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Non-Invasive Anemia Detection in Pregnant Women

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Abstract—Every year thousands of women lose their life during labor period because of excessive hemorrhage, especially in rural areas. The target is to detect anemic symptom during pre-labor period so, that appropriate precautions can be taken in advance like better diet, medication etc. Current methods for measuring hemoglobin concentration are invasive, requiring blood access and a medical expert. This paper describes a novel technique for measuring hemoglobin concentration noninvasively. At different wavelengths absorption coefficient of blood differs and this fact is used to measure the optical characteristics of blood. In this newly developed system, principle of pulse oximetry is used. Oxygenated and deoxygenated hemoglobin absorbs different amount of light at two wavelength 660nm and 940nm. Transmitted light through finger is detected by a photodiode. Ratio of absorbance of light by oxyhemoglobin to deoxyhemoglobin molecule in arterial volume is calculated for determination of Hemoglobin.

Keywords— *non-invasive hemoglobin, IR, LED, absorption of light, arterial volume*

1. Introduction

In a developing country like India, where more than 30% of population is below poverty line, getting proper medical facilities is still a distant dream. Every year thousands of women lose their life during labor period because of excessive hemorrhage, especially in rural areas. WHO has estimated that prevalence of anemia in pregnant women is 14 percent in developed countries, 51 per cent in developing countries and 65-75 percent in India

alone[6]. Prevalence of anemia in South Asian countries is among the highest in the world. It is estimated that about half of the global maternal deaths due to anemia occur in South Asian countries and India alone contributes to 50% of global maternal deaths and about 80 per cent of the maternal deaths due to anemia in South Asia[5].

The measurement of total hemoglobin in blood is one of the most common procedures conducted when assessing an individual's overall health status. Current methods for determining the concentration of hemoglobin and other blood constituents require direct blood access which cannot be done without the involvement of primary health centres atleast. There are numerous disadvantages associated with obtaining a blood sample from a patient, including pain and inconvenience to the patient as well as the more serious risk to both patient and caregiver of blood-borne disease transmission. There may also be morbidity associated with repeated sampling from a patient requiring chronic blood constituent monitoring. In cases where the blood is transferred to a laboratory for analysis, there is a risk of sample mix-up or loss causing false reporting of results. For these reasons, it is desirable to have a means of measuring blood constituents without requiring blood access [1]. The goal of this project was to evaluate a novel technique for measuring the concentration of hemoglobin in blood noninvasively. The unique optical property of hemoglobin molecules make it suitable for noninvasive technique [6]-[7].

In this newly developed optical sensor system two different wavelengths of light uses for the measurement of Hb concentration. This non-invasive optical measurement method is based on radiation of red and near infrared light, emitted by Light Emitting

Diodes (LED) at particular wavelength of 660nm and 940nm. Ratio of absorbance in arterial blood volume of both red and IR signal after normalization is calculated for determination of Hb. Signal acquisition by this method is totally noninvasive. The sensors assembled in this investigation are fully integrated into wearable finger clip.

2. Experimental Methods

2.1 System Overview

Basic block diagram of non-invasive hemoglobin measurement system.

