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CASE REPORT

Near infrared spectroscopy (NIRS) in neonatal intensive care unit: experience of a brazilian university hospital

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Abstract

Near-infrared spectroscopy (NIRS) is a non-invasive method to assess regional brain and/or renal oxygenation, and an important tool for a better clinical management. The aim of this study was to describe clinical cases of newborns admitted to the Neonatal Intensive Care Unit of a Brazilian university hospital who were monitored with NIRS, and to evaluate the applicability of NIRS demonstrating its use as a continuous monitoring method for newborns at high risk for brain injury. This study was part of the Conclusion Work of Medical Residency in Neonatology in Neonatology. Case 1: Persistent ductus arteriosus-NIRS guided indication for drug treatment. Case 2: Septic shock-NIRS was helpful identifying the need of inotropes. Case 3: Anemia of prematurity-NIRS showed an increase of cerebral oxygenation after red blood cells transfusions. Case 4: Hypoxic-ischemic encephalopathy-NIRS identified sign of poor neurological prognostic. NIRS is a continuous cerebral and renal perfusion monitoring method that has easy and good applicability and no complications. The cases reflect the importance and potential of NIRS in clinical practice and in helping diagnose for newborns, as well as enabling prognostic assessment. NIRS proved to be a method of good applicability, without short-term complications. Observing brain oxygenation values can help to avoid conditions associated with the development of neurological sequelae.

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INTRODUCTION

Many high-risk newborns evolve with neurological sequelae and brain injuries in neonates can be caused by changes in cerebral perfusion and oxygenation, showing how important is brain monitoring to reduce morbidity[1].

Near Infrared Spectroscopy (NIRS) is a non-invasive and secure method for continuous monitoring of regional tissue oxygenation at the bedside[2,3]. It allows a real-time assessment of hemodynamic and oxygenation changes in regional tissue, by monitoring the balance between oxygen supply and consumption, being possible to monitor even the most clinically unstable and immature newborn[2,4]. NIRS provides regional oxygen saturation (rSO2) status using a similar technique of pulse oximetry (SpO2), taking advantage of the differential absorption spectrum between oxygenated and deoxygenated hemoglobin in relation to the near-infrared light beam[2,3,5].

The proximal detector receives signal from superficial tissues, while the distal detector receives signal from superficial and deep tissues. The proximal value is subtracted from the distal value. The result represents oxygen saturation at a depth of 1 to 2cm in the deep tissue and demonstrates the rSO2 of the underlying tissue[5]. A decrease in rSO2 indicates a decrease in blood flow, resulting in decreased oxygen supply or increased oxygen extraction from the underlying tissue. Bedside physicians can check rSO2 at real time to get immediate treatment, guide interventions and receive immediate response through specific interventions, and NIRS may also be helpful to assess prognosis[5].

A multicenter, randomized study, SafeboosC Study, demonstrated that regional cerebral oxygen saturation (rScO2) remained quite stable, especially within the 55-85% range in 166 extremely premature newborns during the first 72 hours of life[1]. This rScO2 interval has been used as a reference for normality in several studies[6-8]. Cerebral oxygenation above or below this range in a length of time, may be related to worse neurological comorbidities and prognosis[2,4].

NIRS allows monitoring changes in regional oxygenation, oxygen extraction and perfusion of the immature brain, in addition to assessment of auto-regulation blood flow in premature and term newborns[2-4]. This monitoring method may be associated with a better long-term cognitive and motor prognosis, possible due to the ability to avoid oscillations in cerebral oxygenation[2]. However, the high cost of inputs, lack of knowledge by professionals and, mainly, lack of evidence, are still limitations for the use of NIRS in neonatal intensive care units (NICU)[2].

This study aimed to describe clinical cases of high-risk newborns admitted to the NICU of a Brazilian university hospital who were monitored with NIRS, and to evaluate the applicability of the use of NIRS demonstrating its use as a method of continuous monitoring cerebral and systemic (renal) oxygenation in newborns. This study was part of the Conclusion Work of Medical Residency in Neonatology. The device used was INVOS™ 5100c (Medtronic) and electrodes used were from neonatal size[1,4,6].

