NEAR INFRARED SPECTROSCOPY FOR BRAIN OXIMETRY

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ABSTRACT

Monitoring of the oxygen saturation is an important procedure adopted during most surgical procedures and for continuous monitoring in ICU. The normal way involves measurement of arterial saturation at pulsatile locations like ear lobe, finger or the forehead. Complex cardiac procedures like cardiac bypass surgery involve additional measurement of cerebral oxygenation. Newborns with critical health conditions are born in neonatal intensive care unit (NICU). The most important problem they face is the risk of brain injury. The best form to monitor brain injury is through monitoring tissue oxygenation. This paper gives a review on near infrared spectroscopy (NIRS), technical aspects and clinical applications of Brain Oxygen Monitoring.

Keywords: Brain Oximeter, Cerebral Perfusion, NIRS, Reflectance Oximetry, Regional Oxygen Saturation

I. INTRODUCTION

Oxygen is the basis of the human survival. Oxygen diffuse through the arterioles in to the lungs and complexed with the hemoglobin molecules in the red blood corpuscles (RBC's). Oxygen plays a critical role in overall metabolism. A rich network of blood vessels supplies enough blood to brain and hence enough oxygen is delivered for healthy brain metabolism. No matter adults brain occupies only 2% of the total body weight but it consumes about 15% of the cardiac output and almost about 18-20% of total body oxygen consumption [1]. Monitoring of brain becomes essential during complex procedures like cardiac and major vascular surgery. Cerebral oximtery is a method to monitor regional cerebral perfusion. Cerebral Hypoxia, Cerebrovascular diseases, Cerebral Palsy are some of the conditions which can be diagnosed using this technique. [2] Preterm neonates always have a risk for brain injury, so it becomes critical to monitor their Brain oxygenation. Near Infrared Spectroscopy (NIRS) offers one the safe and cost effective method to monitor brain oxygenation. In the NIR spectral region of 700-1000nm the biological tissueincluding the skull is translucent, photons are scattered and absorbed inside the scalp but few survive and exit the skin which can be detected with a set of detectors.[1] Signal detection is based on non-harmful levels of light.

II. WORKING PRINCIPLE OF NIRS

Infrared light is composed of a broad range of electromagnetic waves with wavelengths longer than the visible light and shorter than microwaves and millimeter waves (about 770 nm to 1 mm). Infrared light is further classified as "near infrared" (600 nm – 1400 nm) and "far infrared" (1400 nm – 1 mm). [3]

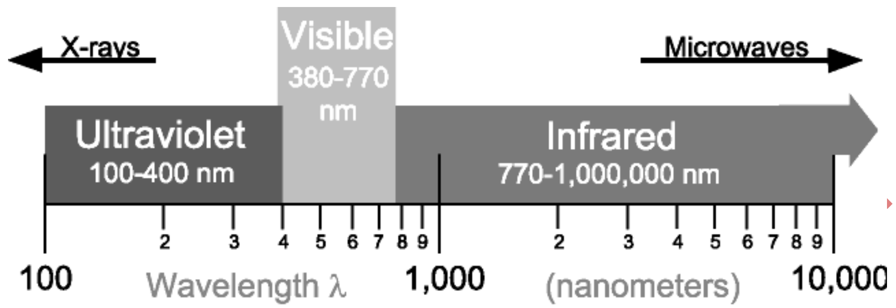

Fig.1: Optical Portion of the electromagnetic spectrum

In the NIR spectral region of 700-1000nm the biological tissues including the skull is translucent, photons are scattered and absorbed inside the scalp but few survive and exit the skin back to the detectors.

The technique is based on the transparency of biological tissue to light in the near infrared part of the spectrum and its subsequent absorption by chromophores present in oxygenated haemoglobin (HbO2) and deoxygenated haemoglobin (Hb) in the cerebral blood vessels within the near infrared light beam at different wavelengths of the near infrared spectrum. When oxygen binds to Haemoglobin (HbO2) the molecules absorption of NIR light is different compared with the deoxygenated haemoglobin molecule (Hb). Absorption changes in near infrared light can be converted into concentration changes of HbO2 and Hb. [4]

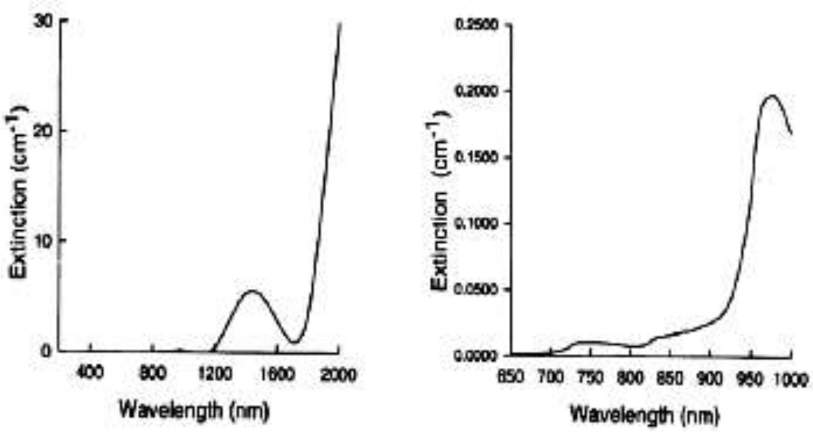

Fig.2: Absorption Spectra of pure water [3]

