ORIGINAL AND CLINICAL ARTICLES

DOI: https://doi.org/10.5114/ait.2024.146710

Perioperative changes of the linguistic functions in women after gynecological laparoscopic operations under propofol or sevoflurane-based anesthesia

Włodzimierz Płotek[1], Artur Bekała[2], Jadwiga Łuczak-Wawrzyniak[3], Katarzyna Dudzińska-Rapczewska[3], Małgorzata Gasińska-Błotniak[1], Marcin Cybulski[4], Agnieszka Kubik-Komar[5], Elżbieta Kubera[5], Maciej Wilczak[3], Wojciech Dąbrowski[6]

[1]Anesthesiology and Intensive Therapy Clinic, University Clinical Hospital No. 4, Lublin, Poland
[2]Anesthesiology and Intensive Care Ward, Heliodor Święcicki Gynecological & Obstetric Clinical Hospital, Poznań, Poland
[3]Heliodor Święcicki Gynecological & Obstetric Clinical Hospital, Poznań, Poland
[4]Department of Clinical Psychology, Poznań University of Medical Sciences, Poznań, Poland
[5]Department of Applied Mathematics and Computer Science, Lublin University of Life Sciences, Lublin, Poland
[6]First Department of Anesthesiology and Intensive Therapy, Medical University of Lublin, Lublin, Poland

Abstract

Background: Perioperative stress and exposure to anesthetics may trigger alterations in cognition. In this study, a group of women underwent neuropsychological evaluation to measure the influence of inhalational and intravenous anesthesia on linguistic performance, in the context of the perioperative inflammatory response and duration.

Methods: Patients undergoing elective gynecological laparoscopic operations were randomly assigned to receive either propofol-based anesthesia (PBA) or sevoflurane-based anesthesia (SBA). The Vocabulary subtest of the Polish version of the Wechsler Adult Intelligence Scale-Revised, Łatysz test [ŁT, subtests: correct words (CW) and all words (AW)], and Word Fluency Test [WFT subtest letters: F, A, S, and categories: animals (An), fruits (Fr), vegetables (Ve)] were applied before and 24 h after anesthesia. Leukocyte count and smear as well as C-reactive protein were analyzed in the same time period. Duration of anesthesia was recorded.

Results: Sixty-one patients were included in the study (PBA: 29, SBA: 32). The comparison of the pre- and postoperative difference in results between the PBA and SBA groups showed a significant difference in one test (WFT-A). A postoperative increase in the results occurred in more scales in the SBA group (ŁT-CW, ŁT-AW, WFT-A, and WFT-Ve) than in the PBA group (ŁT-AW). There were single correlations between the inflammatory markers and the results of linguistic tests. The duration of anesthesia did not influence the results of linguistic tests.

Conclusions: The linguistic performance in the perioperative period was stable, with increases noted in several of the tested domains, predominantly in the SBA group.

Key words: linguistic functions, propofol, sevoflurane.

Anaesthesiol Intensive Ther 2024; 56, 5: 305–315

Received: 19.12.2023, **accepted:** 28.11.2024

CORRESPONDING AUTHOR:
Dr. Małgorzata Gasińska-Błotniak, Anesthesiology and Intensive Therapy Clinic, University Clinical Hospital No. 4, 8 Jaczewskiego St., 20-954 Lublin, Poland, e-mail: gasinskamalgorzata@wp.pl

Cognitive functions are the processing of information received from the environment, storing and transforming it, and outputting it back to the environment in the form of a response – behavior. They include memory, attention, speech, perception, and more complex processes such as abstract thinking, computation, decision making, concept formation, judgment formation, and complex purposeful movements. The study of cognitive functions has prognostic significance. Many factors, including perioperative metabolic and psychological stress, may impair patients' cognitive functions [1].

The notion of general anesthesia encompasses reversible depression of the central nervous system (CNS) allowing physicians to apply surgical procedures to patients. The long-term observation of patients after major surgery under various anesthesia protocols showed that in many cases, the CNS was impaired [2–5].

According to Eurostat data, in many European countries the number of laparoscopic procedures is constantly rising (Eurostat 2022) [6]. They are currently performed in a short 1–2-day hospitalization scheme. Researchers are also conducting intensive investigations to identify the most suitable type of anesthesia for short-term hospitalization.

The focus of this study was an analysis of the verbal knowledge, phonological loop, and word fluency in a group of women who underwent elective laparoscopic gynecological procedures during 2-day hospitalization.

The major study objective was the assessment of the impact of general anesthesia on linguistic functions in patients after gynecological laparoscopic procedures under general anesthesia in the immediate perioperative period in the context of the perioperative inflammatory status and anesthesia duration.

METHODS

The study received the approval of the Bioethics Committee of the Poznań University of Medical Sciences (consent number: 453/20). Written informed consent was obtained from all subjects.

The patients found to be eligible for elective gynecological laparoscopic procedures were divided into 2 groups according to the type of anesthesia administered: propofol-based anesthesia (PBA) and sevoflurane-based anesthesia (SBA). The patients were randomly assigned to the PBA or SBA group during the pre-operative interview by means of the envelope method: the envelope with the type of anesthesia (propofol vs. sevoflurane) was drawn by the researcher after establishing the patient's eligibility for anesthesia. Patients were informed about the type of anesthesia planned for the operation. On the same preoperative day, and within 24 hours after the surgery, the patients were tested by a licensed psychologist, and the blood samples were collected.

Inclusion criteria:

a) female, age > 18 years, eligible for laparoscopic gynecological procedures;
b) American Society of Anesthesiologists (ASA) physical status/risk category I, II, or III;
c) native speakers of Polish;
d) informed consent to participate in the study;
e) at least 8 years of mandatory education;
f) the Beck Depression Inventory-Second Edition (BDI-II) < 14 points

BDI-II is a 21-item, multiple-choice self-report inventory designed to assess the level of depression in adults. Each item is scored 0 to 3 points for a total score range of 0 to 63. A result ≥ 14 points is considered indicative of depression. In such a case, appropriate information and proposed further treatment steps were given to the patient by a psychologist [7].

The following were adopted as the exclusion criteria:

a) non-compliance with the inclusion criteria.

