



Evaluation of Tissue Oxygenation Using Near-infrared Spectroscopy and Nursing Care in Newborns: A Review of the Literature

Yenidoğanlarda Yakın Kızılötesi Spektroskopi ile Doku Oksijenasyonunun Değerlendirilmesi ve Hemşirelik Bakımı: Literatür Derlemesi

Hande ÖZGÖRÜ¹, Suzan YILDIZ²

¹Süleyman Demirel University, Health Services Vocational School First and Emergency Aid Program, Isparta, Türkiye

²İstanbul University-Cerrahpaşa, Cerrahpaşa Florence Nightingale Faculty of Nursing, Department of Child Health and Diseases Nursing, İstanbul, Türkiye

ABSTRACT

Term and preterm newborns are exposed to many invasive procedures in the neonatal intensive care unit (NICU). During these procedures, preterms face many complications, especially respiratory system and gastrointestinal tract complications, since they do not complete their systemic development. Near-infrared spectroscopy (NIRS) is used in the diagnosis and treatment of these problems. It is an up-to-date application that evaluates the effectiveness of various non-pharmacologic interventions. At the same time, NIRS is a research technique that uses the absorption and reflection of a near-infrared light spectrum to measure tissue oxygenation, indirectly representing regional blood flow. Currently, it is possible to simultaneously measure regional oxygenation in multiple areas of the body, including the brain, kidney, and abdominal circulation. Regional (cerebral, abdominal) tissue oxygen saturation measured using NIRS has become an increasingly used parameter in the monitoring of cerebral hemodynamics in newborns, in the diagnosis and treatment of gastrointestinal tract complications such as nutritional intolerance and necrotizing enterocolitis. When the literature is examined, it is seen that studies on NIRS focus on cerebral oxygenation in preterm newborns. It is very important for nurses working in the NICU to use NIRS devices, know the points to be considered in follow-up, and learn

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Yenidoğan yoğun bakım ünitesinde (YYBÜ) term ve preterm yenidoğanlar birçok invaziv işleme maruz kalmaktadır. Bu işlemler sırasında özellikle pretermli sistemsel gelişimlerini tamamlamadıkları için solunumsal ve gastrointestinal sistem başta olmak üzere birçok sistemle ilgili komplikasyonlar ile karşı karşıyadır. Bu sorunların tanılama ve tedavi aşamasında kullanılan *near-infrared spectroscopy* (NIRS) (yakın kızılötesi spektroskopi) cihazı, çeşitli non-farmakolojik girişimlerin etkinliğini değerlendiren güncel bir uygulamadır. Aynı zamanda NIRS, doku oksijenasyonunu ölçmek için yakın kızılötesi bir ışık spektrumunun emilimini ve yansımalarını kullanan ve dolaylı olarak bölgesel kan akışını temsil eden bir araştırma tekniğidir. Şu anda, beyin, böbrek ve abdominal dolaşım da dahil olmak üzere vücudun birden fazla bölgesinde bölgesel oksijenasyonu aynı anda ölçmek mümkündür. NIRS ile ölçülen bölgesel (serebral, abdominal) doku oksijen doygunluğu, yenidoğanlarda serebral hemodinamiklerin izlenmesinde, beslenme intoleransı, nekrotizan enterokolit gibi gastrointestinal komplikasyonların tanı ve tedavisinde kullanımı artan bir parametre haline gelmiştir. Literatüre bakıldığında NIRS ile ilgili yapılan çalışmaların preterm yenidoğanlarda serebral oksijenizasyon üzerine yoğunlaştığı görülmektedir. YYBÜ’nde çalışan hemşirelerin NIRS cihazını kullanması, takibinde dikkat

Address for Correspondence: Hande Özgörü PhD, İstanbul University-Cerrahpaşa, Institute of Graduate Education, Department of Child Health and Diseases Nursing Doctoral Program, İstanbul, Türkiye

E-mail: ozgoruhande93@gmail.com

ORCID IDs of the authors: H.Ö.: 0000-0002-9263-8372, S.Y.: 0000-0002-2528-2185

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ABSTRACT

how to interpret them in order to identify complications at an early stage. The purpose of this literature review was to evaluate the information on the measurement of cerebral and abdominal tissue oxygenation in newborns using NIRS technology and nursing care in light of current literature.

