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The Role of Cerebral Oximetry in Predicting and Preventing Postoperative Cognitive Dysfunction

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Abstract: Postoperative Cognitive Dysfunction (POCD) is a serious problem that is frequently seen in elderly patients and can cause permanent cognitive decline, prolonged hospital stay, loss of independence, decreased quality of life and even mortality. Identifying individuals at risk of developing POCD can prevent this condition by enabling the development of early interventions. Cerebral perfusion disorder is considered to be one of POCD's mechanisms. There are studies on the predictability and preventability of cognitive disorders that may develop after surgery with the use of cerebral oxygenation monitoring. However, the effect of intraoperative cerebral oximetry use on POCD, especially in elderly patients, is controversial. This may be due to multifactoriality in the POCD mechanism. In this article, we aimed to present the study results and inferences regarding the relationships between the areas of monitoring cerebral oxygenation and the pathogenesis of POCD. © 2024 NTMS.

Keywords: Postoperative Neurocognitive Disoders; Spectroscopy; Near-infrared; Regional Cerebral Oxygen Saturation (rScO2); NIRS-based Clinical Algorithm.

1. Introduction

Monitoring Cerebral Oxygenation

Efforts have been devoted to monitoring tissue oxygenation for more than a century. The ear oximeter was developed in the 1940s and the pulse oximeter in the 1970s. Near Infrared Spectroscopy (NIRS) was first introduced by Franz Jöbsis in 1977. Near-infrared Spectroscopy (NIRS) is a noninvasive and relatively low-cost device that measures tissue oxygen saturation and changes in hemoglobin volüme [1]. NIRS uses near infrared (NIR) light lengths of 700-1000 nm, similar to pulse oximetry [2]. NIR rays are not absorbed by water or protein, but penetrate into deeper tissues and are absorbed by substances called chromophores. Chromophores are molecules such as oxyhemoglobin (O_2Hb), deoxyhemoglobin (HHb), myoglobin, bilirubin, cytochrome oxidase, urobilin, and they can absorb light of 200-800 nm wavelength. NIRS measures the light absorbed by chromophores [3]. The value of NIRS is expressed as 'Regional Oxygen Saturation ($rScO_2$)' and NIRS provides continuous, noninvasive monitoring of rScO2 [2,3].

NIRS electrodes are placed in the frontotemporal region. While pulse oximetry is dependent on pulsatile blood flow (plethysmographic) and measures only the

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oxyhemoglobin of arterial blood, NIRS measures the difference between O2Hb and HHb which reflects oxygen uptake in the tissue bed and is not flow dependent[2]. Therefore, it can be used during cardiopulmonary bypass [4].

The value of NIRS estimates the average of arterial, venous and capillary oxygenation at the tissue level. Since 70-80% of the blood in the brain is in the venous compartment, NIRS mainly reflects venous blood oxygenation, but the rScO2 value represents the weighted average of tissue oxygenation. In other words, it shows the balance between oxygen need and oxygen delivery rather than oxygen delivery [2,5].

There are other devices developed to evaluate tissue oxygenation that use different techniques. While the measurement value in the INVOS device is expressed as 'regional oxygen saturation - Rsco2', in the NIRO device it is expressed as 'tissue oxygenation index - TOI' and in the FORE SIGHT device it is expressed as 'cerebral tissue oxygen saturation - SctO2'[6].

Where is Cerebral Oxygenation Monitoring Used?

Although there is insufficient evidence to recommend the use of NIRS as a routine monitoring method in general anesthesia, its use is common especially in cardiac and carotid endarterectomy surgeries. The frequent occurrence of neurological dysfunctions after cardiac surgery has supported the clinical use of cerebral oximetry [2]. Reducing the risk of postoperative neurological complications is an important goal [4].

There are also studies on its use in non-cardiac surgeries such as surgery which using a sitting or head-up position where cerebral desaturation may occur (for example, the sunbed position in shoulder surgery and single lung ventilation)[4]. NIRS probes can be used to monitor regional tissue oxygenation in pediatric patients by placing them in different parts of the body such as the forehead (cerebral), abdomen (mesentery), and waist (renal) [2].