Also, we adopted additional exclusion criteria in the context of their possible influence on cognition. These exclusions criteria were:

b) concomitant severe metabolic conditions, including:
   – decompensated diabetes with glycated hemoglobin level (HbA_{1c}) of ≥ 7%;
   – thyroid conditions with levels of the thyroid hormones and thyroid-stimulating hormone above the normal range;
c) concomitant severe, unstable cardiovascular and pulmonary conditions (e.g.: cardiac shock, pulmonary edema, pneumonia, pulmonary thrombosis);
d) concomitant anemia (hemoglobin and hematocrit levels below the normal range);
e) concomitant severe kidney and liver conditions (diagnosed and specified in medical documentation by internal medicine specialists);
f) a history of severe neurological incidents (status post cerebrovascular incident, a history of central nervous system injury, cerebral tumor or status post cerebral tumor excision, meningitis and/or encephalitis);
g) addictions to:
   – alcohol – conforming to the diagnostic criteria of alcohol use disorders (AUD) (in compliance with DSM-5) [8];
   – narcotics;
   – other psychoactive substances and medication;
h) presence of diagnosed and treated mental conditions (including a history of acquired abnormalities in cognitive functioning: traumatic, post-infectious, also diagnosed dementia of any kind, developmental disorders);
i) illiteracy;
j) presence of unaided auditory or visual impairment;
k) pain intensity on the Numerical Pain Scale (NRS) scale ≥ 4 at rest and > 5 points when coughing in the post-operative period.

Anesthesia protocol

Each of the patients had a pre-operative interview one day before the surgery. The patients were premedicated with oral midazolam (Dormicum, Roche Polska Sp. z o.o., Poland) at a dose of 0.1–0.15 mg kg^{-1}. Anesthesia in both groups was induced intravenously with fentanyl (Fentanyl WZF, WZF Poland) at a dose of 2–3 µg kg^{-1} and with propofol (Propofol 1% MCT/LCT Fresenius, Fresenius Kabi Deutschland GmbH) at a dose of 1.0–2.5 mg kg^{-1}. The patient was intubated orally after muscle relaxation with rocuronium bromide (Roqurum, Jelfa, Poland) at a dose of 0.6 mg kg^{-1}. In the PBA group anesthesia was maintained with further propofol infusion as follows:

an initial intravenous infusion of 10 mg kg^{-1} h^{-1} for 10 minutes, followed by a 10-minute infusion of 8 mg kg^{-1} h^{-1}, and finally an infusion of 4–6 mg kg^{-1} h^{-1}. In the SBA group anesthesia was maintained with sevoflurane (Sevorane, AbbVie Polska Sp. z o.o., Poland) administered at a dose allowing for age-adjusted MAC 0.8–1.0. In both groups additional doses of fentanyl and rocuronium bromide were administered according to the patients' individual needs. During the anesthesia the patients received volume-controlled ventilation, with individually adjusted parameters of tidal volume, breathing rate per minute and positive end-expiratory pressure. The tracheal tube was removed once the residual neuromuscular block had been reversed with neostigmine (Polstigminum, Teva Pharmaceuticals Polska Sp. z o.o., Poland) at 20 µg kg^{-1} *i.v.*, after a prior administration of atropine (Atropinum Sulfuricum WZF, WZF, Poland) at a dose of 0.5–1.0 mg *i.v*. Anesthesia was induced with Maquet Flow-I anesthesia machines (Getinge AB, Sweden).

The patients were monitored for the following parameters: electrical activity of the heart (ECG), non-invasive arterial blood pressure, hemoglobin saturation with oxygen measured by pulse oximetry (SpO_2), capnometry and capnography. Detailed ventilation parameters were measured with the spirometer system of a ventilator and gas sensors. Additionally, standard measurements were taken: body temperature (electronic thermometer), depth of anesthesia (bispectral index), which was strictly kept within the range of 40–60, and muscle relaxation (train of four).

After the surgical procedure the patients were transferred to the recovery room for further monitoring and treatment. Once they had achieved at least 9 points on the 10-point Aldrete scale, they were transferred to the department to which they had initially been admitted.

Analgesia was initiated with a preoperative intravenous administration of 1.0 g of acetaminophen (Paracetamol B. Braun, B. Braun Melsungen AG, Germany), with subsequent intravenous administration of metamizole (Metamizole Kalceks, AS KALCEKS, Latvia) at a dose of 1.0 g. The postoperative wound was infiltrated by the operator with a 0.25% solution of bupivacaine administered at a dose of 30–50 mg (Bupivacainum Hydrochloricum WZF 0.5%, WZF, Poland). Further doses of acetaminophen and metamizole were administered at a minimum of 6-hour intervals. The patients who experienced pain exceeding NRS 4 points received oxycodone (Oxycodone Molteni, L. Molteni & C, Italy) intravenously in fractionated doses of 1–2 mg to alleviate the pain.

Laboratory tests

Venous blood was first sampled on the day before the surgery and then 24 hours after the surgery. The blood count was measured with a Sysmex XN-1000 analyzer, whereas the C-reactive protein (CRP) was measured with a Cobas C 501.

The patients were subjected to neuropsychological tests on the day before the surgery and within 24 hours after the surgery. The tests included:

1. The Vocabulary subtest of the Polish version of the Wechsler Adult Intelligence Scale-Revised (VS-WAIS-R(PL)) on verbal comprehension, language mastery level, learning capacity, and verbal expression. The raw results were used [9].
2. Word Fluency Test (WFT) on letter verbal (phonological) fluency or categorical verbal (semantic) fluency. In the phonological fluency test, the patients were given one minute to provide as many words starting with a given letter as possible (a set of letters: F, A, S). In the categorical test the patients were asked to list as many words as they could within a particular semantic category, e.g., animals, fruits, vegetables. The result was the number of words uttered by the patient within 1 minute in each of the tests. The test assesses many cognitive functions, e.g. attention, semantic memory, working memory, executive functions, abstractive thinking or verbal intelligence [10].
3. Phonological loop assessment – the Łatysz Test. It uses artificially created vocabulary items devoid of any meaning, which ensures the exclusion of any compensation mechanisms resulting from word memory. The test is composed of 71 words with no meaning in Polish, yet meeting the requirements of Polish phonology. The result of this test was measured as the number of correctly decoded pseudo-words (ŁT-CW: Łatysz Test-correct words) and all words read (ŁT-AW: Łatysz Test-all words) within one minute for each subtest. The test assesses decoding without referring to the meaning. It measures 'pure' phonological processing without the participation of other linguistic skills (i.e. lexical, syntactical, or memory or familiar words). The test concerns the written language [11].

The linguistic tests were performed by a licensed psychologist in a quiet room.

