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Effects of intraoperative body temperature, blood pressure, cerebral tissue oxygenation, and anesthesia type on postoperative cognitive functions in geriatric arthroplasty surgery for hip fracture

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ABSTRACT

Objectives: This study aimed to explore the effects of cerebral oxygenation, body temperature, hemodynamic changes, and anesthesia type on postoperative cognitive dysfunction (POCD) in geriatric patients undergoing hip fracture surgery.

Patients and methods: One hundred five elderly patients (59 males, 46 females; mean age: 76.7±8.8 years; range, 65 to 95 years) who were scheduled for hip fracture surgery under general or spinal anesthesia between March 2021 and March 2023 were enrolled in the prospective observational study. The cognitive functions were evaluated using the Mini-Mental State Examination (MMSE). Postoperative MMSE values <24 were considered indicative of POCD. Cerebral oxygenation was evaluated before and during the operation using near-infrared spectroscopy (NIRS), and body temperature was measured using a tympanic thermometer, with values <36°C considered hypothermia. The relationship between decreases in blood pressure ≥30% and POCD was investigated. The relationship between decreases in NIRS of 25% and POCD was also investigated.

Results: Postoperative cognitive dysfunction was observed in 29 (27.25%) of the 105 patients. The MMSE value was 24 in 67.06% of 29 patients, and all these patients developed POCD. The incidence of POCD in patients with a preoperative MMSE1 score of 30 was 12.30% (p=0.001). No relationship was identified between MMSE changes and anesthesia type, hypotension, and decreases in the NIRS (p=0.439, p=0.399). Hypothermia was found to be significantly related to POCD (p=0.013). The degree of hypothermia decreased the postoperative MMSE value at different rates. A 1°C body temperature decrease caused a 16.7%, 44.4%, and 50% decrease in MMSE scores of one, one, and two patients, respectively.

Conclusion: Hypothermia was found to be significantly related to POCD. The same degree of hypothermia caused different MMSE changes. Since the number of patients with POCD was very low, the effect of amounts of body temperature changes on clinically significant MMSE changes could not be supported by logistic regression. The preoperative MMSE values, MMSE change rates, and age were found to be effective in POCD. Maintaining the body temperature throughout the operation will ensure the preservation of postoperative cognitive functions.

Keywords: Anesthesia, arthroplasty, cerebral tissue oxygenation hypothermia, hypotension, postoperative cognitive dysfunction.

Hip fractures are associated with high mortality and morbidity, and the global increase in the older adult population is driving an increase in the incidence of the condition. There were an estimated 1.66 million hip fractures worldwide in 1990, and this number is expected to increase to 6.26 million by 2050.[1] Femoral neck and intertrochanteric fractures are the most common hip fractures in geriatric patients, and 30-day mortality was reported in 4.3%, four-month mortality in 11.4%, and one-year mortality in 18.8% of cases following hip fracture surgery.[2] Advanced age has been identified as an important factor associated with mortality following hip fracture surgery, with

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30% of cases being above the age of 85 years. The possible complications associated with hip fracture operations include bone cement implantation syndrome, perioperative bleeding, thromboembolism, and postoperative cognitive dysfunction (POCD) with postoperative delirium or depression.[3]

Advanced age, male sex, multiple comorbid conditions, preexisting cognitive impairment, multiple drug use, anemia, malnutrition, history of alcohol abuse, and impaired sensation have all been found to be effective in the development of POCD in older adults' hip fracture cases.[4]

Previous studies of older adult hip fracture surgery recipients have reported associations between POCD and traditional inflammatory markers, such as C-reactive protein, interleukin-6, and interleukin-8.[5]

Postoperative cognitive dysfunction can manifest as memory and attention loss, reduced visual-spatial intelligence, and declined information processing and psychomotor speeds. The most notable symptoms are memory deficits and a reduced ability to cope with intellectual difficulties.[6] Postoperative cognitive dysfunction rates vary depending on the type of surgery and the procedure risk, with greater risks associated with aortic (up to 29%), major abdominal (up to 50%), cardiac (up to 51%), and orthopedic (up to 54%) surgeries. Orthopedic sources of POCD can be encountered after hip fracture operations. Previous studies have reported that the inflammatory processes associated with surgical trauma, long-term hypotension, and the subsequent complications play a role in cognitive dysfunction.[7] Current guidelines recommend perioperative normothermia, defined as a body temperature below 36°C, as a goal in perioperative patient care to decrease the avoidable complications associated with surgery. Hypothermia may cause a decrease in the partial oxygen pressure of the brain and can accelerate the inflammatory processes.[8]