What is Cerebral Oxygen Desaturation Value?

There is wide interindividual variability for regional cerebral tissue oxygen saturation value. The normal range is between 60% and 75%, with a coefficient of variation of approximately 10% for absolute baseline values [6]. Physiological values have been reported as 55-60% in some cardiac patients [7]. Since the normal value of the cerebral oximeter can vary greatly between individuals, it is more appropriate to use it as a trend monitör [6]. In the clinic, the trend in values is more important than absolute values [7]. Ideally, baseline NIRS, inspiratory CO2 concentration (FiCO2), carbon dioxide partial pressure (PaCO2), oxygen saturation (SaO2) and vital values should be noted before induction of anesthesia. Although there is no consensus on what amount of decrease in cerebral oxygen saturation from baseline will pose a clinically significant threat to brain oxygenation, the 'paradigm' used to define abnormal is a decrease of more than 20% from baseline, a difference of more than nine units between the right and left, and values below 50%. The values below 40% are considered a sign of cerebral ischemia [3,4].

Intraoperative Neuromonitoring

Postoperative neurological complications may result from neuronal/vascular damage, embolism and inflammation. The heterogeneity of pathological processes causes different clinical phenotypes of neurocognitive disorders (such as postoperative delirium-POD, postoperative cognitive dysfunction-POCD, and stroke). Multifactorial etiology provides the basis for the use of different neurological monitoring methods, especially during cardiac surgery [8].

Currently, there is no single neuromonitoring method that can be considered adequate and ideal. The concept of 'Multimodel Neuromonitoring' refers to the combination of hemodynamic parameters and special invasive-noninvasive neuromonitoring methods [9]. Transcranial Doppler (TCD), Jugular venous bulb saturation (JVBS), electroencephalogram (EEG) and NIRS are among these monitoring methods [8]. The relationship between the NIRS and postoperative neurocognitive functions has been the subject of studies.

Postoperative Cognitive Dysfunction

Postoperative Cognitive Dysfunction (POCD) is defined as a significant decrease in cognitive functions that occurs after anesthesia and surgery compared to the preoperative period. Decline is observed in multiple main neurocognitive areas such as executive function, verbal memory, visuospatial abstraction, attention and psychomotor speed [10-12].

The mechanism that causes POCD is not yet fully understood [10,13]. It is thought to have a multifactorial etiology [14]. Age is the major identified risk factor for POCD, other risk factors include cardiac surgery, prolonged cardiopulmonary bypass (CPB) duration, preoperative mild cognitive impairment (MCI), pre-existing cerebral, vascular or cardiac disease, history of alcohol abuse, low education level, extensive surgeries performed under general anesthesia, development of intra/postoperative complications, secondary surgeries, ischemia, homeostasis disorder, use of long-acting anesthetics and the presence of genetic predisposing factors (carrying the APOE4 genotype, etc.) [10, 15-17].

Possibly, microembolism, perfusion problems, and inflammatory response contribute to the pathogenesis of cognitive decline in cardiac surgery patients and lead to cerebral tissue hypoxia [13,18]. There are studies showing that the incidence of cerebral oxygen desaturation is significant in non-cardiac surgeries such as brain surgery, carotid surgery, general surgery, and thoracic surgery [19]. There are studies in the literature investigating the relationship between regional cerebral oxygen desaturation and neurological complications.

Can Cerebral Oxygenation Monitoring Be Used to Predict and Prevent the Development of POCD?

The proper functioning of the central nervous system is extremely dependent on providing adequate nutrient and oxygen supply, effective removal of waste products, and maintaining an appropriate neurochemical environment. A condition such as hypoxia, hypoglycemia or any medication that affects the metabolic state of the brain and general homeostasis may cause postoperative functional impairment of the brain.

Cerebral hypoperfusion due to hypotension may lead to cognitive deficits, but strong enough evidence has not been obtained in studies on this[13]. The effect of NIRS-guided intervention on neurocognitive disorders after cardiac and non-cardiac surgeries is still a controversial issue [18].

