MONITORING OF CEREBRAL OXYGENATION USING NEAR INFRARED SPECTROSCOPY IN PRETERM NEONATES ON ASSISTED VENTILATION

Nicoleta Ioniță[1,2*], Mirabela Adina Dima [1,2*], Alina Elena Agoşton-Vas[2], Constantin Ilie[1,2]

Abstract

In the Neonatal Intensive Care Unit (NICU) we deal with one of the most vulnerable patients, the premature born infants. Nowadays despite medicine evolution the percent of prematurity is high; due to developing therapeutic modalities their life expectancy increases but one of the major concern for us is their outcome. In this study we monitored for 48 hours a group of 42 neonates admitted in the NICU. Inclusion criteria: gestational age < 32 weeks, cardio-pulmonary resuscitation in the delivery room, no congenital malformations, the need for Surfactant administration and mechanical ventilation. We monitored vital signs and besides cerebral and somatic oxygenation using Near Infrared Spectroscopy (NIRS). This technique is based on the optical properties of the tissue due to the natural chromophores, hemoglobin, deoxyhemoglobin and cytocrome oxidase with different characteristic absorption spectra in the visible and near-infrared wavelength range. We used an INVOS 5100 device. We compared the values recorded using NIRS with the values showed on the monitor of the pulsoxymeter, blood gases and blood pressure. Our main goal was to prevent hyper or hypoxia. Guiding our therapeutical decisions and modifying ventilator parameters with good response on the cerebral oxygenation, we concluded that NIRS is a very useful noninvasive and real time method of investigation. Meanwhile we had no significant changes in the peripheral oxygenation. Avoiding hyper and hypoxia in premature neonates can improve their neurodevelopmental outcome.

Key words: premature infants, cerebral oxygenation, near infrared spectroscopy, brain, mechanical ventilation, outcome.

Introduction

The most vulnerable category of patients in the Neonatal Intensive care Unit (NICU) are premature infants. In Europe the percentage of premature births is 8% and in Romania is over the European range. Premature infants mortality is high, almost 40%. They are extremely vulnerable to all the environmental and medical aspects. These infants and especially their brain is very immature [10]. Nowadays the main concern in the NICU is to improve their outcome, that's why the intensive care protocols are looking forward to establish less manipulating and invasive therapeutic management [5,6]. As we mentioned premature infants' brain is not ready for the extrauterine life and its adaptation and development shows up with sequels. Most of these patients need resuscitation in the delivery room; the first therapeutic gesture is to administer oxygen. It can save their life but it can also be harmful. In the NICU it is very important to know when, for how long and how much oxygen to administer. Pulsoximetry and blood gases are routinely used in order to avoid hypo and hyperoxia. But recently was concluded from literature and clinical cases that it is not conclusive if we want to appreciate brain oxygenation. A promising method to investigate that is Near Infrared Spectroscopy (NIRS); it was first described by Jobsis in 1977 [1]. First reported studies on cerebral oxygenation in newborn infants belong to Brazy, Darrell, Lewis, Mitnick and Jobsis from 1985 [2,3]. Reynolds and colleagues (Edwards et al., 1988; Reynolds et al., 1988; Wyatt, Cope, Delpy, Wray & Reynolds, 1986) monitored sick newborn infants and they reported the changes in regional hemoglobin concentrations, cerebral blood flow and cerebral blood volume. This technique is based on the optical properties of the brain tissue due to the natural chromophores, hemoglobin, deoxyhemoglobin and cytocrome oxidase with different characteristic absorption spectra in the visible and near-infrared wavelength range [3]. To convert the changes in absorption and attenuation in concentration of the chromophores it is used the Modified Lambert Law.

Objectives

Human brain is one of the most complex organs and not even nowadays enough investigated. Moreover newborns' brain is immature and more susceptible because of prematurity. Although the etiology of brain damage is multifactorial and even partly unknown, hypoxia, hyperoxia and hemodynamic instability during the first days of life seem to play an important role. Our purpose is to improve our understanding regarding premature infants' brain and to develop our abilities and therapies in order to offer them a better neurodevelopmental outcome. NIRS is a modern and noninvasive method of monitoring and we want to take advantage of that. We monitored a group of premature neonates using an INVOS device and we had a real time monitoring of the brain oxygenation so we could intervene earlier, compared to the interventions guided on the routinely used methods of investigation.