CASE 1 – PERSISTENT DUCTUS ARTERIOSUS (PDA)

Newborn delivered by C-section due to twin gestation, first twin, female, Apgar 2/4/7, birth weight was 960 grams and gestational age (GA) 29 weeks. On eighth day of life, it was observed a murmur and physical examination compatible with PDA and signs of pulmonary congestion. An echocardiogram was performed and showed a 3mm PDA. The newborn evolved with hemodynamic instability and need of inotropes, she was monitored with NIRS and it was observed a poor cerebral and renal perfusion and the treatment with nonsteroidal anti-inflammatory drug was indicated. In echocardiogram control, it was observed closure of the ductus arteriosus and rScO2 and regional renal oxygen saturation (rSrO2) returned to normal (Figure 1 A).

CASE 2 - SEPTIC SHOCK

Newborn whose mother did not have any prenatal care, alcohol and illicit drugs addicted, including crack use during pregnancy. Newborn was born by vaginal delivery at home, female sex, unknown Apgar, birth weight 2120 grams, gestational age of 35 weeks and 1 day. Newborn admitted with respiratory failure and need of invasive mechanical ventilation and administration of exogenous pulmonary surfactant. She evolved with septic shock and pulmonary hypertension, requiring the use of inhaled oxide nitric and inotropes. During NIRS monitoring, it was observed significant decrease in renal and cerebral saturations. Dopamine was introduced and we observed an increase cerebral and renal blood flow once inotropic drugs can increase cerebral perfusion (Figure 1 B).

CASE 3 – ANEMIA OF PREMATURITY

Newborn whose mother had HELLP syndrome (abbreviation of: H: hemolysis EL: elevation of liver enzymes, and LP: thrombocytopenia), female sex, Apgar 3/8, birth weight 1520 grams and gestational age of 32 weeks and 6 days. Anemia of prematurity was diagnosed, and she required two blood transfusions on 11th and 27th days of life. Before transfusion, although rScO2 presented values inside reference values, after receiving red cell concentrate, there was an increase in regional oxygen saturation (Figure 2 A).

CASE 4 - HYPOXIC-ISCHEMIC ENCEPHALOPATHY (HIE)

Newborn born by vaginal delivery at home, male sex, unknown Apgar, birth weight 2355grams, gestational age 37 weeks and 4 days. He was admitted with approximately 30 minutes of life and had signs of severe HIE. He needed invasive mechanical ventilation, and blood gas analysis on