Keywords: Nursing care, near-infrared spectroscopy, newborn

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etmesi gereken noktaları bilmesi ve yorumlanmasını öğrenmesi komplikasyonların erken dönemde tanımlanması açısından oldukça önemlidir. Bu literatür derlemesindeki amaç; yenidoğanlarda serebral ve abdominal doku oksijenizasyonunun NIRS teknolojisi ile ölçülmesine yönelik bilgileri ve hemşirelik bakımını güncel literatür ışığında değerlendirmektir.

Anahtar Kelimeler: Hemşirelik bakımı, yakın kızılötesi spektroskopi, yenidoğan

Introduction

Near-infrared spectroscopy (NIRS) devices were first used in medical research by Jöbsis (1) in the 1970s and have been shown to be a non-invasive technique that monitors regional tissue oxygenation [the percentage of oxyhemoglobin (HbO_2) and deoxyhemoglobin (HbR) (regional oxygen saturation: $\text{HbO}_2 / (\text{HbO}_2 + \text{HbR})$ concentration in tissues] reflecting the perfusion status (2,3). In doing so, it uses the absorption and reflection of a near-infrared light spectrum (light with a wavelength of 700-1000 nm) (4,5).

This technique is used to assess cerebral and abdominal tissue oxygen saturation in various disease states of preterm and term neonates to monitor cerebral hemodynamics, increase awareness of abnormal perfusion status, potentially reduce the risks associated with many diseases that can lead to ischemic injury, provide data in the diagnosis and treatment of gastrointestinal tract complications such as nutritional intolerance, necrotizing enterocolitis (NEC), and improve the effectiveness of various non-pharmacologic interventions. It is preferred to provide data on treatment and evaluation of the effectiveness of various non-pharmacological interventions (6-9). It is also increasingly used to measure tissue oxygenation in other organs and determine blood flow. Today, with the NIRS technique, it is possible to measure regional oxygenation simultaneously and continuously in many parts of the body, including the brain, intestine, kidney, pulmonary, muscle, peripheral and liver circulation, without interrupting routine care (10-12). However, more research is needed to establish universal normative data based on cerebral and abdominal oxygenation in newborns. The use of different devices, follow-ups at different ages, the inadequacy of studies especially in preterm and term newborns, and the use of different optical probes and algorithms by device manufacturers limit the widespread clinical application of the device (6).

Regions Where NIRS is Used in Newborns

In newborns, the NIRS is often used in the cerebral and abdominal regions.

Cerebral NIRS: This can help identify and treat cerebral injuries related to regional perfusion and ischemia, primarily intraventricular hemorrhage and white matter injury (4). Preterms, due to their underdeveloped cerebral autoregulation system, are unable to provide sufficiently consistent cerebral blood flow in the face of stressors (13). NIRS can help continuously

monitor regional brain tissue perfusion and obtain clear data on the balance between oxygen use and requirement (3). In addition, because acute fluctuations in partial arterial carbon dioxide pressure (PaCO_2) are associated with fluctuations in cerebral blood flow, the use of NIRS in mechanically ventilated severely preterm patients may guide detecting and correcting these changes before damage occurs (14). If the cerebral NIRS value remains below 40-45% in a short period of time, such as 30 minutes, it may have negative effects on cerebral blood flow and brain development (3,4).

Although the specific values differ in various NIRS devices, cerebral regional oxygen saturation (crSO_2) is generally lower than abdominal oxygenation (splanchnic/somatic rSO_2) because the brain has more metabolic activity and consumes more oxygen (15). Factors that affect the accuracy of measurements include the placement of sensors in different parts of the forehead, the shape of the forehead, extracranial structures, blood flow, and the depth of the brain surface (6).