Statistical analyses

The following tests were used to assess the homogeneity of the group of patients: the *t*-test to determine whether there were significant differences in the mean age and the body mass index (BMI) between the two sample groups, and the log-likelihood ratio test (G-test) to assess the relationship between the level of education and the variants of anesthesia. This test is recommended for small sample sizes [12].

The *t*-test was also employed to verify whether the duration of anesthesia differed significantly between the sample groups. Differences in rocuronium bromide and fentanyl usage were examined with the Mann-Whitney *U* test because the assumption of a normal distribution was not met.

Spearman's correlations were calculated to assess the relationship between linguistic functions and the duration of anesthesia. The difference between the measurement results was calculated. The relationships between changes in the white blood cells (WBC), its smear, as well as CRP and changes in the linguistic function test values after the surgery were determined in the same way.

The *t*-test for paired samples (for normally distributed differences) as well as the non-parametric Wilcoxon test were used to assess changes in the blood indices and linguistic tests' results over time in both groups separately. The *t*-test and the Mann-Whitney *U* test were applied for differences between the measurements to compare changes between the groups.

Statistica 13 and R 4 (R Core Team) were the software used for statistical analyses [13].

RESULTS

Test groups

29 patients were selected for PBA, and 32 for SBA.

Age and BMI

The patients were aged 19–69 years (mean age 40.57 years), and their BMI was 16.61–36.57 kg m^{-2} (mean BMI 24.08 kg m^{-2}) (Table 1). The *t*-test was applied in the groups as the data distribution was close to normal. The mean age and BMI in the groups were comparable ($P = 0.344$ and 0.380, respectively).

Education

Most of the patients had higher education (41 patients: PBA – 18, SBA – 23). There were 17 patients with secondary education (PBA – 8, SBA – 9) and 3 patients with primary education (PBA – 3, SBA – 0). There were no differences in the levels of education between the groups ($P = 0.096$).

Risk assessment according to the ASA

Most of the patients were classified as ASA 2 (46 patients: PBA – 25, SBA – 21). There were fewer patients classified as ASA 1 (14 patients: PBA – 4, SBA – 10). There was only one woman classified as ASA 3 (SBA). There was no statistically significant difference between the groups (G = 4.2435, $P = 0.1198$).

Anesthesia parameters

The duration of anesthesia was 32–135 minutes (mean duration 79.59 min) (Table 2). The distribution of the duration of anesthesia was close to normal. The *t*-test was applied to analyze the differences between the group means. The duration of PBA was significantly longer than the duration of SBA (85.24 min vs. 68.75 min; $t = 2.136$, $P = 0.0368$). In both groups a similar dose of fentanyl was used (PBA and SBA means: 0.28 mg vs. 0.27 mg, respectively; Mann-Whitney *U* test, $P = 0.502$). By contrast, higher doses of rocuronium bromide were applied

TABLE 1. Patients' age and body mass index

Group	*n*	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
Age (years)								
PBA	29	42.00	43.00	24.00	65.00	34.00	48.00	10.51
SBA	32	39.28	38.50	19.00	69.00	31.50	46.00	11.64
Accumulated	61	40.57	39.00	19.00	69.00	32.00	47.00	11.11
Body mass index (kg m^{-2})								
PBA	29	23.51	21.87	16.61	36.57	19.96	25.33	5.02
SBA	32	24.60	23.43	17.30	36.51	21.79	27.09	4.55
Accumulated	61	24.08	22.77	16.61	36.57	21.05	26.37	4.77

PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia

TABLE 2. Anesthesia parameters in the studied groups

Type of anesthesia	*n*	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
PBA	29	85.24	80.00	35.00	135.00	67.00	115.00	30.80
SBA	32	68.75	65.00	32.00	130.00	41.50	88.50	29.48
All patients	61	79.59	73.00	32.00	135.00	50.00	100.00	30.99

All durations given in minutes. PBA – propofol-based anesthesia; SBA – sevoflurane-based anesthesia in PBA (PBA and SBA means 53.45 mg vs. 41.77, respectively; Mann-Whitney test $P = 0.003$).

Results of linguistic tests

The detailed results achieved by patients in the VS-WAIS-R(PL), ŁT, and WFT are presented in Table 3.

The comparison of differences in the results of linguistic tests before and after the anesthesia between the PBA and SBA groups by using Mann-Whitney *U* test revealed that the result was statistically significant only in one test (WFT-A) ($Z = 2.68$, $P = 0.007$). There were no other differences between the PBA and SBA groups.

TABLE 3. Patients' scores in the linguistic tests

VS- WAIS-R (points) Other tests (number of words)	Mean	Median	Minimum	Maximum	Standard deviation
PBA					
VS-WAIS-R(PL)-1	40.83	41	24	61	10.36
VS-WAIS-R(PL)-2	42.41	42	22	63	11.07
ŁT-CW1	47.28	47	16	71	13.94
ŁT-CW2	49.31	50	21	71	12.25
ŁT-AW1	49.72	51	22	71	12.99
ŁT-AW2	51.45	51	30	71	11.51
WFT-F1	12.28	12	7	24	3.77
WFT-F1	13.07	13	8	19	3.07
WFT-A1	12.52	12	7	20	3.23
WFT-A2	11.90	13	5	20	3.27
WFT-S1	13.31	12	6	20	4.08
WFT-S2	14.35	14	6	21	3.65
WFT-An1	20.93	21	13	29	4.86
WFT-An2	21.55	21	13	31	5.38
WFT-Fr1	16.55	16	10	23	3.51
WFT-Fr2	15.55	16	5	23	3.53
WFT-Ve1	15.24	14	9	20	2.98
WFT-Ve2	15.69	16	10	21	2.95
SBA					
VS-WAIS-R(PL)-1	48.78	50.5	29	66	11.02
VS-WAIS-R(PL)-2	49.63	51.5	19	66	11.48
ŁT-CW1	53.56	54.5	29	71	12.29
ŁT-CW2	55.00	57.5	29	71	11.50
ŁT-AW1	54.75	55	31	71	12.09
ŁT-AW2	56.38	58.5	30	71	11.16
WFT-F1	14.09	13	7	22	4.36
WFT-F2	14.50	15.5	7	23	4.49
WFT-A1	13.19	12	2	26	5.36
WFT-A2	14.53	15	5	26	5.36
WFT-S1	14.78	15	3	22	4.45
WFT-S2	15.50	15	8	23	4.18
WFT-An1	21.28	20	13	34	4.89
WFT-An2	22.56	22	10	35	5.18
WFT-Fr1	17.56	18	11	25	3.28
WFT-Fr2	18.22	18.5	9	24	3.53
WFT-Ve1	16.03	16	3	26	4.40
WFT-Ve2	17.84	17	9	32	4.81

