

The Effects of the Near-Infrared Spectroscopy on Postoperative Neurocognitive Functions

Abdullah Yalçın¹, Tülin Gümüş², Ayça Tuba Dumanlı Özcan^{2*} and Serdar Süleyman Can³

¹Department of Anesthesiology and Reanimation, Hacettepe University, Turkey

²Department of Anesthesiology and Reanimation, Ankara City Hospital, Ankara, Turkey

³Department of Psychiatry, University of Yıldırım Beyazıt faculty of Medicine, Turkey.

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ABSTRACT

Background: This study designed to examine the effects of NIRS, near-infrared spectroscopy on the prevention of early neurocognitive dysfunctions in geriatric patients who undertook the total hip replacement (THR) and femur fracture surgery.

Methods: Sixty patients scheduled for hip surgery, were elaborate in this study. Each patient completed a neurocognitive test, with the Montreal Cognitive Assessment Scale (MoCA) and the Mini-Mental Test (MMSE). After routine monitoring, the placement of BIS and rSO₂ monitoring was performed following the invasive arterial pressure. The patients were allocated in to the two groups, as Group2 (rSO₂ monitoring, n=30) and Group 1 (n=30). The cerebral rSO₂ values, in Group2 were recorded preoperatively. For the management of anesthesia, the aim was to keep cerebral rSO₂ above 75% of the basal value. All neurocognitive tests, which were completed preoperatively by all the patients, were re-administered on postoperative day 1.

Results: Postoperative 24th h MoCA scores in patients without rSO₂ monitoring were worse than the preoperative scores (p<0.001). 24th h MoCA scores in Group2 was meaningfully higher than the group1 scores (p<0.001). In Group 1, the postoperative MMSE value was meaningfully lower than the first MMSE score (p<0.001). In Group 2 MMSE and MoCA scores are similar at the time points.

Conclusions: The cerebral oxygen saturation monitoring and follow-up in geriatric patients who have undergone hip surgery under general anesthesia can decrease the risk of developing postoperative cognitive function impairments.

Keywords: Montreal cognitive assessment scale, Mini-Mental test, Near-infrared spectroscopy, Postoperative neurocognitive disfunction

Abbreviation: MoCA: Montreal Cognitive Assessment Scale; MMSE: Mini-Mental Test; NIRS: Near-Infrared Spectroscopy; rSO₂: Regional Cerebral Oxygen Saturation; SNOSE: Sequentially Numbered Opaque Sealed Envelope; ASA: American Society of Anesthesiologists; MAP: Mean Arterial Pressure

INTRODUCTION

The hip surgery in elderly patients is enhanced the morbidity and mortality rates due to both attributes of the surgery and demographic and clinical features of the patients [1]. Post-operative cognitive disfunction is one of the complications developed in especially elderly patients following major surgical operations [2]. In post-operative period, cognitive disfunction is frequently observed in elderly patients who has undergone hip surgery [3]. Increasing population of elderly patients transformed post-operative cognitive disfunction into one of the most essential difficulty of peri-operative period in recent years [4]. It is demonstrated that

cerebral oxygen desaturation episodes are related with postoperative cognitive disfunction (POCD), and episodes

Corresponding author: Ayça Tuba Dumanlı Özcan, Department of Anesthesiology and Reanimation, Ankara City Hospital, Ankara, Turkey, Tel: +905057154125; E-mail: draycaozcan@gmail.com

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measured and corrected decreases neurocognitive dysfunction incidences [5]. It is reported that preoperative and postoperative cognitive dysfunction are observed in elderly patients who suffer from hip fracture and it is correlated with low cerebral oximetry values [6]. Cerebral oximeter (SO) is a non-invasive optical technique on the basis of NIRS (Near-Infrared Spectroscopy) which monitors the balance between oxygen delivery and regional cerebral oxygen saturation (rSO₂) non-invasive technique. NIRS measures the ratio of oxyhemoglobin ratio in the area under the sensor. This ratio is described as percent of rSO₂. Nominal values in healthy people are between 58-82 % [7]. Mini mental test is the most indicative test reflecting the changes in cognitive function between preoperative period and postoperative period [8]. In the scale, the highest attainable score is 30. The threshold value for elder Turkish patients is 23/24 [9]. MoCA is advised to be used in especially weak period of cognitive disorder spectrum. The highest attainable score is 30. The threshold value for elder Turkish patients is 21 [10]. In the study we aimed to observe if it is useful to employ routine application of NIRS (Near infrared spectroscopy) monitorization to prevent early neurocognitive dysfunction in geriatric patients who is undergone hip surgery.

