

Chapter 4

Use of Near-Infrared Spectroscopy in the Neonatal Intensive Care Unit

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ABSTRACT

Near-infrared spectroscopy was first described in 1977 as a non-invasive technique to measure the cerebral oxygenation and cytochrome oxydase. Different techniques have been developed resulting in new instruments that make it possible to measure cerebral oxygenation in a non-invasive way. In this chapter the physiology and pathophysiology in relation to the measurement of cerebral oxygenation are explained and the direct possible clinical use enlightened, with special focus on measurement of ischemic cerebral hypoxia. The measurement of other organs like the liver, the bowel and the peripheral circulation are described. At the end, a short overview of future possible bed-side measurements like functional near-infrared spectroscopy, near-infrared imaging and photoacoustic measurements are given.

1. INTRODUCTION

In this chapter an overview will be given regarding the use of near-infrared spectroscopy in the neonatal intensive care unit. The focus will be on the use of direct cerebral monitoring and the topics

regarding functional near-infrared spectroscopy and imaging will not be discussed in detail.

Near infrared spectroscopy (NIRS) is for the first time described for medical use in 1977 by Jobsis (1977). In this paper it was used for the measurement of cytochrome oxydase in myocardial insufficiency. The use in neonates to measure cerebral oxygenation was first reported by Brazy (1986) and Delpy (1987). Since then near-infrared

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spectroscopy started to become more popular for research in neonates; however, it remained a difficult task to acquire stable measurements. This was mainly due to the instrumentation that was very sensible for movement artefacts and also because of the applied technique (Beer-Lambert Law) where absolute values are not measured. Different studies in physiology, pathophysiology and the use of medication were performed during the 80's and 90's in research settings. It was the introduction of spatially resolved spectroscopy by Matcher (1995) and Suzuki (1999) that made it possible to measure absolute values with spatially resolved spectroscopy. Because this method is less movement-sensitive, easier to use and reporting absolute values it led to commercial monitors that are increasingly used in cardiac surgery and also in neonatal intensive care units. The objectives of this chapter are to describe the technique of near-infrared spectroscopy, the use of NIRS in the neonatal intensive care unit for research and the future possibility to use this monitoring for clinical purposes.

2. TECHNIQUE OF NEAR-INFRARED SPECTROSCOPY

The relative transparency of biological tissue to light in the near infrared part of the spectrum (700-1000 nm) enables photons to be detected following passage through tissue at distances of up to 8 cm. As the light passes through the head it is attenuated due to a combination of absorption and scattering. Brain contains three changing chromophores that are present in variable concentrations: oxyhaemoglobin, deoxyhaemoglobin and cytochrome oxidase. Attenuation of transmitted light in the brain due to other causes (muscle, bone, bilirubin, ...) will be assumed to be constant over the period of monitoring. Consequently any change in observed attenuation is due to a change in the concentration of these chromophores. Because of safe levels of light input, it is difficult to

use source-detectors distances of more than 5 cm (Wolf, 2009) and because of scattering and acquiring enough depth of measurement the minimum interoptode distance will probably be around 1.5 to 2 cm (Faris, 1991). The depth measured with this method is around half of the source-detector distance, so between 1 and 2.5 cm (Choi, 2004). Different techniques are used to measure the cerebral oxygenation.

2.1. The Continuous Wave Single Distance Spectrometers: The use of the Beer Lambert Law

For accurate quantification, the distance travelled by photons through the tissue (the optical pathlength) must be known and remain constant. The distance between the emitting and receiving optodes is known, but light does not travel in straight lines. Instead, photons are scattered by tissue components and diffused through the brain. The Modified Lambert-Beer Law allows converting changes in absorption and attenuation in changes in concentration of the chromophore (Elwell, 1995).

$$A = \text{Log } I_0/I = \alpha \cdot c \cdot d \cdot B + G$$

A is the attenuation measured in optical density. I_0 is the light intensity incident on the medium and given by the laser or LED light of the spectroscope. I is the light intensity transmitted through the medium and measured by the spectroscope. α is the specific extinction coefficient of the absorbing compound measured in $\mu\text{molar}^{-1} \cdot \text{cm}^{-1}$, this is well known and shown in Figure 1. C is the concentration of the absorbing compound (HbO_2 , HbR or cyto) in the solution measured in μ molar. d is the distance between the points where the light enters and leaves the solution measured in cm. B is the differential pathlength factor. Because light does not travel through tissue in a straight way, d (the geometrical pathlength) has to be multiplied by B to find the differential pathlength which is

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