Near-infrared spectroscopy (NIRS) is used to measure cerebral oxygenation.[9,10] Cerebral oxygen saturation monitoring is a real-time noninvasive approach to the maintenance of cerebral oxygen balance involving the measurement of the relative proportions of arteriovenous blood and capillary blood components in the target area. The weighted average of the arteriovenous blood oxygen saturation in the local brain tissue is then calculated, reflecting any changes in the oxygen supply and oxygen consumption balance in the brain. The approach ensures that early precautions are taken in the event of such developments as long-term hypotension and massive bleeding, which may disrupt the oxygenation/perfusion rate of the brain due to surgery or anesthesia but has yet to be widely adopted in operating rooms and intensive care units around the world. Brain perfusion impairments can lead to the onset of inflammatory processes and a loss of cognitive function. Preserving intraoperative cerebral oxygenation can support the preservation of postoperative cognitive functions.

The present study aimed to investigate the effects of changes in intraoperative body temperature, hemodynamic factors, cerebral tissue oxygenation, and anesthesia type on the development of POCD in geriatric patients undergoing surgery for total or partial hip prosthesis due to femoral head and neck fractures.

PATIENTS AND METHODS

In this prospective observational study, 105 patients (59 males, 46 females; mean age: 76.7±8.8 years; range, 65 to 95 years) with an American Society of Anesthesia (ASA) score of 2 and above who were scheduled for total or partial hip prosthesis for the treatment of femoral head or neck fractures at the Dr. Abdurrahman Yurtaslan Ankara Oncology Training and Reseach Hospital, Department of Anesthesiology and Reanimation were enrolled for the study between March 2021 and March 2023.

Patients who were younger than 65 years, those with a history of cerebrovascular disease, those who were illiterate, those with visual and auditory impairments, those who were unable to complete the cognitive function tests, and those who were in shock due to trauma were excluded from the study. Demographic data of the patients were recorded. Along with the routine preoperative preparations, the patients' preoperative body temperatures were calculated using a tympanic thermometer in the premedication room before the operation.

The basic cognitive functions of the respondents were evaluated using the preoperative Mini-Mental State Examination (MMSE) tool,[11,12] which assesses the respondents based on 30 items under five main headings: orientation (10 points), recording memory (3 points), attention and calculation (5 points), recall (3 points), and language (9 points). Those with a MMSE score ≥24 were considered cognitively normal and were included in the study.[12] The preoperative MMSE application was denoted MMSE1.

The patients underwent electrocardiogram, pulse oximetry, end-tidal carbon dioxide, noninvasive blood pressure assessment, NIRS monitoring, and body temperature monitoring (tympanic) under general anesthesia, and these values, along with hemodynamic data, were recorded every 30 min. After preoxygenation, general anesthesia was induced with midazolam, fentanyl, lidocaine, propofol, and rocuronium. After intubation, anesthesia was maintained with 50% oxygen-air, sevoflurane, and remifentanil.

The respondents who declined regional anesthesia, those with coagulopathy, those with infections in the regional anesthesia application area, those with high intracranial pressure, and those with hypovolemia or severe aortic and mitral stenosis were operated under general anesthesia. All the remaining patients underwent regional anesthesia. Heavy bupivacaine 0.5% was used in doses of 12 to 15 mg for spinal or combined spinal-epidural anesthesia. The same monitoring was applied to patients who underwent regional anesthesia.

All patients were warmed with a heating blanket during the operation, and a tympanic thermometer was used to monitor temperature. Fluid balance and intraoperative blood loss were recorded during the follow-up of all patients. We opted for a restrictive transfusion approach, in line with the Red Blood Cell Transfusion: 2023 AABB International Guidelines, in which a lower hemoglobin concentration is adopted as a threshold for transfusion (most commonly, 7.0 to 8.0 g/dL).[13] In cases requiring blood products, blood warmers were used to balance their temperatures with the body temperature.

Among the patients in the study, most underwent partial hip replacement surgery, while a smaller proportion of the sample, who were physically active, had a long life expectancy, and had no comorbidities, underwent total hip prosthesis. The same surgical procedures were performed by the same surgical team depending on the type of operation, and the operation times of all patients were recorded.

After the operation, all the patients were transferred to a postanesthesia care unit (PACU) and were discharged based on their modified Aldrete score, the most common approach to the assessment of suitability for discharge, based on activity level, respiration, circulation, consciousness, and oxygen saturation. A modified Aldrete score of >9 was required for discharge from PACU.[14] After the patients woke up in the PACU and were able to answer our questions (modified Aldrete score >9), the MMSE tool was reapplied, denoted as MMSE2. Further applications of the MMSE tool at the end of the first postoperative day and on the third day were recorded as MMSE3 and MMSE4, respectively.