Tian et al. examined 12 randomized controlled trials (RCTs) involving cardiac surgery patients and showed that intraoperative cerebral desaturation was associated with the incidence of POD) and that rScO2-guided intraoperative intervention was associated with a lower risk of POD/POCD and shorter intensive care stay. The definition of cerebral desaturation in the reviewed studies was accepted as a decrease below 70-90% of the initial rScO2 or a decrease below 50-60% of the absolute rScO2 value [18].

Holmgaard et al. examined the relationship between intraoperative decrease in cerebral oxygen saturation and POCD in patients undergoing pump-assisted heart surgery. The rScO2 value was calculated as the average of the left and right sensor values, based on the cumulative periods during which the rScO2 was ≥10% below the preoperative value for each patient. No significant difference was found between patients with and without POCD at discharge in terms of cumulative times with preoperative rScO2 values ≥10% below. Additionally, no significant difference was found when preoperative rScO2, mean rScO2 during cardiopulmonary bypass (CPB) or intraoperative rScO2 and minimum rScO2 values of patients with and without POCD at discharge were analyzed. They could not find any relationship between intraoperative rScO2 variables and the occurrence of POCD after cardiac surgery [20].

Tang et al. followed 76 patients who underwent thoracic surgery with single lung ventilation with FORESIGHT cerebral oximetry and evaluated them with a mini mental state exam. They found that there was a relationship between the intraoperative decrease in SctO2 and early cognitive impairment [19] .

In the study of Chen et al., 7 RCTs- including non-cardiac surgeries (2 studies on abdominal surgery patients and 4 studies on orthopedic surgery patients) were analyzed. In the subgroup analysis of abdominal surgery and orthopedic surgery in elderly patients, the mean intraoperative cerebral oxygen saturation of patients with POCD was found to be significantly lower than the group without POCD [21].

Murniece et al. examined the effect of an intraoperative NIRS-based clinical algorithm on postoperative cognitive functions in patients who underwent spinal surgery in the prone position. The study group (23 patients) received intervention if rScO2 values decreased bilaterally or unilaterally by more than 20% from baseline values or fell below the absolute value of 50%. In the control group (11 patients), standard intraoperative anesthesia monitoring was applied, rScO2 was monitored blindly, and intervention was made according to hemodynamic parameters and the amount of bleeding. Montreal-Cognitive Assessment (MoCA) test was applied to both groups preoperatively and on postoperative day two. rScO2 fell below the threshold in three patients in the study group and one patient in the control group. While none of the three patients had POCD, one patient in the control group developed POCD. It has been suggested that a significant rScO2 decrease may occur while other intraoperative measurements remain stable and that the use of a NIRS-based clinical algorithm may help prevent POCD in patients after spine surgery [22].

In the study of Ding et al., they investigated the role of rScO2 monitoring in preventing POCD in elderly patients. Six RCTs including 377 patients were examined, and the incidence of POCD ranged from 17% to 89%, and the overall prevalence was found to be 47% in the pooled analysis. The use of rScO2 monitoring has been found to be associated with a lower risk of POCD and a shorter length of hospital stay in older patients undergoing noncardiac surgery. It has been suggested that rScO2 monitoring in high-risk populations may have the potential to prevent POCD [23].

In the past, evidence on whether interventions for cerebral oxygen desaturations reduce the risk of neurological outcomes has been limited to case reports and observational studies. Randomized, controlled algorithm-based interventional trials for cerebral desaturations in patients undergoing cardiac surgery are now available[24,25.] According to meta-analyses, there is insufficient evidence to support or refuse whether interventions for cerebral desaturations during surgery improve neurological outcomes[4]. Differences in results between studies may be due to different rScO2 monitoring principles and the heterogeneity of the patient groups monitored.

