ISSN: 2717-8161 REVIEW ARTICLE

New Trend Med Sci 2024; 5(Supplement Issue):156-160 https://dergipark.org.tr/tr/pub/ntms

Advancing Patient Care: The Role of Cerebral Oximetry in Intensive Care Units

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Article History
Received 28 Nov 2023
Accepted 20 July 2024
Published Online 28 July 2024

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Doi:10.56766/ntms.1397430

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Abstract: One of the most important parameters of patient follow-up in intensive care units is monitoring. The brain is one of our most metabolically active organs and is very sensitive to hypoxia and ischemia. Therefore, monitoring cerebral oxygenation is important. Although there are many methods for monitoring cerebral tissue oxygenation, cerebral oximeters are frequently used due to their bedside use, non-invasiveness and ease of use. These devices work on the basis that near-infrared light is absorbed at different rates by oxygenated hemoglobin and deoxygenated hemoglobin. It can be used in intensive care units to detect cerebral ischemia or hypoxia early and prevent secondary damage in patients with traumatic brain injury (hemorrhage, stroke). ©2024 NTMS.

Keywords: Cerebral; Oximetry; Hypoxia-ischemia.

1. Introduction

The human brain is one of the most metabolically active organs in the body. Although the weight of the brain is about 2% of the total body weight, the cerebral blood flow volume constitutes 15-20% of the cardiac output [1]. Adequate delivery of O2 to the brain via precise regulation of cerebral blood flow (CBF) is therefore vital to maintaining optimal function and avoid cellular damage and/or death. Describing the influence of oxygen (O2) availability on CBF and brain metabolism is an essential step toward a better understanding of brain energy homeostasis and associated clinical implications. Impairment of cerebral tissue oxygenation may be due to inadequacies in oxygen delivery to the brain or increases the oxygen that the brain's need. In the last decade, cerebral tissue oxygenation monitoring has become an emerging monitoring modality mainly because it enables evaluating the coupling of macro-hemodynamic variables with regional or local hemodynamics at the tissue of interest.

There are various methods for cerebral tissue oxygenation monitoring. One of these is the jugular venous oxygen saturation (SjvO2) measurement. SjvO2 is used for indirect assessment of brain tissue oxygen consumption and reflects the dynamic balance between whole brain oxygen supply and consumption. Therefore, it is considered as a useful indicator of the relationship between whole-brain blood flow and brain metabolism [2]. Measurements are obtained from blood taken intermittently from a catheter placed in the jugular bulb and is an invasive method. While it has the advantage of showing the blood oxygen saturation of

Cite this article as: Turan S and Sevim-Yakın S. Advancing Patient Care: The Role of Cerebral Oximetry in Intensive Care Units. *New Trend Med Sci.* 2024; 5(Supplement Issue):156-160.Doi:10.56766/ntms.1397430

the whole brain, it remains insufficient in the presence of regional hypoxia. There is a risk of hematoma and venous thrombosis in this method, and this risk increases as the follow-up period extended [3].

Monitoring of brain tissue partial pressure of oxygen (PbtO2) is a new cerebral blood oxygen saturation monitoring technique. PbtO2 provides information about perfusion and circulation, as well as oxygenation of brain tissues at the cellular level [4]. This method is quite invasive because it is performed with microelectrodes implanted in the brain tissue. It reflects partial oxygen pressure in the brain, temperature and pH values [5]. It has a high reliability compared to other methods. However, its clinical use is limited because it is invasive and can cause local brain tissue damage and infection.

Cerebral oximetry evaluates regional tissue oxygenation through the transcutaneous membrane via electrodes placed on the frontal cortex. Near infrared resonance spectroscopy (NIRS) is a monitoring method based on the principle of utilizing the tissue permeability feature of near infrared light [6]. Normal values in healthy people range between 58-82%. NIRS is a non-invasive method and is frequently used intraoperatively and postoperatively in many surgical procedures [7]. Its use is also increasing in intensive care units in patients with traumatic brain injury, stroke and cardiac arrest.

Figure1: First day NIRS values of a patient who developed bilateral SAH because of a traffic accident.

