0.496
<b>Frequency of injection of NMBA, 1/2/3/4</b>	28/3/0/1 (87.5/3/0/1)	31/1/1/0 (93.9/3/3/0)	0.371
<b>Duration of surgery, min</b>	58.6 ± 19.8	56.1 ± 16.8	0.579
<b>Duration of anesthesia, min</b>	94.4 ± 22.4	102.3 ± 18.2	0.122
<b>Duration of extubation, min</b>	11.7 ± 4.3	16.2 ± 7.5	0.005*

Abbreviations: ASA, American Society of Anesthesiologist; NMBA, neuromuscular blocking agent.

<sup>a</sup> The values are represented as number (%) or mean ± SD.

**Table 2.** Perioperative Changes of Patient State Index Values During Interventional Neuroradiology Procedure<sup>a</sup>

Mean PSI Values	S Group (N = 32)	P Group (N = 33)	P Value
<b>Baseline awake</b>	92.0 ± 5.5	90.4 ± 5.8	0.266
<b>During induction</b>	52.2 ± 18.8	50.1 ± 20.8	0.677
<b>During procedure</b>	42.1 ± 10.1	26.4 ± 9.2	0.000*
<b>During extubation</b>	81.9 ± 6.9	78.8 ± 10.2	0.152
<b>After extubation</b>	85.3 ± 6.4	81.5 ± 11.8	0.108

Abbreviation: PSI, patient state index.

<sup>a</sup> The values are represented as mean ± SD.

showed quicker extubation and more nicardipine requirement during extubation than propofol anesthetic. Propofol anesthetic showed more intraoperative phenylephrine requirement than sevoflurane anesthetic.

The patient state index demonstrated high sensitivity to the changes in states and the changes between the different stages of anesthesia. Moreover, significant differences were observed between the mean PSI values obtained from induction until the return of consciousness (5). The PSI values were found to be lower in the propofol group than in

the sevoflurane group during the INR procedure.

Anesthetic considerations for INR procedures include the maintenance of sufficient muscle relaxation, and rapid and safe recovery from GA for immediate postoperative examination (2). Lower disturbance of the cardiovascular and cerebral hemodynamic variables is also an important factor (3). Significant reductions of the cerebral blood flow (CBF), the cerebral metabolic rate of oxygen (CMRO<sub>2</sub>), and the intracranial pressure (ICP) are features of propofol anesthesia (11). Sevoflurane has also been shown to have a suitable pharmacological profile with intraoperative adjustment and rapid onset and offset (12).

Sevoflurane and propofol have different EEG profiles in that the further deepening of propofol anesthesia inhibits the cortex more and more until burst suppression (13). The prediction probability (P<sub>k</sub>) of PSI to predict the Ce of propofol (0.87) was greater than that of sevoflurane (0.79) (6, 14). Lee et al. (15) demonstrated that the PSI value was reliable for the assessment of propofol sedation. Moreover, the BIS, another intraoperative index for DOA monitoring, has been found to predict the depth of hypnosis with propofol slightly more accurately than with sevoflurane (4). Therefore, we assumed that the PSI would detect

**Table 3.** Use of Drugs in Interventional Neuroradiology Procedure<sup>a</sup>

	S Group (N = 32)	P Group (N = 33)	P Value
<b>During procedure</b>			
Infusion of phenylephrine, no/yes	25/7 (78.1/21.9)	11/22 (33.3/66.7)	0.0007*
Bolus injection of ephedrine/phenylephrine, no/yes	15/17 (46.9/53.1)	14/19 (42.4/57.6)	0.7203
<b>During extubation</b>			
Bolus injection of nicardipine, no/yes	19/13 (59.4/40.6)	29/4 (87.9/12.1)	0.0197*

<sup>a</sup> The values are represented as the number of the patients (%).

the changes in propofol concentrations better than those in sevoflurane concentrations.

The sevoflurane group showed faster recovery from the neurologic procedures than the propofol group (16, 17). Although the clinical benefits of faster recovery under sevoflurane are unknown, smooth and rapid emergence from GA is essential to facilitate early neurological assessment after neurosurgery. Recently, anesthesiologists should consider applying intraoperative neurophysiologic monitoring (IOM) during neurosurgery. In our INR suite, total intravenous anesthesia (TIVA) has been preferred over volatile anesthesia since IOM started to be applied to patients.

The amount of given NMBA is usually smaller in volatile anesthesia than in TIVA, as the action of NMBA is influenced by the use of volatile anesthetics (18). We know that sevoflurane increases the potency of rocuronium compared with propofol (19). Sevoflurane may provide a deeper level of anesthesia than propofol at comparable BIS values (50 - 60) during INR procedures (16). We avoided the administration of additional NMBA as possible (20) and found the propofol concentration to be relatively high in the propofol group. Propofol showed more incidence of movement than sevoflurane during procedures of approximately 90 minutes (16). The PSI may reflect this point and recovery time from propofol anesthesia was longer than sevoflurane anesthesia similar to other studies (16, 17).

More intravenous hypotensive agents were administered to the patients in the S group during extubation. We believe this reflected a rough process of extubation. The prevention of non-ruptured aneurysms from rupturing is the most important goal, and avoiding acute alteration of the blood pressure is essential to the management of INR procedures (2). More attention had to be paid to the hemodynamic profiles during extubation in the sevoflurane group. More intraoperative phenylephrine was administered in the propofol group than in the sevoflurane group. This finding is consistent with the findings of other studies (16, 21). In the TIVA group, MAP significantly de-

creased after induction and during GA maintenance (16). The hypotension associated with propofol may be detrimental to the elderly and patients with coronary vascular diseases (21). Therefore, it is important to avoid hypotension under propofol anesthesia.

Intraoperative EEG provides a global assessment of cerebral ischemia but cannot be used to monitor the posterior fossa (22). Furthermore, lower BIS values in cerebral coil embolization can occur due to unexpected situations such as cerebral vasculitis (23). The probable confounding effect of the patients' non-ruptured intracranial aneurysm on EEG tracing and PSI values may exist.

This study had some limitations. First, it is a retrospective study performed by a single surgeon at a single center. It may not be generalized with the situation in other centers. Second, we could not record the amounts of propofol and remifentanyl and the end-tidal concentrations of sevoflurane. Third, we could not provide equi-PSI depth of anesthesia on both study groups due to the retrospective design.

In conclusion, the PSI can detect changes in anesthetics concentrations and in the depth of anesthesia during INR procedures. Patient state index values can reflect the GA depth. Although propofol showed more requirements for phenylephrine and a longer duration of extubation, smoother recovery might be achieved after propofol anesthesia.

## Footnotes

**Authors' Contribution:** Concept and design: Ki Hwa Lee; literature search: Eunsu Kang; clinical studies: Eunsu Kang and Ki Hwa Lee; data acquisition and analysis: Jae-hong Park; manuscript writing and review: Ki Hwa Lee and Eunsu Kang; manuscript editing: Ki Hwa Lee.

**Conflict of Interests:** There is no conflict of interests.

**Ethical Approval:** This study was approved by Inje University, Haeundae Paik Hospital, Institutional Review Board (2015-05-005).

**Funding/Support:** This work was supported by the 2018 Inje University research grant.

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