International Journal of Advanced Smart Convergence Vol.9 No.3 71-77 (2020)
http://dx.doi.org/10.7236/IJASC.2020.9.3.71

IJASC 20-3-9

Effects of changes in blood pressure during brain vascular surgery on intraoperative neuromonitoring

Kyuhyun Lee[1], Jaekyung Kim*[2]

[1]*Graduate student, Department of Health Sciences, Dankook University, Chunan 31116, Korea.*
E-mail: 20394@snubh.org
[2*]*Professor, Department of Health Sciences, Dankook University, Chunan 31116, Korea.*
E-mail: dkwkqj@naver.com

Abstract

This study was conducted in order to determine how reductions in blood pressure during surgery affect intraoperative neuromonitoring. This retrospective study considered a total of 339 patients: 194 patients with normal neuromonitoring findings (57%), 145 (42%) with abnormal neuromonitoring findings, and 34 (10%) with postoperative neurological deficits. Comparisons between the three groups revealed that overall blood pressure during surgery, postoperative blood pressure, and the difference between the maximum and minimum blood pressure could affect the intraoperative neuromonitoring findings. While we indicate that a drop in blood pressure to below 70 mmHg could affect neuromonitoring results, differences in the dosage of anesthetic agents did not significantly affect reductions in blood pressure or neuromonitoring findings. The association of monitoring with blood pressure found in this study is expected to help future examiners. However, this study did not clarify the relationship between anesthesia and blood pressure and how it could affect intraoperative neuromonitoring. Therefore, further research on this part is thought to be necessary.

Keywords*: Anesthesia, Brain function, Intraoperative blood pressure, Intraoperative neuromonitoring, Infarction, Mean blood pressure*

1. Introduction

During cerebrovascular surgery, blood circulation in the brain is temporarily cut off to allow surgeons to manipulate the blood vessels or bypass blood flow. Based on the evoked potential test, intraoperative neuromonitoring is an electroneurophysiological test that can provide important information to the surgeon during cerebrovascular surgery and help to minimize postoperative deficits [1]. Furthermore, intraoperative neuromonitoring can reveal blood supply disorders in the brain tissue that may induce ischemic brain damage [2]. Brain perfusion is used in cases of blood circulation disorders to help regulate blood flow and thus preserve neural tissue and function. During surgery, the outcome of brain perfusion varies widely between individuals according to hemoglobin content, hemolysis, blood pressure, cerebrospinal pressure, anatomical structure of the cerebral blood vessels, and condition of the blood vessels [3]. Patients with poor blood pressure control

Manuscript Received: June. 20, 2020 / Revised: June. 25, 2020 / Accepted: July. 3, 2020
Corresponding Author: dkwkqj@naver.com
Tel: +82-41-550-1451, Fax: +82-41-550-1450
Professor, Department of Health Sciences,Dankook University, Chunan 31116, Korea

have a poor prognosis after surgery and cannot be treated with autonomous brain perfusion during surgery. Treatments for these patients are limited to the use of clips or pharmacotherapy. Disorders of the supply of blood to the brain may also occur postoperatively and result in neurological deficits [4].

Controlling blood pressure during surgery is closely linked to the administration of anesthesia, and both are influenced by many factors, including surgical time and bleeding [5]. Brain surgery is mostly performed with intravenous anesthesia. Although propofol is the most frequent intravenously administered anesthetic, it can have varying effects on the cardiovascular and autonomic nervous systems that adversely affect blood pressure coordination [3, 6]. The adjunctive use of opiate analgesics, such as remifentanyl can exacerbate the effects of propofol by lowering the heart rate, respiration rate, and arterial pressure.

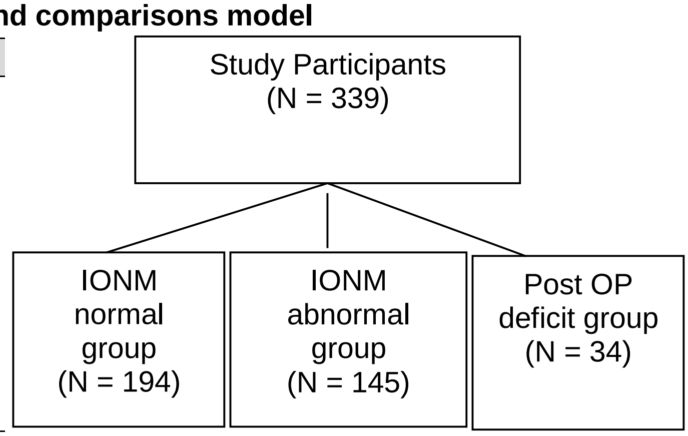
While the existing literature indicates that problems in blood pressure control can affect intraoperative neuromonitoring, few have documented aberrant intraoperative findings(ex. Perfusion disorder, infarction) in the context of the patients' blood pressure. we need to study this part more. To address this dearth in the literature, this study determined the extent of the reduction in blood pressure required to affect intraoperative neuromonitoring, and how the degree to which the changes in blood pressure correlate with dosage of anesthesia delivered during surgery.