NIRS Working Principle

Its working principle is like a classical pulse oximeter. It works on the basis that the rays coming out of the transmitter diode are detected by the receiver diodes. The spectral absorptions of oxygenated hemoglobin and deoxygenated hemoglobin are different, and NIRS uses this difference [8,9]. The basis of the NIRS operating principle is the Beer-Lambert law. According to this law, light is absorbed according to the properties of the material it passes through. Uptake by tissues is related to the wavelength of the light. Ultraviolet light, visible light and infrared light are absorbed by DNA, proteins, hemoglobin and water. Therefore, they cannot pass into tissues, and it is not possible to make measurements in the body using this spectrum. Since near infrared light is not absorbed by water or proteins, it can penetrate deeper tissues and is used in cerebral oximeters [10]. Additionally, tissues contain molecules called chromophores that can absorb near infrared light. Chromophores have specific absorption rates depending on the oxygen concentration in the tissue. The amount of light absorbed by tissues depends on the chromophore concentration [8]. At least two different wavelengths must be used to compare chromophore concentrations in NIRS measurements. Since the absorption difference between oxygenated hemoglobin and deoxygenated hemoglobin is greatest in light with wavelengths between 700 and 850nm, these two wavelengths are commonly used in measurements [9]. Although two wavelengths were used in devices produced in the past, today multiple wavelengths are used in devices to increase the accuracy of measurements [11]. The most advanced devices used today have four electrodes. The oximeters operate as continuous wave (CW), frequency dependent or time dependent, depending on the techniques used.

NIRS Advantages

NIRS is a low-cost and easy device that can be applied at the bedside. Its biggest advantage is to be non-invasive. Since it does not require pulsatile flow, it can also be used during cardiopulmonary bypass. It cannot distinguish between the arterial and venous systems, so it indicates the balance between oxygen delivery and consumption rather than oxygen delivery [12]. Additionally, it can provide information about cerebral oxygen use and cell metabolism [13,14].

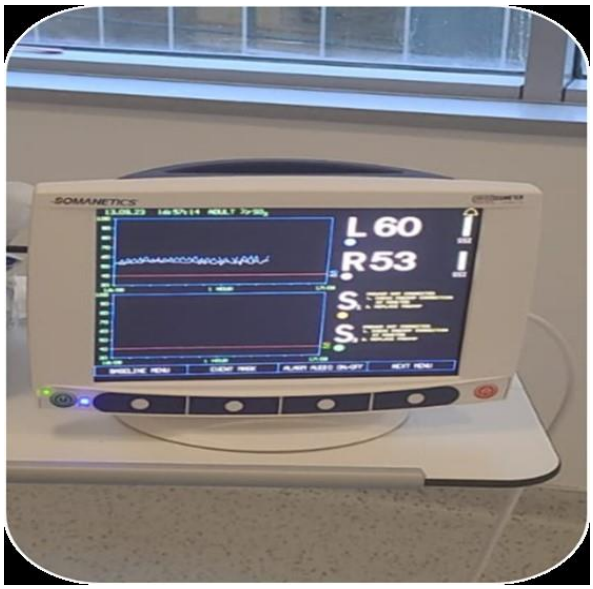

Figure 2: Day 5 NIRS values of the same patient. Delayed cerebral ischemia was detected.

NIRS Limitations

The main limitation of cerebral oximeters is that they are affected by signals from extracranial tissue. For this reason, measurements cannot directly reflect brain oxygen saturation. To avoid this limitation, some companies have been able to distinguish the signals coming from the scalp and deep tissue by using two detectors [15,16]. Cerebral oximeters calculate saturation by assuming that arterial and venous blood are in a certain ratio. And the partial pressure of carbon dioxide affects this ratio. This must be considered in these measurements. Measurements may show large differences in cases where the hemoglobin level changes suddenly (hematoma, hemodilution) or in cases where the distance between the light source and the detector increases (tissue edema) [17,18]. Head movement can also cause artifacts and inaccurate measurements [19]. Another important limitation is that normal values vary widely between individuals. Therefore, there is no cut-off value or gold standard values for diagnosis. Therefore, it can only be used as a trend monitor [19].

Clinical Use

The occurrence and progression of brain damage have a great importance on the mortality and morbidity of patients in intensive care unit. Although its mass is small, the brain uses 25% of the glucose and 20% of the oxygen provided for its normal functions. Brain oxygen consumption is 3.5 ml/100gr tissue/1 min. The regulation of blood flow and continued oxygen delivery are very important to maintain its functions. Monitoring cerebral tissue oxygenation is therefore an increasingly common practice in intensive care units.

The most important purpose of monitoring cerebral tissue oxygenation in intensive care units is to prevent secondary brain damage caused by hypoxia or ischemia. Patients with traumatic brain injury, patients with subarachnoid hemorrhage (SAH), patients with stroke, septic encephalopathy and cardiac arrest are monitored by NIRS [20]. Although there is no gold standard in numerical values, an initial NIRS value of less than 40, but more importantly, a change of more than 25% compared to the baseline, is useful in predicting cerebral ischemia [21].