The preoperative body temperature value was measured using a tympanic thermometer in the premedication room before surgery and denoted body temperature 1 (BT1). The mean temperature values measured intraoperatively and immediately after the operation were considered BT2, with values <36°C considered hypothermia. The body temperature change rate was calculated with the following formula: [(BT1-BT2)/BT1]. The basal mean arterial blood pressure value was denoted BP1, while BP2 was the mean arterial blood pressure values measured throughout the operation. The rate of change between BP 2 and BP 1 was calculated with the following formula: [(BP1-BP2)/BP1]. Changes >30% were considered significant hypotension.[15]

Cerebral oxygenation was measured throughout the operation from the right and left NIRS palettes affixed noninvasively to the forehead area over the right and left lobes of the brain. For the calculation of cerebral oxygenation with NIRS, the mean S value recorded from both lobes of the brain prior to anesthesia was accepted as the basal value (S1).

Since the position of the patient depends on the operation being performed, being neutral, right lateral decubitus, or left lateral decubitus, the values recorded by both probes were averaged. Near-infrared spectroscopy measurements were averaged throughout the operation and recorded as S2, and the rate of change between the preoperative and intraoperative NIRS values (S1 and S2) was calculated with the following formula: [(S1-S2)/S1]. Values >25% were considered significant change. The normal range was considered to be between 60 and 75%, with a coefficient of variation for absolute baseline values of approximately 10%. A mean NIRS value <50% or a 20% reduction from the individual baseline was considered indicative of the need for intervention.[16]

The rates of change, calculated as the difference between the two variables, was given as a percentage. The MMSE change rate was based on the average of the postoperative MMSE2, MMSE3, and MMSE4 values, compared with the MMSE1 test result. If any of the postoperative MMSE values from the second, third, or fourth tests were lower than MMSE1 (<24), they were recorded as POCD, compatible with the literature.[12] The MMSE change rate was calculated with the following formula: MMSE1-(MMSE2, MMSE3, and MMSE4 average)/MMSE1. The mean MMSE scores were not considered POCD if the MMSE was decreased relative to MMSE1 but not below 24.

To observe the impact of variables affecting POCD, the patients were divided into two groups: those who developed POCD and those who did not. These two groups were examined in terms of the change rates in body temperature, blood pressure, NIRS, types of anesthesia, types of operations, MMSE values, change rates, operation durations, sex, and age.

Statistical analysis

All parameters were analyzed using IBM SPSS version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive analyses were first performed to check for any missing or incorrect data, and the frequencies of the demographic data were interpreted. The normality of the distribution of the variables was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests, with skewness and kurtosis values examined for additional support. The Kolmogorov-Smirnov and Shapiro-Wilk tests revealed that most of the variables were nonnormally distributed ($p<0.05$). A Pearson correlation analysis was used for variables with a normal distribution, and a Spearman correlation test was used for those with a nonnormal distribution. Finally, since no relationship was found in the correlation analyses, the variables change rates in BT1-BT2, BP1-BP2, S1-S2, and MMSE1-MMSE2 were made categorical and chi-square analyses were made. The Mann-Whitney U test and t-tests were applied to compare patients who did or did not develop POCD. Logistic regression analysis was used to additionally explain the relationship between dependent and independent variables. As a result of the logistic regression analysis, the explanation rate of the independent variables for the dependent variable (POCD) was found to be 58.9 to 85%. It was observed that the collected data gave compatible results at a rate of 89.5%. A p-value <0.05 was considered statistically significant.

RESULTS

A summary of the age, sex, ASA score, anesthesia type, and operation duration of the patients is presented in Table I. The mean operation time was 106.9±28.15 min.

The minimum, maximum, mean and standard deviation of the body temperature, blood pressure, NIRS, MMSE1, MMSE2, MMSE3, and MMSE4 values of the patients were evaluated, revealing the lowest preoperative body temperature to be 35°C and the highest body temperature to be 37°C. The lowest intraoperative body temperature was 33°C, and the highest was 36.90°C. Furthermore, the lowest

TABLE I
Descriptive findings regarding demographic information

Demographic information	n	%
Age (year)		
65 years	17	16.2
66-75 years old	31	29.5
76-85 years old	37	35.2
86 years and older	20	19.0
ASA score		
2	14	13.3
3	71	67.6
4	20	19.0
Sex		
Female	46	43.8
Male	59	56.2
Type of anaesthesia		
General	33	31.4
Regional	72	68.6
Operation time (min)		
80 min and under	18	17.1
81-100 min	31	29.5
101-120 min	42	40.0
140 min and upper	14	13.3

ASA: American Society of Anaesthesia.