1, 2 – preoperative and postoperative days, An – animal, Fr – fruit, F, A, S – letters, ŁT-AW – Łatysz Test-all words, ŁT-CW – Łatysz Test-correct words, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia, Ve – vegetable, VS-WAIS-R(PL) – Vocabulary subtest of the Polish version of the Wechsler Adult Intelligence Scale-Revised, WFT – Word Fluency Test

TABLE 4. Patients' scores in the linguistic tests before and after anesthesia analyzed using the Wilcoxon test

VS-WAIS-R(PL) (points) Other tests (number of words)	Type of anesthesia	*Z*	*P*
VS-WAIS-R(PL)	PBA	1.45	0.147
	SBA	1.14	0.253
ŁT-CW	PBA	1.78	0.075
	SBA*	2.03	0.043
ŁT-AW	PBA*	1.96	0.050
	SBA*	2.30	0.021
WFT-F	PBA	1.16	0.248
	SBA	0.34	0.734
WFT-A	PBA	1.48	0.140
	SBA*	2.64	0.008
WFT-S	PBA	1.44	0.149
	SBA	1.57	0.117
WFT-An	PBA	1.25	0.212
	SBA	1.41	0.158
WFT-Fr	PBA	1.26	0.206
	SBA	1.33	0.185
WFT-Ve	PBA	0.67	0.501
	SBA*	3.22	0.001

1, 2 – preoperative and postoperative days, An – animal, F, A, S – letters, Fr – fruit, ŁT-AW – Łatysz Test-all words, ŁT-CW – Łatysz Test-correct words, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia, Ve – vegetable, VS-WAIS-R(PL) – Vocabulary subtest of the Polish version of the Wechsler Adult Intelligence Scale-Revised, WFT – Word Fluency Test
*Statistically significant result

The Wilcoxon test (Table 4) showed that a significant postoperative increase in the results occurred more often in the SBA group (increase in results of the: ŁT-CW, ŁT-AW, WFT-A, and WFT-Ve) than in the PBA group (increase in results of the: ŁT-AW). In both types of anesthesia, only the ŁT-AW test presented a significant increase.

Inflammatory response markers

There was a postoperative increase in the WBC and CRP as well as changes in the leukocyte smear (Tables 5–7).

A two-way statistical analysis was conducted to assess perioperative change within the PBA and SBA groups and to compare the results between the PBA and SBA on parallel days.

Trends in inflammatory response markers in PBA and SBA groups on consecutive days

WBC: there was a significant difference between the first and second WBC levels in both the PBA and SBA groups (PBA: $t = -7.06$, $P < 0.001$; SBA: $t = -7.99$, $P < 0.001$).

Leucocyte smear: there was a significant difference between the first and second result in both groups. Changes in the counts of lymphocytes and basophils were significant only in the PBA group (Table 8).

CRP: there was a significant increase in postoperative CRP values in both groups (PBA: $Z = 4.7$, $P < 0.001$; SBA: $Z = 4.94$, $P < 0.001$).

Trends in inflammatory response markers in PBA and SBA groups on parallel days

WBC: the postoperative increase in leukocytes in both groups was not statistically significant ($t = 0.34$, $P = 0.73$).

Leucocyte smear: there was a significantly higher mean perioperative lymphocyte count in the SBA group ($t = -2.36$, $P = 0.022$).

There was no significant difference between the PBA and SBA groups in the mean perioperative changes in the monocyte count ($t = -0.34$, $P = 0.74$).

There was no significant difference between the PBA and SBA groups in the mean perioperative changes in neutrophils ($Z = 1.14$, $P = 0.25$) or eosinophils ($Z = -1.76$, $P = 0.08$).

There was a significant postoperative decrease in basophils in the PBA group ($Z = -3{,}11$, $P = 0019$).

There was no significant differences between the PBA and SBA groups in the CRP level ($Z = 1.83$, $P = 0.068$).

Correlations between results of linguistic tests and inflammatory response markers

There were significant positive correlations between the postoperative increase in the WBC and the difference in the WFT-S (0.38) and between

TABLE 5. Perioperative changes in the leukocyte count (WBC)

Variable	Type of anesthesia	*N*	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
WBC (× 10³/µl)	PBA	29	6.28	6.65	3.84	8.58	5.40	7.43	1.38
WBC (× 10³/µl)	SBA	32	6.54	6.32	3.72	12.33	5.27	7.46	1.76
WBC accumulated (× 10³/µl)		61	6.41	6.34	3.72	12.33	5.28	7.43	1.59
WBC2 (× 10³/µl)	PBA	29	9.16	8.62	5.62	14.87	7.10	10.42	2.56
WBC2 (× 10³/µl)	SBA	32	9.23	8.72	5.73	14.60	7.66	10.93	2.28
WBC2 accumulated (× 10³/µl)		61	9.20	8.62	5.62	14.87	7.51	10.66	2.40

1, 2 – preoperative and postoperative days, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia, WBC – white blood cell count

TABLE 6. Perioperative changes in the leukocyte smear

Variable	Type of anesthesia	*N*	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
Lymph	PBA	29	1.84	1.64	0.79	3.12	1.34	2.49	0.71
Lymph	SBA	32	1.64	1.53	0.93	2.98	1.21	2.01	0.53
Lymph2	PBA	29	1.48	1.35	0.64	2.86	1.05	1.71	0.61
Lymph2	SBA	32	1.63	1.58	0.41	2.80	1.17	2.10	0.56
Mon	PBA	29	0.45	0.45	0.29	0.70	0.39	0.50	0.10
Mon	SBA	32	0.38	0.37	0.18	0.63	0.31	0.47	0.12
Mon2	PBA	29	0.67	0.67	0.32	1.15	0.51	0.77	0.20
Mon2	SBA	32	0.61	0.58	0.10	1.24	0.44	0.73	0.26
Neut	PBA	29	3.81	3.84	1.36	5.97	3.00	4.77	1.14
Neut	SBA	32	4.36	4.40	2.02	10.27	3.24	5.17	1.67
Neut2	PBA	29	6.89	6.77	3.77	12.32	5.10	7.63	2.30
Neut2	SBA	32	6.82	6.41	4.05	11.63	5.31	7.99	2.07
Eos	PBA	29	0.12	0.08	0.01	0.45	0.06	0.16	0.10
Eos	SBA	32	0.08	0.07	0.00	0.26	0.04	0.11	0.05
Eos2	PBA	29	0.05	0.03	0.00	0.41	0.02	0.04	0.08
Eos2	SBA	32	0.06	0.03	0.00	0.30	0.02	0.06	0.07
Bas	PBA	29	0.04	0.04	0.02	0.08	0.04	0.05	0.01
Bas	SBA	32	0.03	0.03	0.01	0.07	0.02	0.04	0.02
Bas2	PBA	29	0.03	0.03	0.02	0.06	0.02	0.04	0.01
Bas2	SBA	32	0.03	0.03	0.01	0.08	0.01	0.04	0.02