2. MATERIALS AND METHODS

Table 1 shows the main variables covered in this study and how they were analyzed. The average blood pressure before, during and after surgery was mainly dealt with, and the anesthetic compared the dose of propofol and Remifentanyl.

Table 1. Variables and comparisons model

Comparison	Variable	Analysis
Normal & Abnormal(IONM event)	1. Blood pressure	
	Pre OP mean BP	F-test
	Intra OP mean BP	
	Post OP mean BP	Equal variance T-test
	Total OP mean BP	
Normal & Post OP neurologic deficit	2. Anesthesia	
	Propofol(MAX,MIN)	Unequal variance T-test
	Remifentanyl(MAX,MIN)	



IONM, intraoperative neuromonitoring; OP, operative; BP, blood pressure; MAX, maximum; MIN, minimum.

2.1 Study Subjects

In this paper, we considered 339 patients who underwent cerebrovascular surgery at Seoul National University Bundang Hospital between October 2018 and August 2020. Our sample included 194 patients with normal neuromonitoring findings (57% of 339 patients), 145 (42% of 339 patients) with abnormal neuromonitoring findings, and 34 (10% of 339 patients) with postoperative neurological deficits. There are about 80 to 90 patients in other studies that have conducted similar studies [6].

None of the selected patients had any neurological disorder apart from that being treated with surgery. Patients who underwent multiple surgeries or received and additional vascular operation were counted as duplicates. The purpose of the examination was explained to all participants prior to obtaining their written informed consent for data collection.

2.2 Examination

We used Xtek Protector (Natus Medical Inc., ExcelTech Ltd., Oakville, Ontario, Canada) as the testing equipment. In accordance with the International 10-20 Electrode system, positive and negative motor evoked potential (MEP) stimulation needles were placed at C2, C4 for stimulation of the right cerebral and C1, C3 for stimulation of left cerebral hemispheres. C2, C4 is located in the right hemisphere centerline of the brain, and C1, C3 is located in the left hemisphere centerline of the brain. They are symmetrical with each other, C3 and C4 are located far left and right. The following stimulus parameters were used: biphasic polarity, continuative 5 pulse stimuli, stimulation rate of 500 Hz, stimulus duration 0.05 ms, and MEP of 150–300 V. MEP stimulation power was recorded in the abductor pollicis brevis, adductor digiti minimi, and the tibialis anterior and abductor hallucis of the lower limbs. The upper Somato sensory evoked potentials (SSEPs) were recorded at C3 and C4 after stimulating the median nerve (stimulation: 15 mA), while the lower SSEPs were recorded at Cz after stimulating the post tibial nerve (stimulation: 20 mA).

2.3 Statistical Analysis

The collected data were analyzed using Microsoft Excel 2010. We compared p- and t-values using equal variances and two-variance t-tests. The average and standard deviations were calculated with technical statistics. The normal distribution of the data was confirmed using the Shapiro-Wilk test, f-test. The significance level for all statistics was set to an alpha level of 0.05.

3. RESULTS

3.1 Patient Characteristics

The characteristics of the overall patients are presented in Table 2. A total of 339 patients participated, with 243 women and 96 men. The average age of participants was 58.2, with cerebral aneurysm surgery accounting for the largest percentage of cerebrovascular surgery, followed by Byass(MCA-STA anastomosis) surgery. Cerebral aneurysm was most common in MCA, followed by Acom.