TABLE II
Descriptive findings regarding variables

Variables	n	Mean±SD	Min-Max
BT1	105	36.140±0.417	35.000-37.000
BT2	105	35.459±0.757	33.000-36.900
BP1	105	99.984±12.719	70.000-146.667
BP2	105	84.810±12.563	57.333-124.667
S1	105	55.500±9.064	25.000-78.500
S2	105	54.476±7.849	31.750-72.250
MMSE1	105	26.126±3.364	24.000-30.000
MMSE2	105	21.886±8.147	1.000-30.000
MMSE3	105	23.276±7.887	5.000-30.000
MMSE4	105	23.581±7.836	5.000-30.000

SD: Standard deviation; BT1: Preoperative body temperature; BT2: Average of intraoperative body temperature; BP1: Preoperative blood pressure; BP2: Average of intraoperative blood pressure; NIRS: Near infrared spectroscopy; S1: preoperative NIRS; S2: Average of intraoperative NIRS; MMSE: Mini mental statement examination; MMSE1: Preoperativ; MMSE2: At the time when the patients were awake in the PACU; MMSE3: First postoperative day; MMSE4: Third day; * p<0.05 statistically significant.

TABLE III
Rates of patients with changes in body temperature, blood pressure, NIRS, and MMSE

	n	%
BT2 <36 celsius	63	81.90
BP1-BP2 change rate >30%	10	9.50
S1-S2 change rate >25%	3	2.86
MMSE1-MMSE2,3,4 change rate	29	27.25

NIRS: Near infrared spectroscopy; MMSE: Mini mental statement examination; BT2: Average of intraoperative body temperature; BP1: Preoperative blood pressure; BP2: Average of intraoperative blood pressure; S1: Preoperative NIRS; S2: Average of intraoperative NIRS; MMSE1: Preoperative; MMSE2: At the time when the patients were awake in the PACU; MMSE3: First postoperative day, MMSE4: Third day.

preoperative MMSE value was 24, and the highest was 30. The lowest postoperative MMSE value was 1.0, and the highest was 30.0 (Table II).

The POCD development rate was 27.25%. In 29 of the 105 patients in the present study, the mean of the MMSE2, MMSE3, and MMSE4 values were lower than MMSE1 and below 24. In only three (2.86%) patients, S2 decreased by 25% compared to the S1 NIRS value. Among the entire sample, 86 (81.90%) developed hypothermia. Hypotension was observed in 10 (9.50%) patients (Table III).

A relationship between the change rate of blood pressure and MMSE scores was not found (p=0.439, Table IV). No relationship was observed between the change rate of NIRS and MMSE scores (p=0.399, Table IV). However, a relationship between the change rates of body temperature and MMSE scores was shown (p=0.013, Table IV), indicating that hypothermia had an effect on POCD. The analysis of how much hypothermia had an impact on MMSE changes is shown in Table V.

Intraoperative hypothermia was noted in 86 of the patients, and an MMSE change rate ≥30% was observed in 12 of these patients. In 10 of these 12 patients, POCD was observed. Hypothermia was noted to be significantly related to POCD (p=0.013, Table IV). The lowest intraoperative body temperature was 33°C, and the mean postoperative MMSE value in this patient was 10±0.

In hypothermic patients who developed POCD, the same degree of hypothermia decreased the postoperative MMSE value at different rates in each patient. A 1°C body temperature decrease caused a 16.7% decrease in MMSE in one patient, a 44.4% decrease in one patient, and a 50% decrease in two patients. A 1.5°C body temperature decrease caused a 7.7% decrease in MMSE in one patient and

TABLE IV
Analysis findings between the change rates of MMSE, and body temperature, blood pressure, and NIRS

	MMSE1-MMSE2-3-4 change rate						
	0.001 and lower		0.001-0.300		0.301 and upper		
	n	%	n	%	n	%	*p*
BT1-BT2 change rate							**0.013***
0.001 and lower	5	8.1	1	4.0	5	27.8	
0.001-0.02	38	61.3	11	44.0	8	44.4	
0.0201-0.03	9	14.5	3	12	4	22.2	
0.0301 and upper	10	16.1	10	40.0	1	5.6	
BP1-BP2 change rate							0.439
0 and lower	9	14.5	4	16.0	3	16.7	
0.1-0.2	36	58.1	9	36.0	8	44.0	
0.21-0.30	14	22.6	8	32.0	6	33.3	
0.31 and upper	3	4.8	4	16.0	1	5.6	
S1-S2 change rate							0.399
0 and lower	24	38.7	8	32.0	5	27.0	
0.01-0.03	18	29.0	7	28.0	2	11.1	
0.031-0.06	6	9.7	4	16.0	5	27.8	
0.061 and upper	14	22.6	6	24.0	6	33.3	

MMSE: Mini mental statement examination; NIRS: Near infrared spectroscopy; MMSE1: Preoperative; MMSE2: At the time when the patients were awake in the PACU: MMSE3: First postoperative day; MMSE4: Third day; BT1: Preoperative body temperature; BT2: Average of intraoperative body temperature; BP1: Preoperative blood pressure; BP2: Average of intraoperative blood pressure; S1: Preoperative NIRS; S2: Average of intraoperative NIRS; * p<0.05 statistically significant.