Near Infrared Spectroscopy (NIRS) was first introduced in 1977 by Jobsis and since then it has been used in different procedures and surgeries to reflect the cerebro-vascular status during anesthesia. NIRS is defined as measurement of spectroscopic changes in optical properties of tissue in NIR wavelength (700 nm to 1000 nm). One of the most useful properties of using NIR wavelengths is that oxygenated hemoglobin and deoxygenated hemoglobin both absorbs light differently in this region.

In one of the simplest forms light from two different wavelength commonly 760 nm and 850 nm are used. At 760 nm, deoxygenated hemoglobin has a higher absorption and at 850 nm, oxygenated hemoglobin has higher absorbance. [5] The detected light intensity level is used to determine the relative change in concentration of oxygenation parameters. Fig.2 shows the absorption spectra of water, water absorption dominates at wavelengths above 1000 nm. In Fig.3, spectra there is dominant absorption below 650 nm.

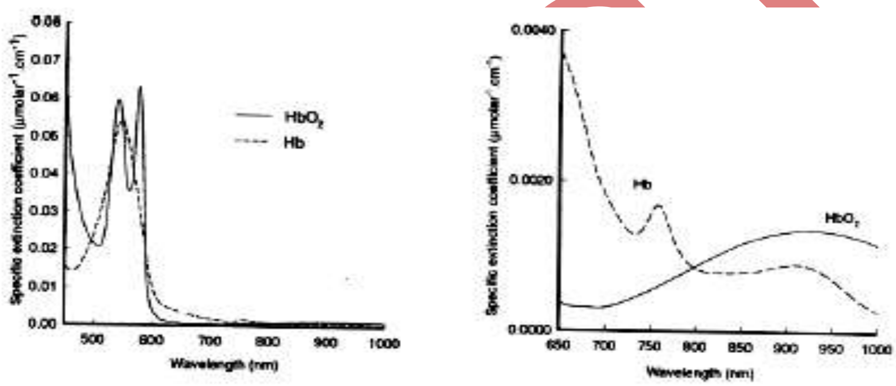

Fig.3: Absorption Spectra for Hb and HbO2[3]

III. BRAIN OXIMTERY PRINCIPLE

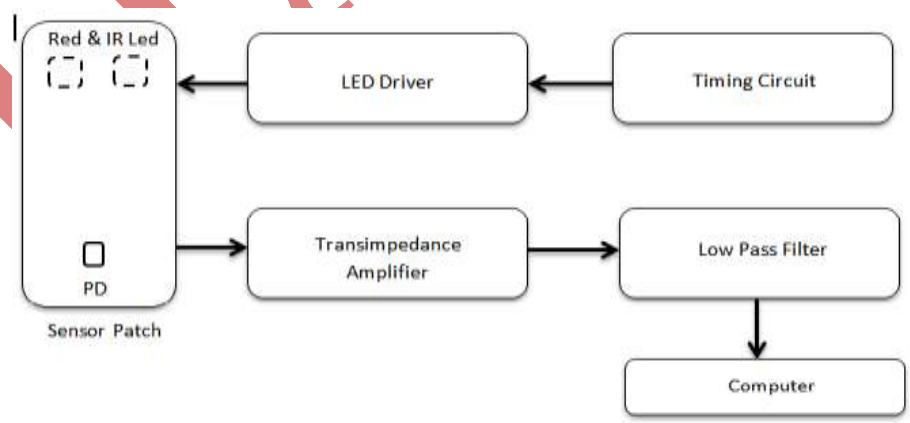

Fig.4: Simplified block of the hardware used in measuring optical signal from the head

The NIRS system mainly consists of optical components, electronic circuits and data processing system. In this system, the optical components are Infrared LED's as light source for irradiating the cerebrum and collect the reflected signal by using photodiode as detector.

Fig.5shows the conceptual diagram of the sensor. The sensor includes two LEDs (760,850nm) and two photodiodes differentially spaced at 3 and 4cm from the light sources. [1] Traditionally NIR Oximetry makes use of NIR Wavelength (760,850) to measure oxygen levels in the blood these two wavelengths are chosen because, at 760 nm, deoxygenated blood has a higher absorption, whereas at 850 nm, oxygenated blood has a higher absorption.