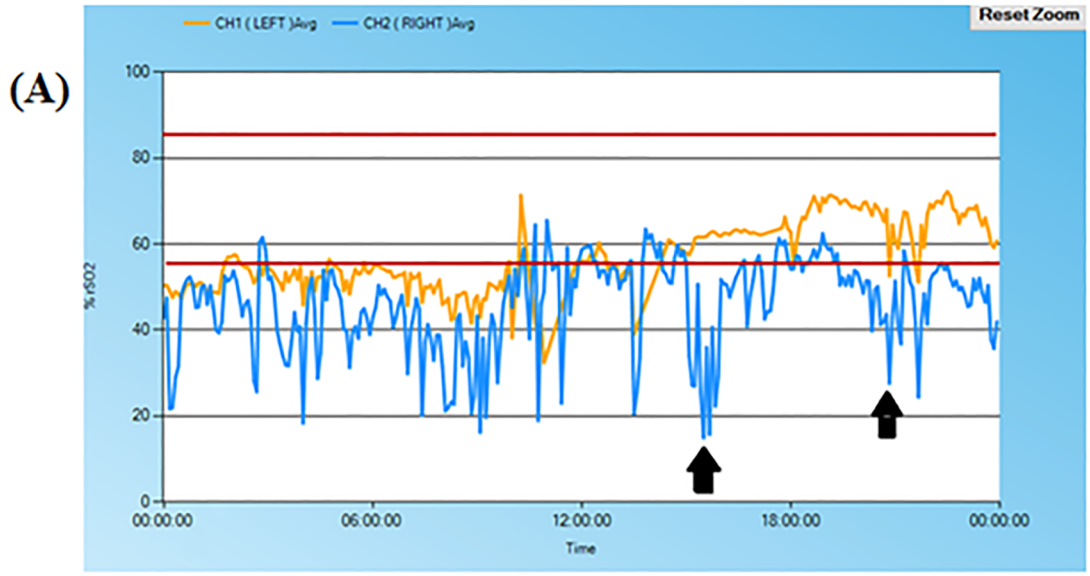


Figure 1. A: Decreased cerebral blood flow (in blue) due to the presence of left/right arterial shunt due to the presence of patent ductus arteriosus in extremely premature newborns.

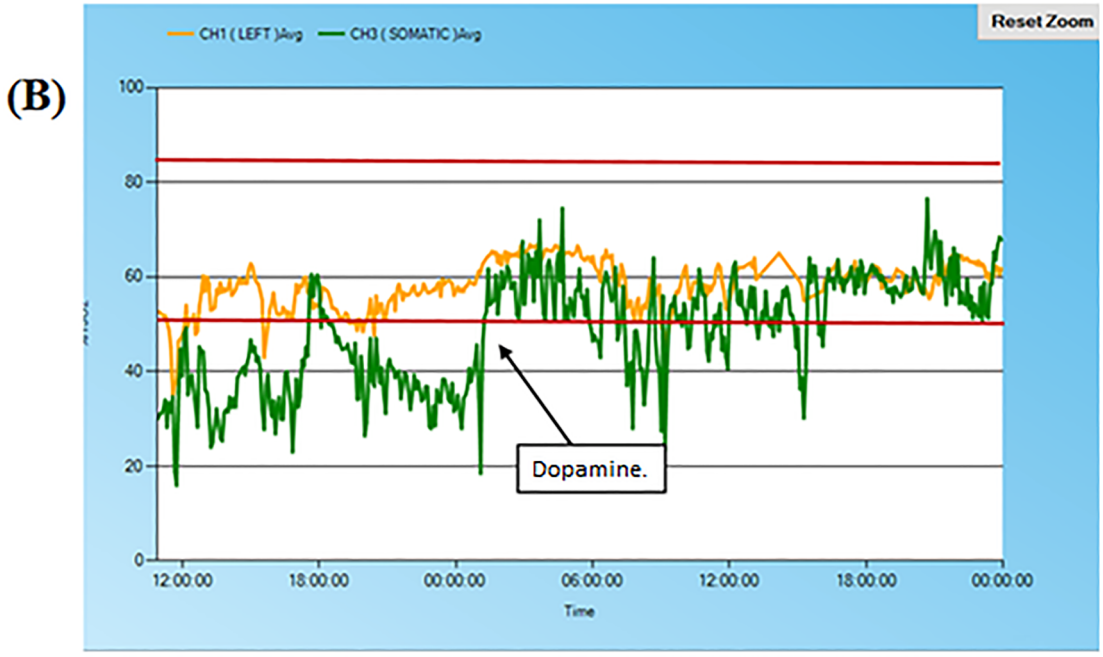


Figure 1. B: Decreased tissue perfusion (renal flow in green) due to altered blood flow caused by the systemic inflammatory process by an infectious agent; C. Self-regulatory mechanism with increased cerebral flow (in yellow).

admission showed metabolic acidosis. It was indicated treatment with therapeutic hypothermia and monitoring with NIRS. During monitoring, despite renal blood flow values were inside reference range, rScO2 values were above the reference range after 24 hours of life. Patient evolved with major lesions in brain magnetic resonance imaging (MRI) and altered neurological physical examination before discharge (Figure 2 B).