MATERIAL METHOD

This randomized, prospective study was started after receiving ethical approval. patients aged between 60-90 years, who were programmed for total hip replacement and femur fracture surgery under general anesthesia, had an ASA (American Society of Anesthesiologists) risk classification of I-III, were at least literate and offered written informed consent under the elective conditions. The patients were separated 2 groups with opaque sealed envelope technique (SNOSE) [Group 2 (rSO₂ n=30), Group 1 (Control n=30)]. The same physician administered the Mini-Mental Test, functional Montreal Cognitive Assessment Scale (MoCA) to the patients before the anesthesia and the Mini-Mental Test and MOCA test were repeated at the postoperative 24th hour. All the patients were followed using standard anesthesia monitoring, radial artery invasive monitoring, BIS (Datex-Ohmeda S5, Finland) and cerebral oxygen saturation monitoring (INVOS 5100). For the patients in Group 1 (Control Group), the cerebral oximeter monitor was turned to the reverse direction from the sight of the investigator. Cerebral oximetry monitor was followed-up in Group 2 (Study Group), and NIRS (INVOS 5100) and rSO₂ values were documented in the groups. The depth of anesthesia was checked using BIS Monitoring (BIS VISTA COVIDIEN REF 185-0151) that were maintained between 40 and 60. Vital parameters were recorded during the surgery. Induction was initiated after the patients were provided with 100% oxygen support for three minutes through a mask. Management of the anesthesia was completed by 1 mg/kg lidocaine (Armita 2%, Osel), 0.5-1 mcg/kg remifentanyl (Ultiva 5 mg, GlaxoSmithKline) and 5

mg/kg thiopental (Pental Sodium, İ.E. Ulagay) and 0.6 mg/kg rocuronium. If there was an adequate muscle relaxation, the intubation was finished, and patients were ventilated using a Dräger (Lübeck, Germany) anesthesia device to save the tidal volume at 6-8 ml/ kg and frequency at 12/ min. To maintain anesthesia, we used 2% sevoflurane (Sevorane, Abbott Lab, UK) and an infusion of 0.25 µg/kg/min of remifentanyl along with 40% O₂ and 60% air. The doses of remifentanyl infusion were continued in both groups to save the MAP above 65 mmHg. Heart rate was maintained at a maximum of 30% change from baseline. Hypotension is defined as a 30% decrease in MAP compared to basal blood pressure, a systolic blood pressure less than 90 mmHg, or a MAP less than 55 mmHg, and hypotension is defined as intravenous fluids or vasoconstrictor Corrected by administration of ephedrine. Arterial blood pressure values were measured and recorded preoperatively, at 60 minutes intraoperatively, and postoperatively. The algorithm described below was followed in the study group when rSPO₂ dropped below 75% of the baseline value or stabilized for more than 15 sec below 50°C. The ventilator, anesthesia circuit and position of the patient's head were checked.

1. An attempt was complete to increase blood oxygenation by increasing F_I O₂.
2. Attempts were made to maintain ETCO₂ at regular intervals. When ETCO₂ dropped below 35, ventilation was reduced to increase the partial pressure of ETCO₂.
3. If mean arterial pressure fell below 20% of baseline, an attempt was made to return arterial pressure to baseline. When brain rSO₂ levels were persistently low, intravenous fluids and administration of a vasoconstrictor (ephedrine) increased mean arterial pressure to 20% above baseline.
4. Erythrocyte transfusion was given when HTC dropped below 27%.
5. In cases where the acceptable cerebral rSO₂ values were not achieved despite all measures, 0.5 mg/kg propofol i.e. bolus was given to decrease brain metabolism. Ten minutes before the end of the procedure, anesthetic gas was stopped, and 100% oxygen was started. All patients received tramadol 1 mg/kg intravenously 30 minutes before completion of surgery. The duration of surgery, anesthesia and hospital stay was recorded. The patients were assessed using the Modified Aldrete's Scoring System and transferred from the recovery room to inpatient wards when their Aldrete scores were 9 points.

Statistical Analysis

Study data were uploaded to a computer and evaluated using "SPSS (Statistical Package for Social Sciences) for Windows 22.0 (SPSS Inc, Chicago, IL)." Descriptive statistics were expressed as mean ± standard deviation,

frequency distribution, and percentage. Categorical variables were assessed using Pearson's chi-square test. The suitability of the variables to a normal distribution was examined using visual methods (histograms and probability plots) and analytical methods (Kolmogorov-Smirnov test). For variables found not to follow a normal distribution, the Wilcoxon signed rank test was used as a statistical method to check statistical significance between two dependent groups. When a significant difference was detected between the independent groups, Bonferroni correction was applied to find the source of the difference. For variables following a

normal distribution, a paired samples t-test between two dependent groups was used. Two-way Repeated Measures Analysis of Variance was used to always examine the changes of variables between groups. The statistical significance level was accepted as $p < 0.05$.