Abdominal NIRS technique: In newborns, the abdominal region is the area used to monitor oxygenation of the kidney, liver, and intestine. It is known that abdominal oxygenation values are closely related to changes in superior mesenteric artery blood flow (7). For this reason, healthy preterms may experience a decrease in abdominal oxygenation values in the first weeks of life and an increase in the following weeks (3,15).

The locations where the probe is placed for cerebral and abdominal oxygenation monitoring are given in Table 1 (3,16,17).

Interpretation of NIRS measurements: The tissue oxygenation index reference range of newborns is expected to vary between 55-85% depending on many factors such as clinical status and postnatal age. However, the universally accepted reference range remains unclear (18). There are also situations that create difficulties in the interpretation of regional oxygenations, including variations in devices and probes, gestational week, and deficiencies in universal normative values (19).

Because NIRS devices can monitor oxygenation in different regions at the same time, it has been stated that interpreting measurements with regional proportioning can give more accurate information about different tissue oxygenation to certain organs (20,21). Cerebro-splanchnic oxygenation ratio values below 0.75 are associated with an increased risk of mesenteric ischemia (2,8,20). However, studies have shown that the splanchnic-

Table 1. Positioning locations of the NIRS probe in newborns

Cerebral NIRS probe	Abdominal NIRS probe
• Middle frontal • Left frontoparietal • Right frontoparietal * Simultaneous monitoring can be done with right and left dual probes	Kidneys • Right retroperitoneal region • Left retroperitoneal region Intestines • Lower right quadrant • Lower left quadrant • Umbilicus Liver • Upper right quadrant
NIRS: Near-infrared spectroscopy	

cerebral oxygenation (SCOR) ratio is between 1.02 and 1.61, which can be seen as a signal of an increased risk of mesenteric ischemia (11,22). There was no correlation between SCOR and gestational age in healthy term newborns, but a positive correlation was found with postnatal clock, and it was shown that its value might be lower than normal in the first days of life (23). It has also been reported that the rate of abdominal oxygenation and SCOR decreases during enteral feeding in anemic preterm neonates (8), and that NEC discrimination cannot be made when abdominal and cerebro-splanchnic oxygenation rates are monitored in preterm newborns with acute gastrointestinal symptoms (24). It has been stated that SCOR elevations may confirm the diagnosis and frequent variability in splanchnic oxygenation can exclude NEC in preterm NEC (22).

Uses of NIRS

According to the regions where NIRS is used in term and preterm newborns, the functions and areas where NIRS is used are gradually increasing. In the literature, NIRS has been used in the planning of diagnosis, follow-up, treatment, and care, as well as in determining the effect of different applications such as smell, music, sleep, and position on oxygenation levels (10,25).

Clinical and Research Results

Areas Where Cerebral NIRS is Used

Diagnosis, follow-up, treatment, and care planning: Cerebral oxygenation monitoring in the delivery room and after delivery may be useful in stabilizing newborns (26,27), providing information about changes in hemodynamics, and especially when used in conjunction with other neuromonitoring tools (28). For this reason, it has been stated that pulse oximetry is a complementary approach and can be used routinely to determine oxygen demand in newborns quickly and accurately (29). It is thought that changes in cerebral oxygen saturation may be effective in providing information about the state of cerebral blood flow or general brain health, in the planning of care by healthcare professionals during high-risk procedures such as cardiopulmonary bypass (15), and monitoring major organ perfusion (such as cerebral, renal, intestinal) adequacy in children, infants, and newborns (9). Monitoring cerebral oxygenation with a predetermined treatment algorithm has been shown to reduce

the amount of cerebral hypoxia in extremely preterm infants (26). It has been used in the treatment of neonates undergoing cardiac surgery (6), and has been found to be significantly lower in neonates with cyanotic and acyanotic heart lesions, and follow-up can be combined with arterial blood pressure monitoring, a continuous dynamic assessment of autoregulation at the bedside. It has been reported that it will provide the possibility to identify times of impaired autoregulation and initiate appropriate measures to increase, decrease, or maintain adequate cerebral blood flow (3). Thus, it is possible to reduce brain damage such as intraventricular hemorrhage or periventricular leukomalacia and facilitates the rational use of inotropes (3,26).