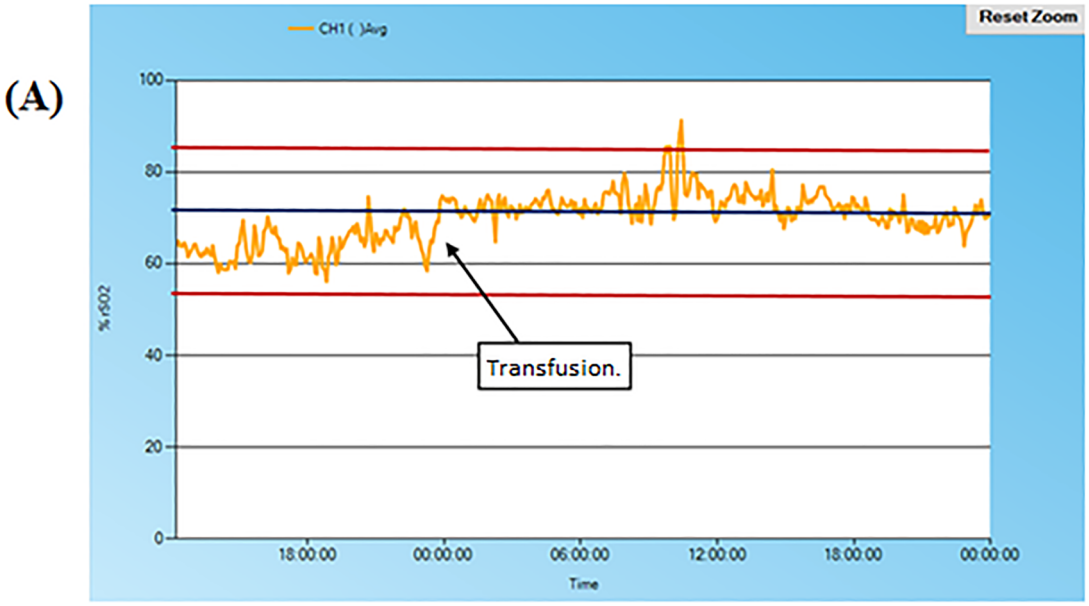


Figure 2. A: Decrease cerebral blood flow due to decreased number of red blood cells.

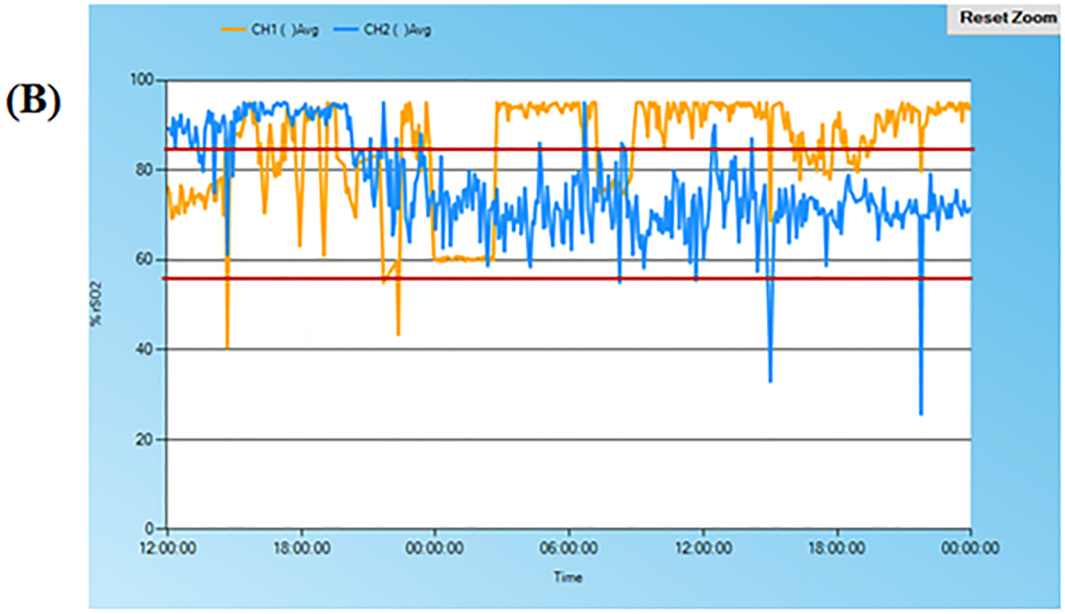


Figure 2. B: Acute cerebral insult of an evolutionary character, leading to a great inflammatory process with neuronal deterioration and apoptosis (cerebral flow in yellow); C. An extremely premature newborn did not show cerebral self-regulation, having a greater chance of peri-ventricular hemorrhages in the first days of life (cerebral flow in yellow and renal flow in blue).