TABLE V
The relationship between 1-3°C temperature difference and MMSE change rate

			BT difference										Total	
			1.00		1.10		1.20		1.40		1.50			
			n	%	n	%	n	%	n	%	n	%	n	%
MMSE1_ MMSE 2,3,4 change rate	0.039	Count	0		0		1		0		0		1	
		% within MMSE1_MMSE 2,3,4 change rate		0.0		0.0		100.0		0.0		0.0		100.0
	0.067	Count	0		0		0		1		0		1	
		% within MMSE1_MMSE 2,3,4 change rate		0.0		0.0		0.0		100.0		0.0		100,0
	0.077	Count	0		0		0		0		1		1	
		% within MMSE1_MMSE 2,3,4 change rate		0.0		0.0		0.0		0.0		100.0		100.0
	0.083	Count	0		1		0		0		0		1	
		% within MMSE1_MMSE 2,3,4 change rate		0.0		100.0		0.0		0.0		0.0		100.0
	0.167	Count	1		0		0		0		0		1	
		% within MMSE1_MMSE 2,3,4 change rate		100.0		0.0		0.0		0.0		0.0		100.0
	0.333	Count	0		0		0		0		1		1	
		% within MMSE1_MMSE 2,3,4 change rate		0.0		0.0		0.0		0.0		100.0		100.0
	0.444	Count	1		0		0		0		0		1	
		% within MMSE1_MMSE 2,3,4 change rate		100.0		0.0		0.0		0.0		0.0		100.0
	0.500	Count	2		0		0		0		0		2	
		% within MMSE1_MMSE 2,3,4 change rate		100.0		0.0		0.0		0.0		0.0		100.0
Total		Count	4		1		1		1		2		9	
		% within MMSE1_MMSE 2,3,4 change rate		44.4		11.1		11.1		11.1		22.2		100.0

			BT difference		Total	
			3.00			
MMSE1_ MMSE2,3,4 change rate	0.222	Count	1		1	
		% within MMSE1_MMSE 2,3,4 average		100.0		100.0
Total		Count	1		1	
		% within MMSE1_MMSE 2,3,4 average		100.0		100.0

MMSE: Mini mental statement examination; BT1: Preoperative body temperature; BT2: Average of intraoperative body temperature; MMSE1: Preoperative; MMSE2; At the time when the patients were awake in the PACU; MMSE3: First postoperative day; MMSE4: Third day.

a 33.3% decrease in one patient. No patient with Stage 2 hypothermia was encountered. A 3°C body temperature reduction caused a 22.2% decrease in MMSE in one patient (Table V).

In patients who developed POCD, the maximum body temperature change rate was 8.20% (decrease), and the minimum was –0.20% (increase). The mean body temperature change rate was 0.175±0.019. In patients who did not develop POCD, the maximum body temperature change was 7.00%, and the minimum change was –0.06%. The mean body temperature change was 0.193±0.018. In the comparison of the two groups, body temperature change rates were not different in the groups that developed and did not develop POCD (p=0.914, Table VI). Although we found that hypothermia was an effective factor in the change of MMSE in previous analyses (p=0.013), the logistic regression analysis demonstrated that hypothermia did not constitute a risk factor for POCD. Since the rates of change in body temperature were so low and the rate of development of POCD was so low, a larger number of cases of POCD are required to assess the effect of this change in BT on the MMSE.

Although there were 86 hypothermia cases in total, changes in body temperature ≥0.300, which could indicate clinical changes in MMSE, were observed in very few cases (Table IV).

In patients who developed POCD, the maximum blood pressure change rate was 46.3% (decrease), and the minimum was -21.4% (increase). The average change rate was 0.154. In patients who did not develop POCD, the average blood pressure change was 0.140. The blood pressure change rates of patients who developed POCD and those who did not develop POCD were not different from each other (p=0.642, Table VI). The blood pressure change rate was ≥30% in three patients who developed POCD. In one hypotensive patient with a blood pressure change rate of 42.8%, MMSE values decreased by 16.7%. In one hypotensive patient with a blood pressure change rate of 46.3%, MMSE values decreased by 11.1%. In a patient with a blood pressure change rate of 37.1%, MMSE values decreased by 33.3%. Hypotension did not cause a significant decrease in POCD.