In the first 24 hours following hypoxic ischemia, significantly elevated cerebral oxygenation and decreased cerebral fractional oxygen extraction values are observed (30). This condition is thought to be caused by a combination of increased cerebral perfusion, impaired cerebral autoregulation, and less oxygen use. Therefore, the concomitant use of NIRS with amplitude-integrated in neonates receiving treatment for therapeutic hypothermia has been shown to be useful in determining the prognosis (4,30,31). In newborns treated for hypothermia, follow-up with combined tools is critical for the first 72 hours, especially between 18 and 60 hours (32).

Newborns hospitalized in the neonatal intensive care unit (NICU) are especially exposed to pain and stress. Long-term or frequent pain experience can have a variety of negative effects in newborns in the short and long term, such as affecting the development and growth of the brain and senses. If pain is not reduced or eliminated with effective approaches, it can cause neurologic or behavioral disorders over time. Cerebral NIRS, an approach that evaluates brain activity in response to stressful and painful stimuli in newborns, is proposed. In this direction, it is stated that applications such as kangaroo care, position changes, and sucrose administration in painful procedures reduce pain and positively affect brain oxygenation (25).

In positioning applications: The NIRS device is an important tool for assessing processes that alter cerebral oxygenation due to significant venous drainage impairment (26). It has been shown that in adult patients at risk of high cerebral pressure due to traumatic brain injury the head and neck are routinely

placed in a neutral position to facilitate venous drainage, and in term neonates, when the head is positioned to one side, it functionally inhibits jugular venous drainage on the same side. Accordingly, impaired venous drainage and decreased cerebral tissue oxygenation have been reported to be among the factors that play a role in intraventricular hemorrhage (33). Early head positioning in the midline in preterm treatment has been adopted in many institutions as an approach to prevent intraventricular hemorrhage, but there are no strong data to support the practice (33-36). It is stated that the prone position in newborns is more effective than the supine position in providing skin-to-skin contact and oxygenation and ventilation (33). Therefore, in arterial oxygenation, the tidal volume is higher and the PaCO_2 is lower. In addition to the prone position, the right lateral position has been shown to be effective in providing oxygenation and ventilation and increasing cerebral oxygenation in the NICU (36). However, sleeping in the prone position is a major risk factor for sudden infant death syndrome. It has been stated that this condition is associated with impaired cerebrovascular control (5). For this reason, it is recommended that parents put newborns to bed in a supine position at home (37).

Scent applications: It is seen that the NIRS device has been used in scent applications that have a positive effect on newborn health in recent years. Changes in cerebral oxygenation in the orbitofrontal cortex are associated with neuronal activation of the olfactory cortex (38,39). During sensory stimulation, there is an increase in oxygen delivery to brain cells. This condition leads to an increase in the concentration of oxygenated hemoglobin in the cerebral cortex (40). Changes in the concentration of oxygenated hemoglobin provide information on oxygen distribution and utilization in connection with cerebral activity (41). There are differences in studies on odor. Cerebral oxygenation levels were found to be higher in newborns who were smelled breast milk than those who smelled formula (40), but smelling breast milk in preterm patients before feeding did not cause a change in cerebral oxygenation (41). While it was found that the smell of hand antiseptic caused fluctuations in cerebral oxygenation in preterms (38), it was reported that the smell of hand antiseptic applied at different waiting periods did not make a difference between the cerebral oxygenation levels of preterms (42).