1, 2 – preoperative and postoperative days, Bas – basophils, Eos – eosinophils, Lymph – lymphocytes, Mon – monocytes, Neut – neutrophils, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia

TABLE 7. Perioperative changes in C-reactive protein

Variable	Type of anesthesia	*N*	Mean	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation
CRP (mg L^{-1})	PBA	29	2.09	0.97	0.30	10.35	0.63	2.90	2.44
CRP (mg L^{-1})	SBA	32	1.21	0.89	0.12	5.00	0.60	1.60	0.95
CRP accumulated (mg L^{-1})		61	1.63	0.93	0.12	10.35	0.60	1.78	1.86
CRP2 (mg L^{-1})	PBA	29	24.06	20.56	2.64	106.59	14.17	26.37	21.17
CRP2 (mg L^{-1})	SBA	32	16.10	10.94	1.57	54.83	5.30	22.00	13.57
CRP accumulated (mg L^{-1})		61	19.88	19.17	1.57	106.50	8.10	25.45	17.90

1, 2 – preoperative and postoperative days, CRP – C-reactive protein, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia

the postoperative increase in the CRP and the difference in the WFT-Fr (0.47) in the PBA group.

In the SBA group, the postoperative increase in leucocytes was negatively correlated with differences in the results of the ŁT-CW (–0.44), ŁT-AW (–0.37), and WFT-An (–0.41).

There were no significant correlations between the results of linguistic tests and perioperative changes in the CRP ($P > 0.05$).

Correlations between results of linguistic tests and duration of anesthesia

The duration of anesthesia did not influence the results of linguistic tests in either type of anesthesia ($P > 0.05$).

DISCUSSION

General anesthesia can be induced with various sets of medications, allowing anesthesiologists to individually tailor the scheme of the procedure to the patient. Researchers are conducting investigations to determine which anesthetic may be more beneficial to the patient: propofol [14–16] or sevoflurane [17, 18]. In laparoscopic operations, the delayed neurocognitive recovery within 5–7 days after the procedure does not appear to depend on the choice of the anesthetic [19]. So far, it has not been conclusively established which anesthetic is better at the early stage of postoperative assessment.

The choice of women for the study provided a unique opportunity to test a homogeneous group

TABLE 8. Results of the *t*-test and Wilcoxon test of perioperative changes in the leukocyte smear

Test	Type of anesthesia		
***t*-test**		***t***	***P***
Lymph	PBA*	3.49	0.002
	SBA	0.09	0.928
Mon	PBA*	–5.18	< 0.001
	SBA*	–5.81	< 0.001
Wilcoxon test		***Z***	***P***
Neut	PBA*	4.62	< 0.001
	SBA*	4.56	< 0.001
Eos	PBA*	3.85	< 0.001
	SBA*	2.65	0.008
Bas	PBA*	3.94	< 0.001
	SBA	1.49	0.136

1, 2 – preoperative and postoperative days, Bas – basophils, Eos – eosinophils, Lymph – lymphocytes, Mon – monocytes, Neut – neutrophils, PBA – propofol-based anesthesia, SBA – sevoflurane-based anesthesia
*Statistically significant result

of subjects. Although women are generally considered more efficient in verbal skills, they were not rated as superior to men's skills [20].

Therefore, in our study the verbal skills of women undergoing laparoscopic operations were tested. The subjects were given both well-known tests (e.g., the verbal comprehension subtest from the revised version of the WAIS-R(PL), WFT) and less common ones (ŁT – a unique test allowing the researcher to test the efficacy of the patient's pure phonological loop), used in earlier studies [21]. It is noteworthy that despite the great popularity of the international version of the Wechsler Intelligence Scale-Revised (WAIS-R), the most common tests were the Digit Span Subtest and the Digit Symbol Substitution Test, which were used in 39% and 33% of scientific articles, respectively [22]. These tests were combined to cover a broad spectrum of language processing, including semantic and phonological aspects, which is a new comprehensive attitude towards cognitive testing. VS-WAIS-R(PL) checks the similarity, naming words, general knowledge and common concepts of the words using the long-term memory. As such, it can be considered more qualitative. On the other hand, the fluency test is rather quantitative in nature. The creation of language requires not only semantic content extracted from the memory (the effectiveness of which is related to the attention, and influenced by emotions, somatic factors, etc.), but also the ability to produce speech by combining phonemes into words (phonological loop). The phonological loop can be treated as the part of the operative memory which lasts merely longer than the short-term memory. The test checks the information retrieval from the long-term memory. The selection of the used tests allowed us to assess both spheres of language: creation of phonemes and application of the semantic content.

The SBA patients had postoperatively significantly better results in both parts of the ŁT and two categories of the WFT. The PBA patients did better in only one part of the ŁT, with a poor borderline statistical result. It is possible to tentatively conclude that in our study, SBA maintained verbal comprehension while the test learning effect was abolished (VS-WAIS-R(PL)), improved phonological loop (ŁT) and some aspects of word fluency (WFT). The result may be discussed in terms of the retest effect after multiple test performances, which is a well-known phenomenon in cognitive studies. The WAIS-R is affected by this phenomenon even when retesting after 3 or 6 months [23]. The effect is often observed after the third application of the test [24]. The retest after a short time could produce an increment. The test learning effect relates to the semantic part of the declarative long-term memory. We may assume that repetition of the test over the short period of time, as well as strong emotional load associated with the hospital setting in which the test was performed, enhanced the learning effectiveness. This effect was absent from both groups of patients in our study, which suggested diminished learning ability in the direct perioperative period. The retest effect can be interpreted as a learning skill maintained in the perioperative period, which is worth further exploration in the future. A very similar attitude to the problem was presented by Zheng *et al*. [25], who postulated that the attenuated practice effect may indicate the presence of brain pathologies. The patients in our study were exposed to considerable physical and emotional stress resulting from hospitalization and surgery under general anesthesia, which could have influenced their initial performance in the tests. The observation regarding the possible retest improvement is worth further exploration, although in another study specifically focused on detecting and analyzing such a phenomenon to either confirm or deny its existence.