Table 2. Demography of participants

Variable	Total No. (%)	
	Participant	339
Sex	Female	243 (71.6)
	Male	96 (28.3)
Age		58.2 (9.9)
surgery	Aneurysm clipping	330 (97.3)
	Bypass	14 (0.8)
	CEA	3 (0.8)
	AVM	3 (0.8)
Vessel	ICA	17 (5.0)
	MCA	200 (58.9)

Acom	58 (17.1)
Pcom	44 (7.3)
ACA	25 (6.4)
AchoA	22 (6.4)
BA	1 (0.3)

CEA, carotid endarterectomy; AVM, arteriovenous malformation; ICA, internal carotid artery; MCA, middle cerebral artery; Acom, anterior communicating artery; Pcom, posterior communicating artery; AchoA, anterior choroidal artery; BA, basilar artery.

Table 3 is the blood pressure of patients compared in this study. The difference between normal patients and patients with abnormalities during surgery can be clearly identified. P value was significant in the overall blood pressure of surgery, postoperative blood pressure, and subtraction of the highest and lowest blood pressure.

Table 3. Comparison of the normal, IONM abnormal, and post-OP deficit groups

Variable	Normal	IONM Abnormal	P value	T value
	Mean(±SD)			
Total Mean BP(mmHg)	78.7(±9.2)	76.2(±8.3)	0.005	2.86
PreOP Mean BP(mmHg)	79(±10.4)	78.5(±10.1)	0.692	0.396
IntraOP Mean BP(mmHg)	78(±9.5)	76.6(±9.0)	0.171	1.371
PostOP Mean BP(mmHg)	78.9(±10.7)	73.3(±9.5)	0.000001	4.944
Max-Min Mean BP(mmHg)	11.9(±7.4)	9.8(±7.1)	0.008	2.675
Propofol (㎍/㎖, MIN)	3.7(±0.4)	3.5(±1.6)	5.2361	9.088
Propofol (㎍/㎖, MAX)	4.1(±2.0)	4.0(±2.0)	0.1107	1.599
Reminfentanyl(㎍/㎖, MIN)	1.9(±0.9)	1.8(±1.1)	4.004	5.603
Reminfentanyl(㎍/㎖, MAX)	3.2(±1.2)	3.0(±1.6)	5.3788	6.369
Variable	**Normal**	**Post op neurologic deficit**	**P value**	**T value**
	Mean(±SD)			
Total Mean BP(mmHg)	78.7(9.2)	75.5(±9.2)	0.038	2.088
PreOP Mean BP(mmHg)	79(10.4	77.3(±11.9)	0.405	0.835
IntraOP Mean BP(mmHg)	78(9.5)	75.8(±10.4)	0.22	1.23
PostOP Mean BP(mmHg)	78.9(10.7)	70.9(±15.1)	0.004	2.948
Max-Min Mean BP(mmHg)	11.9(7.4)	9.2(±6.4)	0.05	1.974

propofol (㎍/㎖, MIN)	3.7(0.4)	3.5(±0.4)	0.133	1.507
propofol (㎍/㎖, MAX)	4.1(2.0)	4.1(±1.9)	0.501	-0.674
Reminfentanyl(㎍/㎖, MIN)	1.9(0.9)	1.8(±1.0)	0.763	0.302
Reminfentanyl(㎍/㎖, MAX)	3.2(1.2)	3.1(±1.0)	0.541	-0.612

MIN : minimum, MAX : maximum, BP : blood pressure, OP : operative

3.2 Differences Between Blood Pressure and Anesthetic Agent

The comparison between the abnormal and normal groups revealed significant differences in overall intraoperative blood pressure, postoperative blood pressure, maximum blood pressure, and minimum blood pressure (p<0.05). The difference between the doses of anesthetic agents administered to the two groups was not significant (p>0.05).

The comparison between the normal and postoperative neurological-abnormality groups identified significant differences in overall blood pressure, postoperative blood pressure, and the difference between the highest and lowest blood pressure (p<0.05). The difference between the dose of anesthetic drugs administered to the two groups was not statistically significant (p>0.05).

The aforementioned results confirm that differences in overall blood pressure during surgery, postoperative blood pressure, maximum blood pressure, and minimum blood pressure were associated with intraoperative neuromonitoring and postoperative neurological deficits.