DISCUSSION

Hemodynamically significant PDA (hsPDA) can decrease cerebral blood flow due to the presence of arterial shunt between Aorta and Pulmonary Artery in extremely premature infants, and it can impair brain oxygenation when rScO2 values are less than 40-45%[4,9]. Prolonged length of cerebral hypoxia has been associated with brain injury and impaired

metabolism[10]. PDA may be related to an increase in pulmonary blood flow and a decrease in systemic blood flow. NIRS can detect decreased regional perfusion, including kidneys and brain. Since kidneys blood flow are not well self-regulated as the brain, renal saturation levels will decrease significantly in the setting of PDA and can be used to predict hemodynamic significance[6]. Studies have reported that hsPDA can affect cerebellum growth, and it was independently and directly related to oxygenation of brain tissue[4,9]. Monitoring rScO2, especially when there is significant cerebral hypoxia as in Case 1, can impact treatment decisions regarding the need for PDA closure treatment[4,9].

In septic shock, there is a decrease in tissue perfusion due to changes in blood flow caused by systemic inflammatory process by the infectious agent[11]. In Case 2, the newborn with septic shock had clinical repercussions and it was observed diminished values of cerebral and renal saturation. A medical professional was notified to perform interventions trying to increase rScO2 and avoid long-term cerebral damage. After the introduction of inotropes, an improvement of regional saturation values occurred[4].

There is a negative association between anemia and cerebral oxygenation. Anemia may contribute to lower values of cerebral saturation due to a decrease in the number of erythrocyte load. NIRS monitoring with rScO2 can help determine the need of blood transfusion in premature newborns with borderline levels of hemoglobin[12]. Tissue oxygen supply is directly affected by hemoglobin levels. The presence of anemia affects directly cerebral and systemic saturation[13]. Regional blood flows increase in preterm infants with symptomatic anemia during red blood cell transfusion and an increase in oxygen supply is observed, compensated by decreased oxygen extraction. Studies suggest that blood transfusions are associated with a decrease in the speed of cerebral blood flow. In Case 3, although the clinical indication of blood transfusion was not associated with a reduction in NIRS values, there was a significant increase in regional cerebral flow and subsequently clinical improvement after two blood transfusions. The NIRS values did not fall below the normal range in this case, however, it was possible to observe how the NIRS behaved before and after the transfusions. It demonstrates that significant changes in oxygen delivery may not be highlighted by pulse oximetry or the vital signs, but it can be detected earlier by monitoring with NIRS[13].

HIE is characterized by an acute cerebral insult which evolves over first days of life, leading to a great inflammatory process with neuronal deterioration and apoptosis[14,15]. In case 4, NIRS monitoring with rScO2 demonstrated alteration of brain blood flow, anticipating unfavorable neurological outcome. The supra-physiologic values of rScO2 during first 24 hours of life in a severe HIE scenario can be explained by the low brain energy metabolism after severe injury. This suggests low oxygen use, cerebral hyper-perfusion and impaired brain blood flow auto-regulation. This finding has been associated with death and impaired neurological outcome[14,15].

These clinical cases aim to portray the importance and potential of NIRS in clinical practice, allowing early and assertive diagnosis and prognosis assessment, guiding treatment decisions in high-risk infant. Observation of cerebral and renal oxygen saturation values changes can potentially help to avoid conditions associated with altered neurological outcomes.

This study observed potential benefits of NIRS monitoring in conducting clinical cases at different settings in NICU and no adverse effects related to the electrodes were observed. The use of NIRS showed to be a non-invasive method with good and easy clinical applicability in the neonatal period, a tool for a refined care with critically ill infants, assisting decision making and anticipating diagnoses and prognosis.

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