In music practice: Music is a non-pharmacologic method recommended to reduce stress and pain in preterm newborns hospitalized in NICUs. Music is effective in stabilizing heart and respiratory rates, reducing the frequency of apnea, and improving feeding tolerance (43). Music (such as classical music, lullabies, traditional music, maternal voice) has many benefits in the development of newborns (44). In the literature, the effect of music on cerebral oxygenation levels of newborns is very limited. Different results have been reported: it was observed that hemodynamic changes caused by auditory stimuli in newborns could be reflected by cerebral oxygenation level (45), lullabies and classical music increased cerebral oxygenation in preterms (46), and short-term music therapy had no significant effect on cerebral oxygenation (43).

During sleep: Changes in cerebral oxygenation due to the increase and decrease of neural activity during sleep can be reflected by fluctuations in the brain. However, the number of studies in the literature examining the effect of sleep on cerebral oxygenation levels of newborns is quite limited. NIRS may be helpful in evaluating physiologic and pathologic mechanisms during sleep, investigating cerebral hemodynamic changes that may be caused by sleep disorders such as apnea episodes, and examining the effect of sleep positions on cerebral perfusion (47,48). In studies; decrease in cerebral oxygenation is observed when periodic respiration is performed during active sleep in preterms. Decrease in cerebral oxygenation and increase in fractional oxygen extraction are observed in active sleep in neonates compared to silent sleep. When apnea is experienced during sleep in preterms, a decrease in cerebral oxygenation is observed. It has been reported that there is no significant change in cerebral oxygenation when newborns are given the prone and supine sleeping position in the first postnatal days (47-49). In another study, cerebral oxygenation was found to be low and fractional oxygen extraction was found to be high in the prone sleeping position of unstable extremely preterm newborns. It was stated that this might be a sign of potential brain damage and further studies were needed (49).

Areas Where Abdominal NIRS is Used

In diagnosis, follow-up, treatment, and care planning: It is seen that abdominal NIRS is used in different conditions such as nutritional intolerance, feeding regimens, and NEC (3,10,50). Managing the nutrition of newborns is especially critical for the most vulnerable group, preterm newborns (49). Enteral nutrition is ideal for the development of the gastrointestinal tract in premature neonates due to its reduction of the risk of nosocomial infections, intestinal motor activity, release of gastrointestinal hormones through trophic effects, and improvement of feeding tolerance (12). However, preterm neonates are at risk for gastrointestinal complications such as feeding intolerance and NEC (7,12). Today, the suspicion of NEC is based on clinical findings and abdominal radiographs are used for diagnosis. However, because the clinical manifestations are not specific to the diagnosis, they can be confused with other pathologic conditions such as sepsis (50). For this reason, NIRS, which has the potential to distinguish other diseases at an early stage, can be used to prevent unnecessary treatment in suspected cases (22). At the same time, it has been stated that enteral feeding increases abdominal oxygenation in stable preterm newborns, splanchnic oxygenation does not change in preterms fed with breast milk, there is a temporary decrease in those fed with enriched breast milk, and a continuous decrease is observed in those fed with formula (39). It has been stated that the frequency of blood transfusions increases the likelihood of developing NEC, abdominal oxygenation increases during and after the procedure, but studies on the effect of nutrition on splanchnic tissue oxygenation during the procedure show variable results (3). Özkan et al. (12), on the other hand, stated that the decrease in mesenteric tissue oxygenation during continuous monitoring of

initial enteral nutrition could be used to predict the development of NEC during follow-up. It has been shown that in the presence of hemodynamic ductus arteriosus, there may be a decrease in mesenteric perfusion. Therefore, the limited number of abdominal NIRS studies and the variable results reveal the need to increase research in this area (22).