[1]University of Medicine and Pharmacy "Victor Babeș" Timișoara, România – Department of Obtetrics-Gynecology and Neonatology, *Ph.D. Student

[2]Clinical Emergency Hospital – Bega Universitary Clinic, Timișoara, România

E-mail: ionita_nicoll@yahoo.com, dima_mirabela@yahoo.com, alinaelena.agoston@yahoo.ro, constantinilie@umft.ro

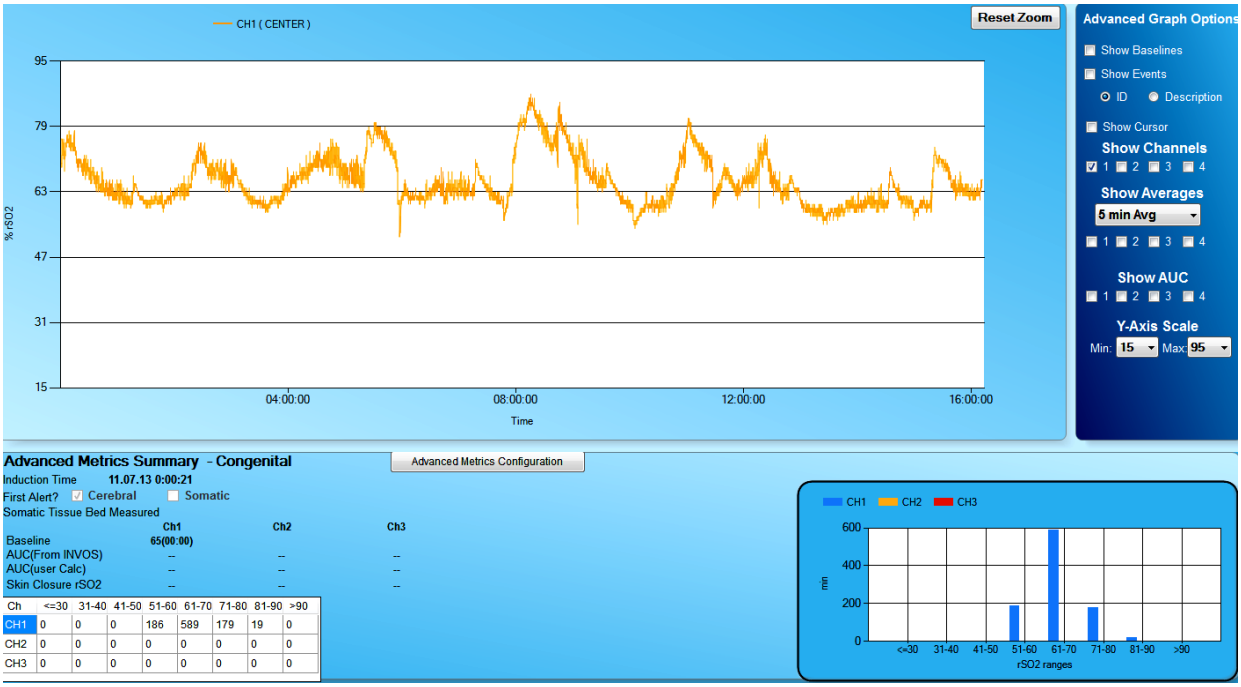

Fig. 1. Cerebral oxygenation recorded in a premature neonate in the NICU

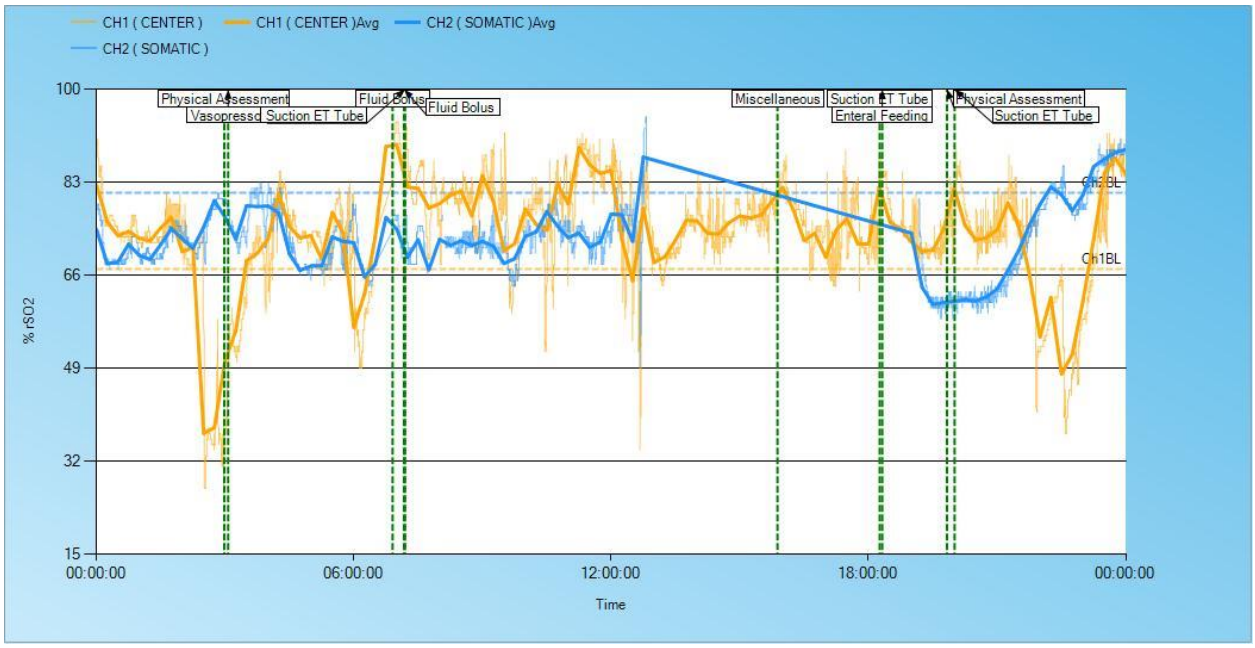

Fig. 2. Cerebral (yellow) and somatic (blue) oxygenation and the fluctuation at the performance of different gestures in the critical care of a premature neonate.

Fig. 3 NICU

Patients and method

We included in our study 180 neonates who were admitted in the NICU between January 2013 – January 2014. We chose for monitoring the neonates with gestational age < 32 weeks and birth weight < 1500 g. Our final study lot consists of 42 neonates; we will mention further the exclusion criteria. 80% of them born by cesarian section; all of them needed cardio-pulmonary resuscitation in the delivery room (VPPO2 +/- MCE); mean Apgar score 6/5. Maternal pathology: pregnancy induced hypertension (15%), premature membranes rupture > 24 hours (25%), untreated urinary tract infections (13%), genital infections most of them with Group B Streptococcus (18%), placenta praevia (18%) , normal inserted placenta detachment (11%). Over 30% of the neonates had maternal-fetal infections; from these cases 9% being no medical followed-up pregnancies. All the neonates included in the study lot were intubated and needed mechanical ventilation for at least 3 days; 26 (61%) of them needed curative Surfactant administration. After taken from the delivery room, each neonate was placed in the NICU in a preheated, humidified incubator. We placed on the right arm the pulsoximetry sensor. We used a Nellcore pulsoximeter. The umbilical vein and artery were catheterized, we intubated the infant and we administered Surfactant (Curosurf) 200 mg/kg as it is mentioned in the guides. Right after we connected the