When the mean NIRS change rates were compared between the groups that did and did not develop POCD, no difference was observed between the two groups (p=0.208, Table VI). The S1-S2 change rate was 0.030 in the group that developed POCD, and it was 0.01 in the group that did not develop POCD. The mean postoperative MMSE value of the patient with the lowest intraoperative NIRS mean was 20.0±0. Preoperative and intraoperative NIRS values were monitored in parallel.

The number of total or partial hip prosthesis operations in patients who developed POCD was

TABLE VI
Occurrence rates of variables in patients who developed and did not develop POCD

	Patients who developed POCD (n=29)			Patients who did not develop POCD (n=76)			
	Mean±SD	n	%	Mean±SD	n	%	*p*
BT change rate	0.175±0.019			0.193±0.018			0.914
BP change rate	0.154±0.150			0.140±0.123			0.642
S1-S2 change rate	0.030±0.072			0.001±0.001			0.208
General/regional anesthesia		13/16	44.80/55.20		20/56	26.30/73.70	0.208
THP/PHP		6/23			15/61		0.559
MMSE1	26.206±2.177			28.434±2.241			**0.001***
MMSE1-MMSE2,3,4 change rate	0.364±0.220			0.013±0.004			**0.001***
Age	79.480±8.923			75.610±8.844			**0.048***
Operation duration (min)	104.660±27.611			106.780±28.516			0.732
Sex							0.757
Female	12				34		
Male	17				42		

POCD: Postoperative cognitive dysfunction; BT: Average of intraoperative body temperature; BP: Preoperative blood pressure; S1: Preoperative NIRS; S2: Average of intraoperative NIRS; NIRS: Near infrared spectroscopy; THP: Total hip prothesis; PHP: Partial hip prothesis; MMSE: Mini mental statement examination; MMSE1: Preoperativ; MMSE2: At the time when the patients were awake in the PACU; MMSE3: First postoperative day; MMSE4: Third day; * p<0.05 statistically significant.

determined, the difference between operation times and the number of POCD developments was investigated and added to the results. Total hip prosthesis operation was performed on 21 patients, and partial hip prosthesis operation was performed on 84 patients. Perioperative cognitive dysfunction developed in six (3.50%) of 21 patients who underwent total hip prosthesis. Twenty-three (3.65%) of 84 patients who partial hip prosthesis developed POCD. Perioperative cognitive dysfunction incidence rates were found to be similar in both operation types (p=0.559, Table VI). The mean operation time was 113.33±22.20 min in patients with POCD who underwent total hip prosthesis and 105.86±24.15 min in patients who underwent partial hip prosthesis. There was no difference in the mean operation times of both operations and the incidence of POCD (p=0.749, Table VI). No patient received intraoperative blood transfusion.

While the mean duration of the operation was 104.660±27.611 min in patients who developed POCD, it was 106.780±28.516 min in patients who did not develop POCD (p=0.732, Table VI). While the mean age was 79.480±8.923 in patients who developed POCD, it was 75.610±8.844 in patients who did not develop POCD, and the difference was significant (p=0.048, Table VI).

The preoperative mean MMSE of patients who developed POCD was 26.206±2.177, while that of those who did not develop POCD was 28.434±2.241, and the difference was significant (p=0.001, Table VI). The change rate of MMSE was 0.364±0.220 in patients who developed POCD, and 0.013±0.004 in those who did not develop POCD (p=0.001, Table VI).

Additionally, in the logistic regression analysis, only age, MMSE1, and MMSE change rate, among the independent variables, explained the POCD variable (Table VII).

The preoperative MMSE value (MMSE1) was effective in the development of POCD. In 18 (67.06%) of 29 patients who developed POCD, MMSE1 values were 24. Perioperative cognitive dysfunction was observed in 100% of the patients with an MMSE1 value of 24 (p=0.001). In 11 (37.93%) of 29 patients who developed POCD, the MMSE1 value was ≥24. Of a total of 57 patients with a preoperative MMSE value of 30, 50 (87.7%) did not develop POCD, and seven (12.3%) developed POCD (p=0.001).

In patients who develop POCD, although the mean postoperative MMSE of each patient was different. If the preoperative value was low, the postoperative value was also found to be low at the above rates. The strongest correlation was noted between MMSE3 and MMSE4 values (p=0.001).

Blood pressure change, NIRS change, and anesthesia type had no effect on the development of POCD. This may be the reason why hypothermia did not identify POCD in additional logistic regression analysis tests performed to identify the development of POCD. Consistent with other test results, logistic regression tests also showed the relationship between preoperative MMSE values, MMSE change rates, and age with the development of POCD (Table VII).