Evaluation of liver and renal oxygenation: Studies evaluating liver oxygenation are very limited in the literature. Due to the softness of the umbilicus and the change in reflected signals due to peristaltic movements, the instantaneous data of NIRS may give inaccurate results. The hard right upper quadrant can provide more stable signal data than the umbilicus (6,17). When monitoring the oxygenation of the liver, the blood within the vascular network in the liver will also be measured. While liver and sub-umbilical oxygenation was found to be low and fractional tissue oxygenation was found to be high in symptomatic preterm patients with NEC (17), it has been reported that liver oxygenation can be used in the follow-up of mesenteric circulation, but more studies are required. It has been observed that abdominal oxygenation gives very variable results compared with liver oxygenation in stable preterm nutritional intolerance, and although the cerebral oxygenation level remains stable during digestive system operations, the renal oxygenation level tends to decrease (15).

Renal oxygenation monitoring can identify peripheral perfusion changes before they are reflected in pulse oximetry and cerebral oxygenation. Current diagnostic criteria may not detect acute kidney injury at its onset. Therefore, renal oxygenation trends offer a non-invasive approach to the assessment of renal function. It has been observed that renal NIRS can provide data on hypoxic states in the intraoperative and postoperative period, and the use of ibuprofen in preterm patients with patent ductus arteriosus (PDA) does not adversely affect renal and mesenteric oxygenation (6,26).

In olfactory applications: Sensory cues from smell can trigger physiologic responses that facilitate the digestion and metabolism of food (38,39). The smell of breast milk in tube-fed preterms may contribute to an increase in the sucking reflex, acceleration of the transition to oral feeding, an increase in abdominal perfusion, and a decrease in hospital stay. At the same time, positive odor stimulation provides intestinal motility, insulin secretion, release of metabolic hormones, and increased appetite (39). Studies evaluating the effect of scent applications on abdominal oxygenation are very limited.

Differences in Cerebral and Abdominal Oxygenation Assessment

In term newborns, oxygen distribution to vital organs such as the brain should be ensured during labor. Therefore, renal and intestinal oxygenation in stable term neonates may be lower compared with cerebral oxygenation. In stable preterm neonates, cerebral oxygenation values remain mostly constant, whereas renal and mesenteric measurements usually fluctuate considerably because the abdominal region is more sensitive than the cerebral

region and is affected by the movements and bowel movements of the newborn (15). For this reason, cerebral oxygen extraction may be higher than mesenteric oxygen extraction in preterm patients with respiratory problems in the postpartum transition period, and an increase in both may be observed over time. Thus, cerebral and mesenteric oxygen extraction may be affected by physiologic changes with gestational week and postnatal age, and normal ranges of cerebral and mesenteric oxygen saturation remain uncertain in extremely low birth weight preterm neonates, especially through postnatal day 7 (5,6,43).

It has been determined that the abdominal oxygenation value of stable preterm newborns in the first weeks of life is lower in those with a lower gestational age (15), and that the changes in cerebral and mesenteric tissue oxygenation of stable very low birth weight babies of >30 days postnatally do not show a significant difference. Studies have emphasized that this may also be due to the clinical stability of infants and the difference between their postnatal ages. Depending on the clinical status of preterm newborns, a significant increase in abdominal tissue oxygen saturation can be detected compared with cerebral tissue oxygen saturation after blood transfusion, or there may be a positive correlation between hemoglobin concentrations and cerebral and abdominal oxygenation (10,15). In their systematic review, Crispin and Forwood (48) examined the role of NIRS in the cerebral, splanchnic, renal, and muscle regions to detect anemia and guide transfusion decisions, and found that there was a correlation between hemoglobin concentrations and tissue oxygenation. However, it has been stated that more research is needed on the values of tissue oxygenation, which may lead to negative clinical outcomes. It has been shown that post-transfusion cerebral oxygen saturation is increased in preterm neonates with and without PDA, whereas splanchnic oxygenation is lower before, during, and after transfusion in those with PDA. Measurement of cerebral oxygenation in preterm and term neonates has older and clearer evidence than measurement of bowel, kidney, and liver oxygenation.