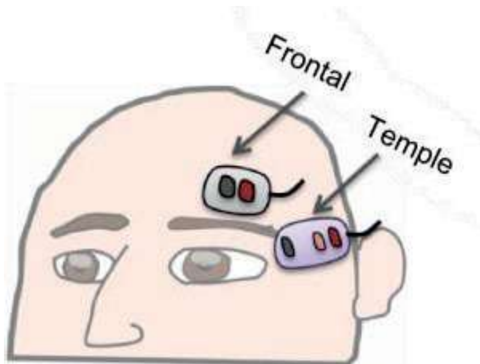

Fig.5: Conceptual Diagram of Sensor Locations [1]

The sensor utilizes two NIRS wavelengths 760 and 850nm. These wavelengths monitor the absorption spectra of deoxygenated hemoglobin and total hemoglobin respectively. Additionally and by using two photodiodes distanced at 3 and 4cm from the light sources the extracerebral and intracerebral signals can be distinguished and by subtracting the shallow detector signal from the deep one the extracerebral signals are reduced and we have a probability of 85% that the resulting signal is coming from the brain tissue. [1]

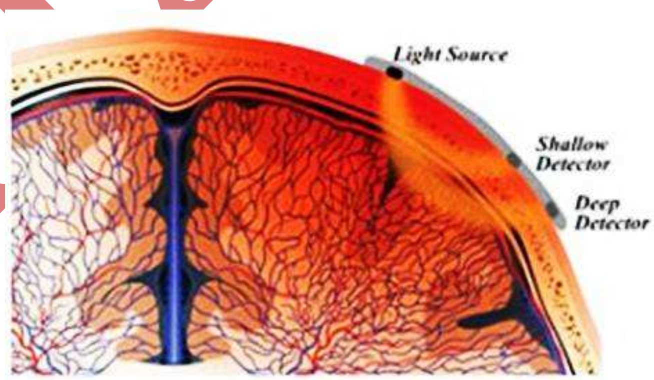

Fig.6: The mean photon path is shaped like a banana or canoe with ends located at the light-emitting source and the corresponding detector [6]

Two NIR wavelength laser diode of 760 nm 850nm are driven by 1 kHz modulation frequency generated by timer circuit. The LED's are driven by a Driver circuit to provide a constant current to drive the LED's. The light emitting from the IR Led was transmitted through the scalp and change in light intensity is detected by photodiode. The raw signal detected by the photodiodes is processed by a Trans-impedance amplifier to amplify the signals resulting from the photons impinging on the detectors to a useful level, since photodiodes produce a very little current from their exposure to light. A low pass filter with an upper cut-off frequency of 20Hz was used to smooth the signal and eliminate the noise. Finally the signal is given to computer for further processing. Using a set of software like Matlab or LabVIEW the signals could be processed and oxygen saturation values can be displayed.

IV. EXPECTED RESULTS

Normal (Regional Saturation Index) rSO2 ranges from 55% to 75%. rSO2 below 50% for a long period, below 40% or change more than 20% of baseline values for a short period is associated with neurologic complication. Deviations of rSO2 from baseline signify dynamic alterations in underlying brain function. Continuous tracking of the record thus allows detection of subtle changes in underlying brain perfusion that indirectly reflects the functional dynamics. The cerebral oximeter has been successfully used to document changes in cerebral perfusion associated with intracranial pressure fluctuations or perfusion changes occurring in the operative or intensive care setting. rSO2 is a vital sign to be monitored especially during the cardio pulmonary bypass to avoid brain injury which lead to neurocognitive dysfunction. [2]

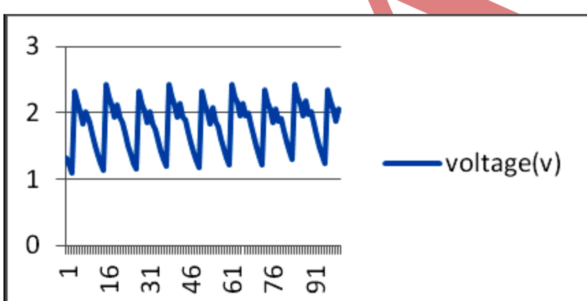

Fig.7: Voltage variations from detector due to infrared light (850 nm)

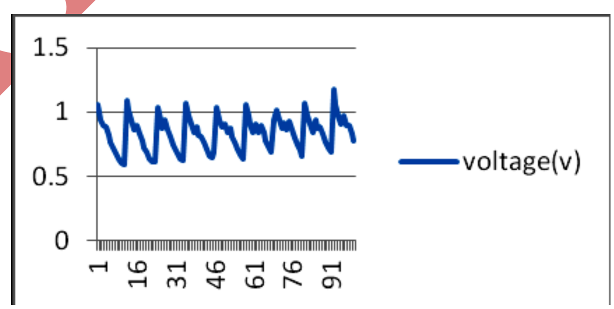

Fig.8: Voltage variations from detector due to infrared light (760 nm)

V. CONCLUSION

Monitoring of oxygen saturation plays a critical role in routine diagnosis and continuous monitoring. Cererbral Oxygenation monitoring will further help in estimating regional oxygen saturation in improperly perfused brain and also in diagnosis of neurological disorder. The system will lead to implementation of a low cost design for monitoring of cerebral oxygenation. The signal processing part will include calculation of R/IR Photodiode signal and using modified beer lamberts law, calculation of cerebral oxygenation will be done in %. Further LabVIEW or Matlab could be used for further processing and display of the signals in a standard GUI.

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