infant to the ventilator we placed on the right forehead [4] the INVOS sensors and we started to monitor the regional cerebral oxygenation (rScO2). Before that we cleaned properly the skin surface and we assured that there are no lesions, hemangioma or excessive hair under the sensor [7]. We used an INVOS 5100 (Somanetics) device, a memory stick was attached to the monitor and data were processed on a laptop IBM Think Pad T410 using SPSS Statistics 17.0. rScO2 was monitored from the first 3 hours of life and during 48 hours; we also monitored cerebral fractional tissue oxygen extraction (cFTOE). The reference limits for rScO2 were established between 55-85%. Blood pressure, heart rate, blood gases (arterial blood), peripheral oxygen saturation (pulsoximetry, SaO2) were also monitored [10] (Fig.3). Together with the SaO2, cFTOE can be calculated ((SaO2-rScO2)/SaO2). Somatic sensors are also available, we placed one on the renal area, but in this paper we will only dscuss the cerebral oxigenation aspects. We excluded from the study lot all the neonates with congenital cardiac malformations other than persistent ductus arteriosus (PDA), central nervous system or gastro-intestinal malformations; inconclusive recordings due to errors when placing the sensors (the skin was not well cleaned or for any other reason the sensor detached and environmental light penetrated), or we did not get parental written consent for the study. We also excluded 2 cases of neonates who died before 72 hours of life and 1 case of a neonate with gestational age < 28 weeks with large PDA who needed transfer for cardiac surgery. We selected from the INVOS menu the events which were to be performed during critical care of the neonates: miscellaneous, physical assessment, oral and endotracheal tube suction, repositioning, feeding, seizures, intravenous bolus and sedation. The nurses were trained in using the INVOS device and to select the event every time they noticed a change in the clinical status of the patient or every time they performed one of the gestures mentioned above.