Reflections of NIRS on the Nursing Profession and Its Use in Neonatal Care

NICUs are areas where newborns are monitored with medical and surgical problems and continuous nursing care and invasive interventions are applied. It is very important for health professionals to adopt a multidisciplinary approach to evaluate critical situations and manage the treatment process effectively (25). This includes the coordinated work of the neonatal physician and the neonatal intensive care nurse in NIRS follow-up. Nurses should diagnose newborns at an early stage in terms of risks that may cause various mortality and morbidity and should perform careful follow-up. One of the guiding devices in this regard is NIRS, which provides ease of use due to its ability to be used at the bedside and is a non-invasive procedure (2). It can be used effectively in many nursing care applications such as the evaluation of vital signs, positioning, intravenous applications, nutritional applications such as orogastric catheter sets, aspiration applications, tracheostomy care, and diaper changing (5).

The fact that preterm babies feel pain frequently and that it persists for a long time may cause neurologic complications in the future. During painful procedures, practices such as kangaroo care, swaddling, and position changes relieve pain and provide changes in cerebral oxygenation levels (25). Therefore, one of the aims of nursing care practices applied to intensive care patients is to protect and maintain tissue oxygenation. For this reason, the points that nurses should pay attention to in monitoring the NIRS device, which is becoming more common in newborns, are important. Thus, the effective use of NIRS devices by nurses plays an important role in protecting newborns from secondary problems (2).

There are some points that nurses should pay attention to in the placement, replacement times, follow-up, and evaluation of NIRS probes:

- The neonatal nurse should position the NIRS sensor according to the area to be evaluated, then attach the end of the sensor cable to the module parts on the monitor and make sure that it fits snugly. Otherwise, the signal quality will be poor and the NIRS value will not be readable (50).
- Placing the sensor on fat deposits, hair, bone spurs, nevi, hematomas, edema or cracked skin, or applying pressure to the sensor may result in inaccurate readings. Nurses should be careful and not stick the probe in these areas (50).
- In newborns receiving phototherapy treatment, the light of the phototherapy device may affect the NIRS value. To avoid this situation, it is recommended to cover the sensor with dark material. The nurse needs to regularly monitor the position of the NIRS probe with phototherapy goggles (50).
- If NIRS monitoring is used in conjunction with electroencephalography, care should be taken to ensure that the area where the probe is attached is clean, as the materials used to attach the electrodes can affect the signal quality.
- Since the adhesive tapes used for umbilical catheter detection in abdominal NIRS follow-up may affect the signal quality, attention should be paid to the place where the probe is attached, and the area should be cleaned (10).
- NIRS values are affected by the baby's movements, improper positioning of the sensor, gestational age, mode of delivery, and the type of device used. There are different emitters, wavelengths, and algorithms among the devices used, and different oxygenation values can be measured (4,16,26).
- It is important for nurses to pay attention to the change of probe location, as prolonged insertion of the NIRS probe in the same spot can lead to inaccurate measurements and irritation (15). In NIRS monitoring studies, skin burns, pressure sores, and persistent skin irritations at term have been observed, especially in preterm neonates (3). Although there is no conclusive evidence of replacement time, it is recommended that nurses change the probe location every 4-6 hours, judging by skin irritation and the need to reposition the sensor. In preterm neonates, the change period may be more frequent

according to need. At the same time, the sensor should be replaced every 24 hours. It has been shown that reapplying sensors used in the same area in 24 INVOS devices can lead to a degree of inaccuracy of up to 6% (26).