NIRS reflects mixed arterial and venous saturation in localized areas of the frontal lobes, not the entire brain. If cerebral ischemia develops in brain regions other than the frontal lobe, intraoperative rSO2 values may remain normal. In case of cortical atrophy in elderly patients, inaccurate measurements may occur due to the increased distance between the skin and brain tissue. POCD has a multifactorial etiology and there are multiple neurocognitive tests to evaluate. Different neurocognitive tests were used in the studies, and this may cause the difference in the results obtained. The mechanism of delayed cognitive recovery is unknown and perhaps cannot be prevented simply by avoiding compromised cerebral oxygenation during surgery.

Hogue et al. found that hypotension was also common in the postoperative intensive care unit and was associated with brain injury biomarker release[4]. Therefore, a strategy to ensure cerebral perfusion both in the operating room and in the intensive care unit may be necessary.

2. Conclusion

In conclusion, NIRS is an easy-to-use, non-invasive cerebral oxygenation monitoring method that may help prevent cerebral desaturation and hypoxic brain injury intraoperatively. However, all available information regarding the patient, surgery, and anesthesia should be carefully evaluated, and it is recommended to plan intervention on a patient-by-patient basis after excluding false positive measurements due to placement of NIRS device probes.

Limitations of the Study

This review paper has several important limitations. First, our study only includes articles published in Turkish and English. This might have excluded potentially significant studies in other languages and poses a risk of language bias. Second, most of the studies included in the review come from specific geographical regions, which limits the generalizability of the findings on a global scale. Additionally, there is considerable methodological diversity and variability in the quality of the included studies. Different data collection and analysis methods make it difficult to compare results, which may affect the overall validity of the review. Some studies carry a high risk of bias due to methodological shortcomings and inadequate reporting. Finally, as this review focuses on a specific topic, other relevant subjects or subtopics have been excluded. This narrows the scope of our research question and limits the broader interpretation of our findings. Therefore, it is important for readers to consider these limitations when evaluating our results.

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Conflict of Interests

T The authors declare no competing interests.

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Author Contributions

TSA and AS designed the study. TSA and AS read the draft and approved the final scenario.

Ethical Approval

None.

Data sharing statement

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Consent to participate

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None.

References

1. Ferrari M, Mottola L, Quaresima V. Principles, techniques, and limitations of near infrared spectroscopy. *Can J Appl Physiol.* 2004; 29(4):463-87.
2. Marin T, Moore J. Understanding near-infrared spectroscopy. *Adv Neonatal Care.* 2011; 11(6):382-88.
3. Sabuncu U, Özgök A. Serebral oksijen satürasyonu monitörizasyonunun rejyonel doku hipoksisini tespit etmedeki yeri. *GKDA Derg.* 2016; 22(3):125-27.
4. Hogue CW, Levine A, Hudson A, Lewis C. Clinical Applications of Near-infrared Spectroscopy Monitoring in Cardiovascular Surgery. *Anesthesiology.* 2021; 134(5):784-91.
5. Maillard J, Sologashvili T, Diaper J, Licker MJ, Keli Barcelos G. A Case of Persistence of Normal Tissue Oxygenation Monitored by Near-Infrared Spectroscopy (NIRS) Values Despite Prolonged Perioperative Cardiac Arrest. *Am J Case Rep.* 2019; 20:21-25.
6. Ghosh A, Elwell C, Smith M. Review article: cerebral near-infrared spectroscopy in adults: a work in progress. *Anesth Analg.* 2012; 115(6):1373-83.
7. Maillard J, Sologashvili T, Diaper J, Licker MJ, Keli Barcelos G. A Case of Persistence of Normal Tissue Oxygenation Monitored by Near-Infrared Spectroscopy (NIRS) Values Despite Prolonged Perioperative Cardiac Arrest. *Am J Case Rep.* 2019; 20:21-25.
8. Milne B, Gilbey T, Gautel L, Kunst G. Neuromonitoring and Neurocognitive Outcomes in Cardiac Surgery: A Narrative Review. *J Cardiothorac Vasc Anesth.* 2022; 36(7):2098-13.
9. Peacock SH, Tomlinson AD. Multimodal Neuromonitoring in Neurocritical Care. *AACN Adv Crit Care*. 2018; 29(2):183-94.
10. Rundshagen I. Postoperative cognitive dysfunction. Dtsch Arztebl Int. 2014;111(8):119-125.
11. Safavynia SA, Goldstein PA. The Role of Neuroinflammation in Postoperative Cognitive Dysfunction: Moving From Hypothesis to Treatment. *Front Psychiatry.* 2019; 9:752.
12. Kapoor I, Prabhakar H, Mahajan C. Postoperative Cognitive Dysfunction. *Indian J Crit Care Med.* 2019; 23(Suppl 2):S162-S164.
13. Pappa M, Theodosiadis N, Tsounis A, Sarafis P. Pathogenesis and treatment of post-operative cognitive dysfunction. *Electron Physician.* 2017; 9(2):3768-75.
14. Van Sinderen K, Schwarte LA, Schober P. Diagnostic Criteria of Postoperative Cognitive Dysfunction: A Focused Systematic Review. *Anesthesiol Res Pract*. 2020; 2020:7384394.
15. Lin X, Chen Y, Zhang P, Chen G, Zhou Y, Yu X. The potential mechanism of postoperative