RESULTS

Of the 60 patients included in this study, 29 (48.3%) were male and 31 (51.6%) were female. The mean age, ASA risk score, gender distribution, and mean BMI are similar in the groups. ($p > 0.05$) (**Table 1**).

Table 1. Demographic and Clinical Characteristics.

Variables	Group 1 (n=30)	Group2 (n=30)	p value
Age (years)	69.3±6.4	67.8±7.8	0.163
Gender			
Men	12 (40%)	17 (56.7%)	0.196
Women	18 (60%)	13 (43.3%)	
BMI	27.2±3.6	27.3±3.5	0.923
ASA (I/II/III)	12/18/0	11/18/1	0.593

The incidence of ES infusion or duration of anesthesia and surgery was similar in both groups ($p > 0.05$) (**Table 2**).

Table 2. Duration of Anesthesia and Surgery in Study Groups (mean± SD).

	Group 1 (n=30)	Group 2 (n=30)	p value
Duration of Anesthesia (min)	135.50±24.99	135.83±52.16	0.169
Duration of Surgery (min)	102.83±25.58	103.00±50.28	0.224
ES replacement	11 (36.7%)	9 (30%)	0.584

Compared to the first values, the SPO2 values significantly increased in both groups. In Group 2, the basal rSPO2 levels for both the right and the left hemispheres were found to be elevated at the 1st minute following intubation. No decrease was noted at later time points compared to the first values. Postoperatively, Hb, HTC, and albumin values were not similar between the two groups ($p > 0.05$). A comparison of the mean arterial pressure levels between the study groups did not indicate any significant difference ($p > 0.05$). ET/CO2 values were similar in both groups ($p > 0.05$). In both groups, BIS values were significantly lower at all time points compared to the first value.

Baseline cerebral rSO2 values for both hemispheres were measured as 63.13 ± 7.90 and 63.33 ± 8.83 , respectively.

There were no significant differences between the two hemispheres in baseline measurements or measurements recorded at subsequent time points ($p > 0.05$). There was no correlation as for the patient's age, ASA score and preoperative albumin levels with the cerebral rSO2 measurements of the left or right hemispheres.

Brain rSO2 values recorded 1 min after intubation were significantly higher compared to baseline values in both left and right hemispheres ($p < 0.001$). For both hemispheres, there were no significant differences in rSPO2 compared to the baseline, except for the measurement obtained one minute after intubation ($p > 0.05$) (**Table 3**).

Table 3. Group 2 Regional Cerebral Oxygen Saturation (rSO₂) Values (mean±SD).

Monitoring Time Points	Group 2; Right rSPO ₂ (n=30)	Group 2; Left rSPO ₂ (n=30)	pL	pR	p
T ₀	63.13±7.90	63.33± 8.83	-	-	0.954
T ₁	71.13±8.02	69.73±8.22	<0.001	<0.001	0.360
T ₂	63.87±9.50	64.97±9.83	>0.05	>0.05	0.308
T ₃	61.47±9.71	64.00±8.50	>0.05	>0.05	0.177
T ₄	61.87±9.92	64.67±7.95	>0.05	>0.05	0.057
T ₅	60.57±9.13	62.03±8.36	>0.05	>0.05	0.273
T ₆	60.50±9.13	62.17±8.98	>0.05	>0.05	0.167
T ₇	64.53±8.02	65.67±7.82	>0.05	>0.05	0.808
T ₈	66.43±7.15	67.50±7.56	>0.05	>0.05	0.656

T₀: Baseline; T₁: 1 min after intubation; T₂: 10th min of operation; T₃: 20th min of operation; T₄: 30th min of operation; T₅: 60th min of operation; T₆: 90th min of operation; T₇: before extubation; T₈: 1 min before extubation; pL: In-group comparison with baseline value of the left hemisphere; pR: In-group comparison with baseline value of the right hemisphere; p: Comparison of rSO₂ values between the left and right hemispheres

Preoperative MoCA scores were similar between the study groups (p>0.05) (Table 4). Postoperative 24 h MoCA values in group 1 were lower than preoperative values (p<0.001). 24th h MoCA scores in Group2 was significantly higher than

the group1 scores (p<0.001) (Table 4). According to the MoCA scores in the control group POCD 63% and in monitored with NIRS group it was 40%.

Table 4. MoCA and MMSE test results in the groups (mean ± SD).