- It is reported that skin burns that may occur due to the use of transcutaneous NIRS in newborns are not caused by damage to the tissue by light intensities, but are a result of the sensor being stuck in the same point for a long time, especially due to the skin sensitivity of extremely preterm newborns (6).
- Major weight changes in the first weeks of life can affect the depth reading of the NIRS sensor. In a study evaluating cerebral, renal, and intestinal oxygenation, a weak positive correlation was found between weight change in the first weeks of life and only intestinal oxygenation in preterm newborns (15).
- After the NIRS probe is attached, it is necessary to wait for a certain period for net measurement. Abnormal values in the first minutes should not be taken into account by the nurse (7,17). Due to the inherent variability of the measurements performed with NIRS sensors, it is important to monitor the baseline data for a sufficient period (several hours) for an accurate result. NIRS values tend to change with increasing postnatal age and can be influenced by factors such as anemia, hypotension, and acidosis (2,15). Nurses should not ignore these conditions in regional tissue oxygenation follow-up.
- Although cerebral oxygenation values remain mostly constant in stable preterm neonates, there are large fluctuations in renal and mesenteric measurements. The purpose of NIRS measurements is to observe persistent and/or frequent changes that are greater than 15% from baseline (2,15). Hyperoxia and hypoxia are undesirable conditions for newborns. Therefore, the tissue oxygenation index reference range of newborns is expected to be between 55% and 85%. In particular, a NIRS value below 45% is considered a dangerous area and the nurse must inform the physician (16). In this respect, it is critical for nurses to have sufficient knowledge of NIRS values for follow-up and evaluation.
- A NIRS value below 55% may occur in conditions such as hypocarbia, hypotension, PDA, anemia, and low arterial saturation, and above 85% may occur in conditions such as hypercarbia, supranormal arterial saturation and hypoglycemia (16). The neonatal nurse should keep in mind that oxygen is a drug and should consider hyperoxia and hypoxia in the evaluation of regional oxygenation.
- Probes may be irritated, frayed, and ruptured due to long use. In such cases, nurses need to replace the probe with a new one.
- A probe is often attached under the umbilicus to evaluate abdominal oxygenation. Especially if intestinal oxygenation is to be evaluated, the bottom of the umbilicus is preferred due to the wide size of the neonatal abdomen and the confounding effect of the current position of the renal and hepatic tissues (7,15). The sub-umbilicus bladder and pelvic wall may also

reflect the oxygenation of muscle tissue, but it is thought to affect it less than the major organs (6). In addition, abdominal oxygenation is difficult to evaluate due to the inside, hollow structure of the intestine, peristalsis, and large surface area (2). Nurses should consider these factors when following up infants undergoing abdominal oxygenation monitoring.

Conclusion

In recent years, the measurement of oxygen consumption of tissues using NIRS technology has become increasingly common in neonatal centers. NIRS can be used effectively in many nursing practices such as the evaluation of vital signs, non-pharmacologic interventions, intravenous applications, aspiration applications, and tracheostomy care. It is seen that the use of NIRS in Türkiye is mostly research-based and its use in the clinic is very limited. The increasing number of studies is promising for its widespread use in the clinic. There is no review in the literature that deals with the nursing care dimension of NIRS use. It is thought that nurses' knowledge of the points they need to pay attention to regarding the use of NIRS and their reflection on their care will contribute to the use of the device in nursing care. With the expansion of work in this area and the increasing spread of this technology in neonatal units, the tool can be used in the routine care of newborns in the near future. In addition, it is important to increase research by considering the diversity in NIRS devices and probes, the high cost of the device, the fact that it is affected by many factors such as gestational week, and the difficulties in interpreting regional oxygenation, such as deficiencies in universal normative values.

In the literature, it is seen that there are more studies on preterm newborns for NIRS technology compared with term neonates. At the same time, studies on the effects of smell, music, sleep and position on cerebral and abdominal oxygenation seem to be limited. In studies on diagnosis, treatment, and care, there are variable results. For this reason, it is recommended to increase medical and nursing studies and clinical awareness in preterm and term newborns. In conclusion, the measurement of cerebral oxygenation in preterm and term neonates has older and clearer evidence than the measurement of gut, kidney, and liver oxygenation. However, for the use of NIRS to become a standard monitoring technique, studies need to be expanded and increased.

Footnotes

Authorship Contributions

Concept: H.Ö., S.Y., Design: H.Ö., S.Y., Data Collection or Processing: H.Ö., S.Y., Analysis or Interpretation: H.Ö., S.Y., Literature Search: H.Ö., S.Y., Writing: H.Ö., S.Y.

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