DISCUSSION

In our study, we did not find any relationship between anesthesia types and POCD. Good preoperative

TABLE VII
Logistic regression analysis of affecting the development of POCD

	B	SE	Wald	df	*p*
Step 1a					
Age	0.125	0.063	3.982	1	0.046
Operation duration	–0.028	0.020	1.948	1	0.163
BT1-BT2 change rate	25.597	25.335	1.021	1	0.312
BP1-BP2 change rate	–3.113	3.881	0.643	1	0.422
S1-S2 change rate	–2.67	4.891	0.003	1	0.956
MMSE1_MMSE2,3,4 change rate	36.348	10.647	11.655	1	**0.001**
MMSE 1 constant	–11.747	5.509	4.547	1	0.033

POCD: Postoperative cognitive dysfunction; B: Beta (the rate at which the independent variable affects the dependent varible); SE: Standard error; df: Degrees of freedom; BT1: Preoperative body temperature; BT2: Average of intraoperative body temperature; BP1: Preoperative blood pressure; BP2: Average of intraoperative blood pressure; S1: Preoperative NIRS; S2: Average of intraoperative NIRS; NIRS: Near infrared spectroscopy; MMSE: Mini mental statement examination; MMSE1: Preoperative; MMSE2: At the time when the patients were awake in the PACU; MMSE3: First postoperative day; MMSE4: Third day; * p<0.05 statistically significant.

cognitive function was noted to have a positive effect on postoperative cognitive function. It was also noted that low preoperative body temperature, blood pressure, and cerebral tissue oxygenation values remained low during the operation. The preoperative optimization of body temperature, blood pressure, and NIRS values may support the stability of these intraoperative values. The careful intraoperative maintenance of the patient's body temperature can contribute to the preservation of postoperative cognitive function. in patients who did and did not develop POCD.[17]

In Ehsani et al.'s[18] study, the incidence of POCD was relatively higher in the patients operated on under general anesthesia compared to those subjected to spinal anesthesia. Although the postoperative observation time was limited to 48 h, the authors noted the return of the patients' cognitive abilities to their preoperative state over time. They concluded that general anesthesia was more strongly associated with early POCD than spinal anesthesia but noted that the results of the study could not be generalized to all patient groups.

Another study compared the effects of hemiarthroplasty and proximal femoral nailing on postoperative cognitive function in elderly adults with hip fractures. Patients with hip fractures who underwent proximal femoral nailing surgery experienced less postoperative cognitive impairment than those who underwent hemiarthroplasty surgery.[19]

Routine cognitive testing is recommended ahead of hip fracture surgery in older adult patients, and the ease of use of the MMSE in this regard has been reported.[20] Mazzola et al.,[20] in their study of 415 older adult patients scheduled for hip replacement surgery, reported a significant relationship between the likelihood of postoperative cognitive changes and preoperative MMSE scores <24. A meta-analysis conducted by Yang et al.[21] involving 5,364 older adult hip fracture surgery patients reported an mean MMSE score of 20.7 and stated that even a mild cognitive impairment increased the risk of postoperative delirium. In the present study, the mean preoperative MMSE value of the patients was 26.126±3.364, and the mean postoperative MMSE value was over 22. It was further noted in the present study that patients with low preoperative MMSE values also had low postoperative MMSE averages. In our study, of a total of 57 patients with a preoperative MMSE value of 30, 50 (87.7%) did not develop POCD, and seven (12.3%) developed POCD. All patients with a preoperative MMSE value of 24 developed POCD.

In a retrospective study conducted in 2020, postoperative delirium following hip surgery was noted in 15.7% of the sample.[22] In our study, this rate was found to be 27.60%. The most common predisposing factors are advanced age, male sex, multiple comorbidities, preexisting cognitive impairment, multiple drug use, anemia, malnutrition, alcohol addiction, impaired vision and hearing, and decreased functional capacity.[23] In the present study, patients with low preoperative MMSE values were found to also have lower postoperative MMSE values, and the postoperative cognitive function of the patients whose cognitive functions were preserved was also good. Furthermore, in our study, the age factor was found to be an effective factor for POCD, consistent with these studies.[21-23] While POCD developed in eight patients between the ages of 65 and 75, POCD was observed in 21 patients over the age of 75, and the average age of patients who developed POCD was found to be significantly higher than those who did not develop POCD.

Xu et al.[24] examined the effect of intraoperative hypothermia on postoperative cognitive functions, as well as the underlying mechanism, in rats. They investigated morphological changes in hippocampal neurons through hematoxylin-eosin staining and hippocampal synaptic plasticity-related protein expression and identified a correlation between intraoperative hypothermia and POCD. They found POCD to be associated with impairments in spatial working memory, spatial learning, and memory and suggested that POCD caused by intraoperative hypothermia may be attributable to hippocampal neuron damage and decreased expression of synaptic transmission-related proteins Arc, p-CREB (S133), and p-AMPAR1 (S831).