Test	Time	Group 2	p1	Group 1	p1
MoCA	Preoperative	21.46 ± 4.35	-0.410	20.40 ± 3.40	-0.001
	Postoperative Day 1	21.83 ± 4.19		19.43 ± 3.76	
MMSE	Preoperative	23.06 ± 3.34	< 0.001	23.73 ± 3.92	-0.139
	Postoperative Day 1	22.03 ± 3.25		24.13 ± 3.85	

p1: When compared to in-group preoperative MMT values.

Preoperative MMSE scores did not change significantly between the two groups (p>0.05). In Group 1, the postoperative MMSE value was significantly lower than the preoperative MMSE (p<0.001). Preoperative and postoperative MMSE values were similar in Group 2 (p=0.139). In group 1 as a control group, POCD was determined 60% and in group 2 it was 30%.

DISCUSSION

NIRS monetarized patients' preoperative and postoperative MMSE scores were not change after the surgery and MoCA scores in 5 patients were increased at postoperative 24th

hour. On the other hand, the MMSE score of the control group was statistically significantly lower than the preoperative score. In group 1 POCD was seen %60-63, in group 2 %40-30. In this study, it was confirmed that cerebral oxygen saturation monitoring in geriatric patients had positive effects on neurocognitive test results in the early postoperative term. It must be emphasized that while there is agreement on which neuropsychological tests should be used to assess postoperative cognitive impairment, the validity and specificity of the tests already available are unknown [2]. In this study, we used MoCA and MMSE tests to detect early postoperative neurocognitive dysfunction. In a report

by Gungen [9] a study conducted found that the threshold for analysis of mild dementia in Turkish elderly patients was 23/24. In the literature there are studies that MoCA and MMSE used. A clinical trial that found the frequency of POCD was higher in sevoflurane group than propofol anesthesia. They observed the patients according to the MMSE and MoCA grades [11]. A study aimed to observe whether combined general and local anesthesia affects perioperative cognitive function compared to general anesthesia alone in elderly patients undergoing arthroplasty [12]. The combined anesthesia allowed the postoperative higher MMSE results. In another study showed that the dexmedetomidine has positive effect on the POCD and improved the MMSE score on the postoperative 24 h [13]. POCD is common neurologic problem occurring in geriatric patients [14]. In the literature that was showed that POD was not related with decreased survival. Endurance was a function of age, surgical duration, ASA score, and ICU length of stay [15]. In this study there weren't any differences between groups in demographic data. We didn't determine any correlation with cerebral rSO₂ and demographic data. There are some strategies that improve the early recognition. The perioperative risk factors can be controlled to treat POCD [16]. When was the cerebral oxygenation added to the routine monitoring that could protect the patients from the POCD? [17]. The NIRS signal has correlation with measures of brain perfusion [18], brain tissue oxygen tension [19] and CT perfusion [20], and in critical care this correlation was demonstrated [21]. NIRS provides continuous measurements of cerebral oxygen by measuring the relationship among the blood hemoglobin concentrations and neural activity [22]. In this study the correlation with hemoglobin and cerebral rSO₂ was laid out. Yutaka Morimoto [23] showed that patient age and low preoperative brain rSO₂ levels are risk factors for the development of postoperative delirium. Papadopoulos [5], the preoperative and postoperative cognitive dysfunction observed in geriatric patients with femur fracture were originated to be correlated with low cerebral oximetry values. The mean MMSE score of that patient population, which was 26.23±2.77 preoperatively, decreased to 25.94±2.52 after the operation and patients with an MMSE grade lower than 23 were considered to have cerebral dysfunction. In another study performed by Slater [24], cerebral desaturation during cardiac surgeries reduced postoperative cognitive functions and elongated the lengths of hospital stay [24]. However, NIRS management is limited in global brain ischemia damage and may omit micro-embolisms or hypoperfusion at sites distant to the frontal region. In their study, Reents [25] did not locate any connection between cerebral desaturation and neurological impairment [25]. The review included 1822 adult evaluating cerebral NIRS monitoring, no significant differences were defined between the groups for mortality postoperative stroke, postoperative delirium and cognitive dysfunction [26]. If there isn't a chance to monitor the cerebral

oxygenation, by the achieving hemodynamic stability may not be enough to reduction postoperative cognitive function impairments. The aim of keeping cerebral rSO₂ level higher than 75% of baseline in patients who were followed via cerebral oxygen monitoring gave us the opportunity to perform interventions to increase cerebral oxygenation. In this study, a lower incidence of postoperative neurocognitive dysfunction was observed in the cerebral oximetry group, highlighting the importance of perioperative brain monitoring.

CONCLUSION

In conclusion, monitoring, and follow-up level of the cerebral oxygen, in geriatric patients who are taken into hip surgeries under general anesthesia are beneficial by reducing the potential for development of postoperative cognitive function impairments.

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