Traumatic Brain Injury, Subarachnoid Hemorrhage, and Stroke

Subarachnoid hemorrhage is a serious disease, the complications of which are life threatening and usually require management in intensive care unit. Delayed cerebral ischemia occurs in some of these patients and has negative effects on mortality and morbidity. A study examined whether the use of NIRS in the follow-up of patients with SAH is effective in predicting delayed cerebral ischemia [22]. A patient's NIRS values are shown in Figure 1 and 2. NIRS changes were recorded in cases where patients had newly developed neurological symptoms, lasted longer than an hour, and had a decrease of more than 2 on the Glasgow coma scale. In these patients with delayed cerebral ischemia, it was observed that there was a decrease of more than 14.7% in NIRS values compared to the baseline level and the sensitivity was calculated as 85.7% [22]. In another study, measurements were made using NIRS in healthy volunteers and patients with stroke, and the correlation with interhemispheric asymmetry and physiological changes was evaluated [23]. In stroke cases, it has been shown that CW-NIRS can detect asymmetry in microvascular hemodynamics between hemispheres during physiological cardiac and respiratory oscillations. It has been shown that, especially in patients where the width of the affected area is unknown, an information can be obtained by making simultaneous measurements in different parts of the head [23]. Similarly, in cases of SAH, intracranial hemorrhage and ischemic stroke, frontal NIRS cerebral oxygenation measurements were correlated compared with regional cerebral blood flow on CT perfusion imaging [24].

Sepsis and Its Impact on Cerebral Function

One of the most common clinical conditions in intensive care units is sepsis. Depending on the source of sepsis, sepsis itself can cause brain damage such as brain edema and seizures, and it can affect brain functions due to its systemic effects such as hypotension, hypoxia, and hypercapnia. NIRS may be preferred as it is an uncomplicated, non-invasive method that can be applied at the bedside to evaluate cerebral oxygenation in the follow-up of septic patients [25]. Most of the monitoring performed in septic patients are indicators of macro-circulation, and even these are normal, there may be inadequate microcirculation. The use of NIRS in the thenar region, which is less affected by local factors such as edema and fatty tissue thickness, can provide us indirect information about local microcirculation [26].

Cardiopulmonary Resuscitation and Cardiac Arrest

NIRS is also helpful in monitoring resuscitation effectiveness in arrest cases. In an observational study, it was tried to understand whether tissue oxygenation index (TOI) values obtained by NIRS could be used to evaluate the return of spontaneous circulation (ROSC) in patients undergoing cardiopulmonary resuscitation (CPR) [27]. More than a hundred out-of-hospital cardiac arrest cases were included and it was observed that ROSC was high in those with high initial TOI values and there was a correlation between them. For this reason, it has been suggested that TOI values can be used to predict ROSC, terminate CPR or make ECPR decisions [27]. Many studies on this subject have confirmed the correlation of regional cerebral oxygen saturation (rSO2) values with ROSC [29]. Although there is no exact threshold value in studies, those with an average rSO2 value of 47 (47 ± 11) are associated with a positive outcome, and those with a mean rSO2 value of 38 (38 ± 12) are associated with a poor neurological outcome [28]. As rSO2 values increase, both ROSC rate

and neurological outcome increase. NIRS does not require pulsatile flow like pulse oximetry, making it easier to use in CPR applications [29].

2. Conclusions

As a result, cerebral tissue oxygenation has an important place in clinical follow-up in intensive care units. Among cerebral tissue oxygenation monitors (SjvO2, PbtO2 and rSO2), NIRS has become a monitor with high specificity and sensitivity that is used increasingly more frequently. It is a useful monitoring method in predicting the prognosis in cases of traumatic brain injury (TBI, SAH and Stroke) and in making a rapid treatment plan in case of sudden neurological changes during follow-up. In cases such as sepsis, which are frequently encountered in intensive care, close monitoring of tissue oxygenation is required, and NIRS has a strong place among tissue oxygenation parameters. Higher NIRS values during cardiopulmonary resuscitation have been associated with better neurological outcomes in adult and pediatric patients. Although it has various limitations, the use of NIRS in monitoring cerebral oxygenation is frequently recommended because it is easy, applicable, low-cost and noninvasive.

Limitations of the Study

This is a review, there is no limitation.

Acknowledgement

There is no acknowledgement.

Conflict of Interests

No conflict of interests of any authors.

Financial Support

There is no financial support.

Author Contributions

Both authors contributed equally for preparation of the review.

Ethical Approval

No need for Ethical Approval.

Data sharing statement

There is no data sharing.

Consent to participate

No consent is required.

Informed Statement

There is no Informed Statement.

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