In an earlier study, patients were divided into two groups based on the temperature of the water to which they were exposed: neutral (35±1°C) and cold (13±1°C).[25] The metabolic rates, Stroop color-word test results, and Profile of Mood States (POMS) were also measured at predetermined intervals. They reported that selective attention, measured by the Stroop color-word test, was impaired following immersion in cold water. Similarly, in the present study, a deterioration in postoperative cognitive functions was noted in the patients who developed hypothermia. In our study, different degrees of hypothermia caused different degrees of MMSE changes. A 1°C body temperature decrease caused a 16.7% decrease in MMSE in one patient, a 44.4% decrease in one patient, and a 50% decrease in two patients.

Frisch et al.[26] reported that hypothermia occurred more frequently during general anesthesia in hip and knee replacement operations, with female patients and those undergoing total hip arthroplasty being at greater risk, but reported no correlation between hypothermia and postoperative complications. In the present study, hypothermia was observed in 81.9% of the patients, and decreases in body temperatures compared to preoperative values led to a significant decrease in postoperative cognitive functions. In our study, no difference regarding the sex of the patients was observed in those who did or did not develop POCD.

Recent studies reported a correlation between NIRS values and various degrees of cognitive impairment.[9,10,27] The machine learning algorithm was shown to be stable across different patient groups and improved generalization and reproducibility.[27] As a new NIRS application, the machine learning algorithm has been used in the diagnosis of different cognitive dysfunctions to date.[27]

Nakamuro et al.[28] investigated a total of 63 patients aged 60 to 80 years who were determined to have nondementia controls or mild cognitive impairment without high-level brain function. They compared the patients in terms of cognitive functions and reported a positive correlation between the functional NIRS index and mild cognitive impairment rates, demonstrating the effectiveness of functional NIRS measurement. In the present study, postoperative NIRS values decreased by more than 25% from the baseline preoperative value in only three patients, and since this number was very low, no significant correlation with POCD was suggested. The continuous intraoperative monitoring of cerebral tissue oxygenation and the timely precautions applied may have contributed to the low change in NIRS and the lack of any change in cognitive function.

Luo et al.[29] reported the development of inflammation and cognitive dysfunction in the hippocampus of mice with sevoflurane-induced hypotension. A systematic review failed to identify any clear association between intraoperative hypotension and the development of POCD.[30] In the present study, a MMSE change was observed in three hypotensive patients. In one hypotensive patient with a blood pressure change rate of 42.8%, MMSE values decreased by 16.7%. In one hypotensive patient with a blood pressure change rate of 46.3%, MMSE values decreased by 11.1%. In a patient with a blood pressure change rate of 37.1%, MMSE values decreased by 33.3%. Hypotension did not cause a significant decrease in POCD.

The limiting factors in this study were the examination of cognitive functions until the third postoperative day. Long-term cognitive dysfunction lasting up to a month may also be observed. However, this study is a guide to protect against early cognitive disorders. Consistent with the literature, total and partial hip fractures were included in the present study. In the analyses, no difference was found between the two types of operations in terms of operation time, blood transfusion requirement, and probability of POCD development. Since it was a clinical study, we found that the effects of independent variables on the dependent variable may be different in each patient. Further studies in this field with a larger number of cases will enable statistical methods to support each other and increase their power.

In conclusion, in this study of geriatric hip fracture cases, hypothermia was noted to cause POCD. The same degree of hypothermia caused different MMSE changes in each patient. Since the number of patients with POCD was very low, the effect of amounts of body temperature changes on clinically significant MMSE change could not be supported by logistic regression. The preoperative MMSE values, MMSE change rates, and age were found to be effective on POCD. No relationship between blood pressure, anesthesia type, NIRS values, and POCD was identified in the present study. Good preoperative cognitive function was noted to have a positive effect on postoperative cognitive function. It was further noted that low preoperative body temperature, blood pressure, and cerebral tissue oxygenation values remained low intraoperatively, and the preoperative optimization of body temperature, blood pressure, and NIRS values may support the stability of these intraoperative values. The careful intraoperative maintenance of the patient's body temperature can contribute to the preservation of postoperative cognitive function.

Ethics Committee Approval: The study protocol was approved by the University of Health Sciences Dr. Abdurrahman Yurtaslan Oncology Health Practice and Research Center Clinical Research Clinical Research Ethics Committee (date: 10.03.2021, no: 2021-03/1063). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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