The second part of our study involved the analysis of inflammatory response markers: the WBC level with the leukocyte smear and CRP. As expected, the WBC count increased in both groups. This is a common phenomenon, e.g., after robotic surgery [26], laparoscopic gastric plication [27], and open-heart surgery [28]. It is considered a normal postoperative inflammatory response. In our study, leukocytosis was not a clinical sign of postoperative infection. The results of our study were similar to those obtained by Kim *et al*. [29], who presented the mean values of total leukocytes 24 h after the laparoscopy-assisted vaginal hysterectomy (Kim: 8.74×10^3/µl vs. our results: 9.13×10^3/µl in the PBA group and Kim: 9.00×10^3/µl vs. our results: 9.23×10^3/µl in the SBA group). Similarly, there were no differences resulting from the types of anesthesia applied. It is noteworthy that our groups of patients were more numerous, although there were more robust types of surgery with a shorter mean duration of anesthesia. Unfortunately, due to the scarcity of available data on the physiological postoperative leukocytosis after gynecological laparoscopic operations, our findings could not be related to other medical data on the subject.

The leucocyte smear was altered in almost all cell lines, except lymphocytes and basophils, which remained unchanged during the sevoflurane-based anesthesia. The comparison of our research results with those obtained by Kim *et al*. [29] revealed a similar increasing trend in neutrophils (regardless of the type of anesthesia), but not in lymphocytes, as the postoperative count of lymphocytes in the SBA group was steady, but it decreased after PBA. The trend was confirmed statistically. Haselager *et al*. [30], noted that propofol decreased the count of lymphocytes but maintained a higher count of neutrophils than sevoflurane. However, the researchers did not observe changes in other types of cells. Gu *et al*. [31] presented a thorough molecular basis in their review article on the influence of anesthetics on immunocytes. In the future more attention should be paid to specific white cell lines, as some of them, e.g., eosinophils, seem to be receiving increasing interest due to their fundamental immunoregulatory role [32]. In our study the number of eosinophils was altered and there were also changes in the other cell lines: monocytes and basophils (but only after PBA). Our research results suggest various schemes of inflammatory stimulation after PBA and SBA.

The last aspect of the perioperative inflammatory response was the analysis of CRP levels. There was a large postoperative increase in the CRP level regardless of the type of anesthesia applied. The CRP increase seems to be a common observation, although Gadalla *et al*. [33] noted a more prominent CRP increase after anesthesia with propofol. The difference may have been caused by the study protocol used in their anesthetic technique (pure volatile induction and maintenance anesthesia [VIMA] and total intravenous anesthesia [TIVA] vs. our induction with propofol and continuation of anesthesia with sevoflurane compared with TIVA) or the greater number of participants in our study, which resulted in higher accuracy. It is important to note the role of laparoscopy itself. A study comparing the intensity of inflammation in endometrial cancer patients after various types of surgery showed that the laparoscopic technique resulted in the lowest magnitudes of CRP and IL-6 increase (no information on the type of anesthesia was given) [34].

Despite the numerous cognitive tests and some of the perioperative inflammatory response markers, no clear pattern of interrelations between them was observed. Postoperative inflammation is a well-documented phenomenon, which translates to neuroinflammation (resulting in synaptic dysfunction, neuronal death, and neurogenesis impairment, glycogen synthase kinase-3 dysregulation) with detectable cognitive sequelae (delirium, cognitive dysfunction) [35]. Surprisingly, the postoperative results of the ŁT and WFT were significantly better. It may have been due to the predominant number of young, well-educated patients participating in our study. Age and years of education are strong mediators of postoperative cognitive dysfunction [36]. The improvement rather than deterioration of some linguistic skills seems to show that the residual effect of medications used during the anesthetic procedure was overcome. The preoperative administration of paracetamol, which may reduce hippocampal levels of IL-1, IL-6, and TNF-α, should also be taken into consideration [37]. Although most studies assessing the cognitive-sparing effect relate to ibuprofen [35], the animal study by Kawano *et al*. [38] showed that postoperative analgesia with ketoprofen (used in our postoperative analgesia regimen) could prevent memory deficits due to its pain-relieving effects.

Another optimistic observation in our study was the possible effect of the duration of anesthesia on the results of cognitive tests. Anesthetics have been tested for their neuroprotective and neurotoxic properties, whereas the molecular basis still needs to be fully elucidated. Small doses administered for a short time may act protectively, but long-term administration is considered toxic [39]. Unfortunately, propofol also precipitates widespread apoptosis during neurogenesis in a time-dependent manner [40]. Moreover, studies on animals showed that after the combined application of propofol and sevoflurane apoptosis was more pronounced than after sevoflurane alone [41]. These data may throw some light on the complicated influence of anesthetics on the central nervous system. The patients in the PBA group required higher doses of the muscle relaxant, which is a well-known phenomenon [42]. After sevoflurane the level of muscle relaxation is comparable to that of PBA at 33% lower rocuronium bromide concentration, so its dose can be significantly reduced [43]. According to the current knowledge, rocuronium bromide does not cross the CNS via the blood-brain barrier. However, there have been studies proving the occurrence of rocuronium in the cerebrospinal fluid after administration, so in both anesthetic and intensive therapy settings during long-term muscle relaxation, the cholinergic transmission in the CNS may be inhibited [44].

To sum up, the tests of linguistic skills gave stable results among well-educated women, with more noticeable improvement in the phonological loop performance, and less pronounced changes in WFT after SBA for gynecological laparoscopic operations. The postoperative feeling of relief after the positive outcome of anesthesia and surgery may turn out to be a stronger mediator than expected.

LIMITATIONS OF THE STUDY

From the methodological point of view, it would be worth comparing the achieved results of these improvements with results of a group of women not subjected to anesthesia and surgical procedures, which could create the control group. In the next studies we will add an additional group of study participants. Additionally, more attention should be paid to the detection of the learning effect as the separate aim of the study in the next scientific undertakings. More numerous groups of participants should be tested.