4. DISCUSSION

Comparisons between the 194 normal patients, 145 with abnormal neuromonitoring findings, and 34 with postoperative neurological deficits revealed significant differences in postoperative average blood pressure, overall blood pressure, and the difference between the highest and lowest blood pressure observed during surgery (p<0.05). Our analysis revealed that decreases in blood pressure during surgery adversely affects brain perfusion [7] and that these adverse effects do not terminate upon completion of the surgery but are instead closely related to the patient's postoperative prognosis. While many studies have performed indirect studies of and postulated hypotheses concerning the association between reductions in blood pressure and intraoperative neuromonitoring, none has concurrently documented intraoperative neuroimaging findings and perioperative blood pressure in the same institution [8]. Addressing this dearth in the literature, we found that the intraoperative blood pressure of patients who were found to have poor postoperative prognoses decreased continuously or rapidly from the initially observed blood pressure; this observation was significantly associated with the results of the postoperative neuromonitoring test. The difference in the postoperative blood pressure between the groups may be attributable to multiple factors, including bleeding, transfusion, normal saline fluid, and the dosage of anesthetic agents administered during surgery. A drop in blood pressure can affect intracranial pressure, adversely influence oxygen metabolism in ventricular tissue and brain nerve cells, and consequently induce hypoxic and transient anemia, which can degrade neural function and impact findings on intraoperative neuromonitoring [9].

A reduction in the amplitude of the motor and sensory evoked potential on neuromonitoring could be detected when the average blood pressure of the patient dropped below 72.5 mmHg. Past research has shown that intraoperative neuromonitoring becomes abnormal once a patient’s average blood pressure drops below 63.5 mmHg [10]. As a continuous decrease in the patient’s blood pressure may induce an irreversible decline in brain function [11] – computed tomography has revealed signs of infarction in the brain shortly following local ischemia [12] – raising the blood pressure during surgery could improve the results of surgical neurosurgery [13].

In this study, 16 of 34 patients with postoperative neurological deficits were diagnosed with or suspected of having infarctions. The identification of infarction in a patient's brain was reflected by the significant decline of motor abilities and decreases in the waveform amplitude and latency extension on the evoked potential test conducted after surgery. While propofol, an anesthetic agent used when nerve monitoring tests are performed during surgery, reportedly adversely affects brain perfusion in the autonomic nervous system [14], this study did not identify any significant differences between the doses of anesthetic agents administered to the two groups (p>0.05). Further research is therefore warranted to determine whether the cause of blood pressure reduction is attributable to anesthesia or bleeding. As large fluctuations in blood pressure can occur very quickly during surgery [15], the surgeon should stop bleeding, temporarily suspend surgery, transfuse blood, or administer hypertensive agents when abnormal findings are observed during neuromonitoring. On the other hand, if changes in blood pressure that affect brain perfusion are not clearly indicated by intraoperative neuromonitoring findings, the patient may suffer from irreversible postoperative deficits. Hence, in addition to neuromonitoring, to prevent false negative or false positive. Factors such as anesthesia and patient vital signals should be checked throughout the surgery [16, 17, 18].

5. CONCLUSION

We confirmed that reductions in the blood pressure of the patients during cardiovascular surgery affect neuromonitoring findings and predict poor postoperative prognosis. What blood pressure means is not simply the flow of blood flow, but directly linked to oxygen in body tissues. Therefore, lower blood pressure in brain tissue poses a variety of risks. Blood pressure control in most patients undergoing cerebrovascular surgery is degraded and may be further weakened by the administration of anesthetic agents and bleeding during surgery. If the patient's brain is not supplied with enough blood, brain tissue can deteriorate and, in severe cases, ischemic infarction may occur. Hence, abnormal findings occur during intraoperative neuromonitoring may indicate the disruption of the patient's brain perfusion and should prompt efforts to improve the patient's condition following the temporary suspension of the surgery, transfusion of blood, or administration of hypertensive agents. If we study with hemoglobin in the future, we will be able to improve the completeness of this study.

REFERENCES

[1] A. Szelényi, and G. Neuloh, “Surgery and Intraoperative Neurophysiological Monitoring for Aneurysm Clipping,” *Neurophysiology in Neurosurgery*, pp. 283-293, 2020.
DOI: https://doi.org/0.1016/B978-0-12-815000-9.00021-6

[2] J. Donnelly, et al., “Pressure Reactivity-Based Optimal Cerebral Perfusion Pressure in a Traumatic Brain Injury Cohort,” *Intracranial Pressure & Neuromonitoring*, vol. 126, pp. 209-212, 2018.
DOI: https://doi.org/10.1007/978-3-319-65798-1_43