cognitive dysfunction in older people. *Exp Gerontol*. 2020; 130:110791.

16. Gong GL, Liu B, Wu JX, Li JY, Shu BQ, You ZJ. Postoperative Cognitive Dysfunction Induced by Different Surgical Methods and Its Risk Factors. *Am Surg*. 2018; 84(9):1531-37.

17. Wang R, Wang G, Liu Y, Zhang M. Preoperative smoking history is associated with decreased risk of early postoperative cognitive dysfunction in patients of advanced age after noncardiac surgery: a prospective observational cohort study. *J Int Med Res*. 2019; 47(2):689-701.

18. Tian LJ, Yuan S, Zhou CH, Yan FX. The Effect of Intraoperative Cerebral Oximetry Monitoring on Postoperative Cognitive Dysfunction and ICU Stay in Adult Patients Undergoing Cardiac Surgery: An Updated Systematic Review and Meta-Analysis. *Front Cardiovasc Med*. 2022; 8:814313.

19. Tang L, Kazan R, Taddei R, Zaouter C, Cyr S, Hemmerling TM. Reduced cerebral oxygen saturation during thoracic surgery predicts early postoperative cognitive dysfunction. *Br J Anaesth*. 2012; 108(4):623-29.

20. Holmgaard F, Vedel AG, Rasmussen LS, Paulson OB, Nilsson JC, Ravn HB. The association between postoperative cognitive dysfunction and cerebral oximetry during cardiac surgery: a secondary analysis of a randomised trial. *Br J Anaesth*. 2019; 123(2):196-205.

21. Chen N, Lu J. Meta-Analysis of the Correlation between Postoperative Cognitive Dysfunction and Intraoperative Cerebral Oxygen Saturation. *Comput Math Methods Med*. 2022; 2022:3731959.

22. Murniece S, Soehle M, Vanags I, Mamaja B. Near Infrared Spectroscopy Based Clinical Algorithm Applicability During Spinal Neurosurgery and Postoperative Cognitive Disturbances. *Medicina (Kaunas)*. 2019; 55(5):179.

23. Ding X, Zha T, Abudurousuli G, et al. Effects of regional cerebral oxygen saturation monitoring on postoperative cognitive dysfunction in older patients: a systematic review and meta-analysis. *BMC Geriatr*. 2023; 23(1):123.

24. Yu Y, Zhang K, Zhang L, Zong H, Meng L, Han R: Cerebral near-infrared spectroscopy (NIRS) for perioperative monitoring of brain oxygenation in children and adults. *Cochrane Database Syst Rev*. 2018; 1:CD010947

25. Serraino GF, Murphy GJ. Effects of cerebral near-infrared spectroscopy on the outcome of patients undergoing cardiac surgery: a systematic review of randomised trials. *BMJ Open*. 2017; 7(9):e016613.

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