CONCLUSIONS

After the gynecological laparoscopic surgery under general anesthesia, the patients' performance in linguistic tests was stable, with a tendency to postoperative improvement. The performance of the phonological loop and word fluency tests in patients subjected to the sevoflurane-based anesthesia improved significantly. The increased postoperative inflammation did not influence the results of linguistic tests convincingly. Fine changes in the leucocyte smear suggested various schemes of immunological stimulation in the types of anesthesia applied. The duration of anesthesia did not influence the results of linguistic tests.

ACKNOWLEDGEMENTS

1. Assistance with the article: none.
2. Financial support and sponsorship: none.
3. Conflicts of interest: none.
4. Presentation: none.

REFERENCES

1. Varpaei HA, Farhadi K, Mohammadi M, Khafaee Pour Khamseh A, Mokhtari T. Postoperative cognitive dysfunction: a concept analysis. Aging Clin Exp Res 2024; 36: 133. DOI: 10.1007/s40520-024-02779-7.
2. Wei S, Cao YR, Liu DX, Zhang DS. Cerebral infarction after cardiac surgery. Ibrain 2022; 8: 190-198. DOI: 10.1002/ibra.12046.
3. Zhang D, Shen Y, Chen Z, Guo Y, Gao Z, Huang J, Lu X. Emotion recognition dysfunction after anesthesia and cardiac surgery. Front Psychol 2022; 13: 1001493. DOI: 10.3389/fpsyg.2022.1001493.
4. Char D, Ramamoorthy C, Wise-Faberowski L. Cognitive dysfunction in children with heart disease: the role of anesthesia and sedation. Congenit Heart Dis 2016; 11: 221-229. DOI: 10.1111/chd.12352.
5. Moller JT, Cluitmans P, Rasmussen LS, Houx P, Rasmussen H, Canet J, et al. Long-term postoperative cognitive dysfunction in the elderly: ISPOCD 1 study. Lancet 1998; 351: 857-861. DOI: 10.1016/s0140-6736(97)07382-0.
6. Surgical operations and procedures statistics. Eurostat Statistics. Last edited on 25 August 2022. Data extracted in July 2022. Surgical operations and procedures statistics – Statistics Explained. Available at: europa.eu.
7. Beck AT, Steer RA, Brown GK. The Beck Depression Inventory – Second Edition. BDI-II. Polish version Łojek E, Stańczak J. Wydanie drugie. Pracownia Testów Psychologicznych PTP, 2019.
8. Bętkowska-Korpała B, Modrzyński R, Kotowska J, OlszewskaK, Celebucka J. Diagnostic interview on alcohol use disorder – DSM-5 classification in the context of addiction treatment challenges. Psychoterapia 2019; 1: 75-91. DOI: 10.12740/PT/108617.
9. Brzeziński J, Gaul M, Hornowska E, Jaworowska A, Machowski A, Zakrzewska M. Skala Inteligencji Wechslera dla Dorosłych – Wersja Zrewidowana. Pracowania Testów Psychologicznych Polskiego Towarzystwa Psychologicznego, 2011.
10. Piskunowicz M, Bieliński M, Zgliński A, Borkowska A. Verbal fluency tests – application in neuropsychological assessment. Psych Pol 2013; 3: 475-485 [Article in Polish].
11. Bogdanowicz M. Jaworowska A, Krasowicz-Kupis G, Matczak A, Pelc-Pękala O, Pietras I, et al. Diagnoza dysleksji u uczniów klasy III szkołu podstawowej. Przewodnik diagnostyczny. Pracowania Testów Psychologicznych Polskiego Towarzystwa Psychologicznego, 2008.
12. Oliveira NL, Pereira CAB, Diniz MA, Polpo A. A discussion on significance indices for contingency tables under small sample sizes. PLoS One 2018; 13(8): e0199102. DOI: 10.1371/journal.pone.0199102.
13. R Core Team R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. Available at: https://www.R-project.org.
14. Zhang GJ, Shan YX, Zhang SJ, Cao SN, Zhu HJ, Li D, et al. Propofol compared with sevoflurane general anaesthesia is associated with decreased delayed neurocognitive recovery in older adults. Br J Anesth 2018; 121: 595-604. DOI: 10.1016/j.bja.2018.05.059.
15. Kalimeris K, Kouni S, Kostopanagiotou G, Nomikos T, Fragopoulou E, Kakisis J, et al. Cognitive function and oxidative stress after carotid endarterectomy: comparison of propofol to sevoflurane anesthesia. J Cardiothoracic Vasc Anesth 2013; 27: 1246-1252. DOI: 10.1053/j.jvca.2012.12.009.
16. Tang S, Huang W, Zhang K, Chen W, Xie T. Comparison of effects of propofol versus sevoflurane for patients undergoing cardiopulmonary bypass cardiac surgery. Pak J Med Sci 2019; 35: 1072-1075. DOI: 10.12669/pjms.35.4.1279.
17. Schoen J, Husemann L, Tiemeyer C, Lueloh A, Sedemund-Adib B, Berger KU, et al. Cognitive function after sevoflurane- vs propofol-based anaesthesia for on-pump cardiac surgery: a randomized controlled trial. BJA 2011; 106: 840-850. DOI: 10.1093/bja/aer091.
18. Wu G, Xu X, Fu G, Zhang P. General anesthesia maintained with sevoflurane versus propofol in pediatric surgery shorter than 1 hour: a randomized single-blind study. Med Sci Monit 2020; 26: e923681. DOI: 10.12659/MSM.923681.
19. Li Y, Chen D, Wang H, Wang Z, Song F, Li H, et al. Intravenous versus volatile anesthetic effects on postoperative cognition in elderly patients undergoing laparoscopic abdominal surgery: a multicenter, randomized trial. Anesthesiology 2021; 134: 381-394. DOI: 10.1097/ALN.0000000000003680.
20. Weiss EM, Kemmler G, Deisenhammer EA, Fleischhacker W, Delazer M. Sex differences in cognitive functions. Pers Individ Diff 2003; 35: 863-875.
21. Płotek W, Cybulski M, Łockiewicz M, Bogdanowicz M, Kluzik A, Grześkowiak M, Drobnik L. Non-word reading test vs anaesthesia. How do anaesthetised patients decode the contents without referring to the meaning? Anestezjologia Intensywna Terapia 2014; 46: 139-144. DOI: 10.5603/AIT.2014.0026.
22. Borchers F, Spies CD, Feinkohl I, Brockhaus WR, Kraft A, Kozma P, et al. Methodology of measuring postoperative cognitive dysfunction: a systematic review. Br J Anesth 2021; 126: 1119-1127. DOI: 10.1016/j.bja.2021.01.035