[3] M. Williams, and J. K. Lee, “Intraoperative Blood Pressure and Cerebral Perfusion: Strategies to Clarify Hemodynamic Goals,” *Pediatric Anesthesia*, vol. 24, no. 7, pp. 657-667, 2014.
DOI: https://doi.org/10.1111/pan.12401

[4] B. Xu, et al., “Relationship between Neurological Complications, Cerebrovascular and Cerebral Perfusion Following Off-Pump Coronary Artery Bypass Grafting,” *Neurological Research*, vol. 37, no. 5, pp. 421-426, 2015.
DOI: https://doi.org/10.1179/1743132815y.0000000030

[5] S. K. Park, et. Al., “Intra-Operative Neurological Monitoring and Anesthesia,” *Korean Journal of Clinical Laboratory Science*, vol. 44, no. 4, 184-198, 2012.

[6] I. B. Cho, et al., “The Effect of Obesity on Awareness in General Anesthesia with Propofol,” *Korean Journal of*

Anesthesiology, vol. 50, no. 4, pp. 379-384, 2006.
DOI: https://doi.org/10.4097/kjae.2006.50.4.379

[7] B. Bruins, et al., "The Anesthetic Effects on Vasopressor Modulation of Cerebral Blood Flow in an Immature Swine Model," *Anesthesia and Analgesia*, vol. 116, no. 4, pp. 838, 2013.
DOI: https://doi.org/10.1213/ane.0b013e3182860fe7

[8] J. A. Friedman, et al., "Ischemic Complications of Surgery for Anterior Choroidal Artery Aneurysms," *Journal of neurosurgery*, vol. 94, no. 4, pp. 565-572, 2001.
DOI: https://doi.org/10.3171/jns.2001.94.4.0565

[9] B. Cauli, and E. Hamel, "Brain Perfusion and Astrocytes," *Trends in Neurosciences*, vol. 41, no. 7, pp. 409-413, 2018.
DOI: https://doi.org/10.1016/j.tins.2018.04.010

[10] S. H. Han, "Perioperative Neurologic Monitoring", *Korean Journal of Anesthesiology*, vol. 54, no. 1, pp. 1-11, 2008.
DOI: https://doi.org/10.4097/kjae.2008.54.1.1

[11] J. Yang, et al., "Raising Mean Arterial Pressure Alone Restores 20% of Intraoperative Neuromonitoring Losses," *Spine*, vol. 43, no. 13, pp. 890-894, 2018.
DOI: https://doi.org/10.1542/peds.142.1_MeetingAbstract.331

[12] V. Fraix, et al., "Brachiofacial Pure Motor Stroke," *Cerebrovascular Diseases*, vol. 12, no. 1, pp. 34-38, 2001.
DOI: https://doi.org/10.1159/000047678

[13] J. Yang, et al., "Neuromonitoring Signals and Blood Pressure: When They Go Low, We Go High," *Official Journal of the American Academy of Pediatrics*, vol. 142, no. 1, pp. 331-331, 2018.
DOI: https://doi.org/10.1097/brs.0000000000002461

[14] J. I. Han, and H.S. Lee, "Adequate Combination of Target Effect-site Concentration of Propofol and Remifentanil for Tracheal Intubation," *Korean Journal of Anesthesiology*, vol. 54, no. 1, pp. 37, 2008.
DOI: https://doi.org/10.4097/kjae.2008.54.1.37

[15] S. W. Baik, "Assessment of Depth of Anesthesia," *Korean Journal of Anesthesiology*, vol. 52, no. 3, pp. 253-261, 2007.
DOI: https://doi.org/10.4097/kjae.2007.52.3.253

[16] A. Mateen, and Q. Zhu, S. Afsar. Record keeping system of bugs for software quality assurance, *International journal of advanced smart convergence*, Vol. 8, No. 4, PP. 207-213, 2019.

[17] N. Y. Kim, and S. D. Kim, "Adaptive Recommendation System for Health Screening based on Machine Learning," *International journal of advanced smart convergence*, vol. 9 no. 2, pp. 1-7, 2020
DOI: http://dx.doi.org/10.7236/IJASC.2020.9.2.1

[18] G. M. Kim, "A Case Study on Smart Concentrations Using ICT Convergence Technology," *International journal of advanced smart convergence*, vol. 8 no. 1, pp. 159-165, 2019
DOI: http://dx.doi.org/10.7236/IJASC.2019.8.1.159