Results

In the end we found conclusive for our study 24 of the recordings. We encountered problems in placing the sensors (they detached or the environmental light penetrated), not all the events were marked at the right time or the memory stick was not attached from the beginning. The 24 recordings are correct and clear. We find important to mention that all the neonates developed right after birth severe respiratory distress, metabolic and then respiratory

acidosis, hypotension, cardiac rhythm disorders (alternating tachycardia and bradycardia), hypoglycemia, apnea, seizures. Before intubation we had a peripheral oxygenation < 75% (SaO2) despite the administration of FiO2> 60%, tachycardia, hypotension, CO2 > 50%, pH< 7,25, $NaHCO3^{-}$ = 12 (mean value), Becf = -14 (mean value). 30 minutes after intubation and after we connected the infant to a ventilator we repeated blood gases analyze and the parameters mentioned above were between ranges; SaO2 > 95%. We also started to administer medication [9]. Initial ventilatory parameters in the IPPV mode: PIP= 20 cmH2O, PEEP = 4 cmH2O, FR= 50 r/min, Ti/Te= 1 / 2, FiO2 = 80%. Our goal was to have a SaO2= 80 - 92%. Some of the premature infants (10) needed higher ventilator parameters: PIP= 22-24 cmH2O, PEEP= 5 cmH2O, FR= 60 r/min, FiO2= 90-100%. We had to maintain the neonates ventilated in the IPPV mode > 3 days; 9 of them were switched to SIMV mode after 24- 48 hours and extubated after 24-32 hours, having a favorable clinical evolution. When we started the monitoring of the rScO2, we had a mean baseline value < 65% (the preterm neonate was already on mechanical ventilation and the SaO2 > 95%). After 10-15 minutes of observation while the infant was also receiving medication and hemodynamic support the rScO2 values raised > 75 %. During hypotension episodes the necessary of cerebral O2 raised [2]; periods with a significant correlation between rScO2 (and cFTOE) and mean arterial blood pressure suggested more periods of lack of cerebral-vascular autoregulation; we noticed decreases of the rScO2 also during seizures, the SaO2 was also decreasing but the fluctuations were higher on the cerebral oxygenation and lasted longer. A heart rate > 200 bpm determined the sudden decrease of the rScO2 [1,2] from 75% to 30%, under the critical limit of 45%, while we had no significant changes on the SaO2 (95-98%). We decided to administer 10% calcium gluconate intravenous slow and we noticed that the heart rate was decreasing < 170 bpm simultaneously with the gradually increasing of the rScO2. This was a prove that we are having a real time monitoring of the cerebral oxygenation. Infants with PDA [8] had lower rScO2 and higher cFTOE values, compared with the neonates without PDA. These neonates were periodically investigated by a cardiologyst who performed cardiac ultrasound; he did not decide in any of these cases to start the administration af Indomethacin or Ibuprofen [8]. We also confronted good peripheral oxygenation, but a persisting low rScO2 (under the baseline value of 65%); we lower the ventilator parameters and we noticed no significant changes in the SaO2 values (< 5%), while the rScO2 was increasing immediately. In 9 cases we had a larger variance of the rScO2 (persisting low values) despite a SaO2 > 92%, low ventilator parameters, normal heart rate, blood pressure and blood gases values. In evolution we noticed that these premature neonates developed IIIrd degree intraventricular hemorrhage and had a severe form of hypoxic-ischemic brain injury.

Conclusions

INVOS is a very reliable method of investigation. The sensors are easy to be applied and also the menu is at reach for all. We had no accidents such as skin burn after applying the sensors. A very important aspect for our neonatal critical care is that NIRS is a noninvasive and real time monitoring method which can be used as a trend. The recordings are not influenced by environmental noise, movements (we could manipulate the neonate while monitoring the rScO2, we changed the endotracheal tube etc), temperature and the sensor does not have to detect a pulse. Guiding on the values from the INVOS monitor we could intervene on time , before having laboratory results despite good values of the SaO2 or apparently stationary clinical status. We concluded that pulsoximetry which is routinely used in the NICU does not have sensitivity and organ specificity. As we previously mentioned premature neonates brain is very immature and too much oxygen or an aggressive mechanical ventilation (high ventilator parameters) can be harmful so using the INVOS device we could intervene on time, reducing the FiO2 or we improved therapeutic procedures. We find important to routinely use NIRS in the premature neonates' critical care in order to improve their neurological outcome.

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Correspondance to:
Nicoleta Ioniță
Clinical Emergency Hospital – Bega University Clinic
12 Victor Babes St
Timișoara, România
E-mail: ionita_nicoll@yahoo.com