23. Estevis E, Basso MR, Combs D. Effects of practice on the Wechsler Adult Intelligence Scale-IV across 3- and 6-month intervals. Clin Neuropsychol 2012; 26: 239-254. DOI: 10.1080/13854046.2012.659219.
24. Scharfen J, Peters JM, Holling H. Retest effects in cognitive ability tests: a metanalysis. Intelligence 2018; 67: 44-66.
25. Zheng B, Udeh-Momoh C, Watermeyer T, de Jager Loots CA, Ford JK, Robb CE, et al. Practice effect of repeated cognitive tests among older adults: associations with brain amyloid pathology and other influencing factors. Front Aging Neurosci 2022; 6: 909614. DOI: 10.3389/fnagi.2022.909614.
26. Goel M, Muntz HG, McGonigle KFM. Leukocytosis after robotic surgery: commonly observed but clinically insignificant. J Minim Invasive Gynecol 2010; 17: S34.
27. Tabatabaie O, Maleki S, Talebpour M. Leukocytosis and neutrophilia after laparoscopic gastric plication. Acta Chir Belg 2017; 117: 99-103. DOI: 10.1080/00015458.2016.1258826.
28. Verkkala K, Valtonen V, Järvinen A, Tolppanen EM. Fever, leucocytosis and C-reactive protein after open-heart surgery and their value in the diagnosis of postoperative infections. Thorac Cardiovasc Surg 1987; 35: 78-82. DOI: 10.1055/s-2007-1020201.
29. Kim WH, Jin HS, Ko JS, Jahm TS, Lee SM, Cho HS, Kim MH. The effect of anesthetic techniques on neutrophil-to-lymphocyte ratio after laparoscopy-assisted vaginal hysterectomy. Acta Anaesth Taiwanica 2011; 49: 83-87. DOI: 10.1016/j.aat.2011.08.004.
30. Hasselager RP, Madsen SS, Möller K, Gögenur I, Asghar MS. Effect of sevoflurane versus propofol on neutropfhil-to-lymphocyte ratio in healthy individuals: a substudy of a randomized crossover trial. BJA Open 2022. DOI: 10.1016/j.bjao.2022.100005.
31. Gu L, Pan X, Wang Ch, Wang L. The benefits of propofol on cancer treatment: Decipher its modulation code to immunocytes. Front Pharmacol 2022; 13: 919636. DOI: 10.3389/fphar.2022.919636.
32. Francis D, Paige L. Eosinophil cytokines, chemokines, and growth factors: emerging roles in immunity. Front Immunol 2014; 5. DOI: https://doi.org/10.3389/fimmu.2014.00570.
33. Gadalla EF, Abdelazem IS, Mosad AA, Mohamed EM. Comparative study between the effect of two anesthetic agents and techniques on the immune system. BJAS 2018; 3: 35-39.
34. Pilka R, Marek R, Adam T, Kudela M, Ondrová D, Neubert D, et al. Systemic inflammatory response after open, laparoscopic and robotic surgery in endometrial cancer patients. Anticancer Res 2016; 36: 2909-2922.
35. Alam A, Hana Z, Jin Z, Suen KC, Ma D. Surgery, neuroinflammation and cognitive impairment. EBioMedicine 2018; 37: 547-556. DOI: 10.1016/j.ebiom.2018.10.021.
36. Char D, Ramamoorthy C, Wise-Faberowski L. Cognitive dysfunction in children with heart disease: the role of anesthesia and sedation. Congenit Heart Dis 2016; 11: 221-229. DOI: https://doi.org/10.1111/chd.12352.
37. Zhao WX, Zhang JH, Cao JB, Wang W, Wang DX, Zhang XY, et al. Acetaminophen attenuates lipopolysaccharide-induced cognitive impairment through antioxidant activity. J Neuroinflammation 2017; 14: 17. DOI: 10.1186/s12974-016-0781-6.
38. Kawano T, Takahashi T, Iwata H, Morikawa A, Imori S, Waki S, et al. Effects of ketoprofen for prevention of postoperative cognitive dysfunction in aged rats. J Anesth 2014; 28: 932-936. DOI: 10.1007/s00540-014-1821-y.
39. Wei H, Inan S. Dual effects of neuroprotection and neurotoxicity by general anesthetics: role of intracellular calcium homeostasis. Prog Neuropsychopharmacol Biol Psychiatry 2013; 47: 156-161. DOI: 10.1016/j.pnpbp.2013.05.009.
40. Xiong M, Zhang L, Li J, Eloy J, Ye JH, Bekker A. Propofol-induced neurotoxicity in the fetal animal brain and developments in modifying these effects-an updated review of propofol fetal exposure in laboratory animal studies. Brain Sci 2016; 6: 11. DOI: 10.3390/brainsci6020011.
41. Tagawa T, Sakuraba S, Kimura K, Mizoguchi A. Sevoflurane in combination with propofol, not thiopental, induces a more robust neuroapoptosis than sevoflurane alone in the neonatal mouse brain. J Anesth 2014; 28: 815-820. DOI: 10.1007/s00540-014-1822-x.
42. Takagi S, Ozaki M, Iwasaki H, Hatano Y, Takeda J. Effects of sevoflurane and propofol on neuromuscular blocking action of Org 9426 (rocuronium bromide) infused continuously in Japanese patients. Masui 2006; 55: 963-970 [Article in Japanese].
43. Rex C, Wagner S, Spies C, Scholz J, Rietbergen H, Heeringa M, et al. Reversal of neuromuscular blockade by sugammadex after continuous infusion of rocuronium in patients randomized to sevoflurane or propofol maintenance anesthesia. Anesthesiology 2009; 111: 30-35. DOI: 10.1097/ALN.0b013e3181a51cb0.
44. Fuchs-Buder T, Strowitzki M, Rentsch K, Schreiber JU, Philipp-Osterman S, Kleinschmidt S. Concentration of rocuronium in cerebrospinal fluid of patients undergoing cerebral aneurysm clipping. Br J Anaesth 2004; 92: 419-421.DOI: 10.1093/bja/aeh062.