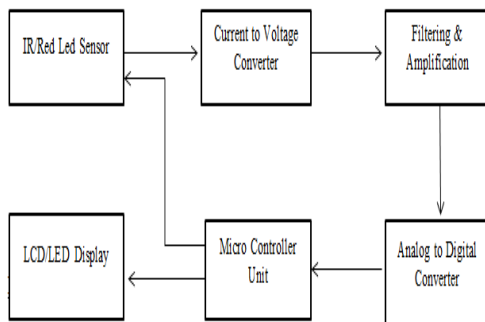


Figure1. Block diagram of hemoglobin measurement system

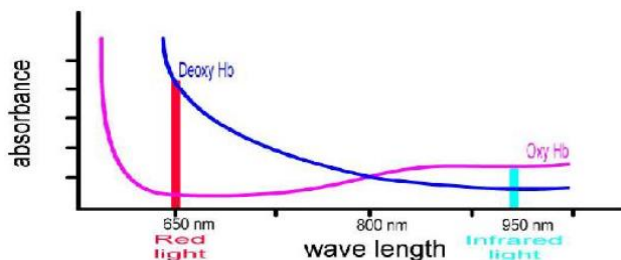


Figure2. Absorption spectra of oxy and deoxyhemoglobin

http://www.howequipmentworks.com/pulse_oximeter/

Light is transmitted through a monitoring site which is usually the finger, ear or toe. The pulse oximeter measures absorbances in the visible and near-infrared ranges of the electromagnetic spectrum, in order to measure hemoglobin saturation. It is well known that oxyhemoglobin is redder than deoxyhemoglobin. As such, deoxyhemoglobin nominally absorbs light at 660 nm more intensely than oxyhemoglobin. There is another difference in absorption characteristics of these two species which is not visible: deoxyhemoglobin nominally absorbs light at 940 nm more intensely than deoxyhemoglobin. The quantity of light absorbed at these two wavelengths is characteristic of a particular mix of oxy and deoxyhemoglobin. Hemoglobin saturation is calculated using absorbance data and a prediction curve which is generated by a large population study which correlates pulse oximetric data with traditional hemoglobin saturation measurements.

Tissue contains absorbing substances other than the species of hemoglobin. However, generally a pulse oximeter can isolate the absorbance of the hemoglobin species of interest from the absorbance of potentially interfering species. It does so by determining the difference between the absorbance of light by tissue before an arterial pulse and the absorbance of light by tissue at the peak of an arterial pulse. The difference in absorbance is attributed to arterial blood at the site of the measurement. In summary, the absorbance prior to a pulse is subtracted from the absorbance at the peak of a pulse to determine the absorbance ratio of arterial blood hemoglobin at different wavelengths [2]-[3].

2.2 Sensor Design

The hemoglobin measurement system consists of number of hardware modules, which include infrared light source, red light source, photo detectors, active low pass filters, notch filter, arm atmega16 microcontroller and LCD display. The sensor consist of emitter as LEDs, with centre wavelengths of 660nm and 940nm. These two wavelengths are selected because at 660nm wavelength absorbance of deoxyhemoglobin greatly exceeds the absorbance of oxyhemoglobin whereas at 960nm wavelength absorbance of oxyhemoglobin greatly exceeds the absorbance of deoxyhemoglobin. To detect the transmitted light transimpedance amplifier is used as detector

2.3 Amplifier and Filter

We know that any bio signal has very less amplitude, and thus very likely to be super imposed by noise and interference. As the analog to digital convertor has high sampling rate, and can sample milli volts of signal, any kind of super imposed noise will disrupt all the readings completely, as even the noise will get sampled and will be digitized. Thus it is very critical and crucial for filtering the signal and get a pure noise free one. Also, for the efficient sampling and digitization, the analog signal must be amplified. Desired signals fall in the range of 0.1-2.5Hz, thus two low pass filters are used to eliminate all the signals except the frequency of below 2.5 Hz. The gain for both the amplifier (A1) is set as about 101. Thus total amplification $A = A1 * A2$. Quad Operational amplifier LM324 chip has been used for the amplification and filtering as they are efficient, cost effective and were available in the lab.

2.4 Program Design

The samples are read in by using the built-in analog to digital converter (ADC) on the Atmega16. The signal is sampled and then sorted in increasing order. The highest and lowest three values are averaged and subtracted to get the absorbance value for arterial volume. This process is done for both 660 and 940nm wavelength. The ratio of two value is display on LCD.

3. Results and Discussion

A system is developed for measurement of hemoglobin non-invasively by using wavelength 660nm and 940nm. A study on 20 adults in range of 20 to 25 year old will be performed to test the ability of this newly developed system to measure the hemoglobin content noninvasively. The photometric measurements for each subject were store using microcontroller.

For photometric experiments Beer-Lambert's law is used to express light absorption as a function of hemoglobin concentration.

Beer Lambert's Law:

$$OD = \text{Log}(I_0/I) = \epsilon CL$$

OD - Optical density or absorbance of wavelength λ .

I_0 - Light intensity of incident light
 I - Light intensity of transmitted light
 ϵ - Extinction coefficient of hemoglobin
 C - Concentration of hemoglobin
 L - Length of light path in the solution

When measured sample has a mixture of oxygenated and deoxygenated hemoglobin:

$$OD^\lambda = \{\epsilon_{\text{HHb}}^\lambda [\text{HHb}] + \epsilon_{\text{HbO}_2}^\lambda [\text{HbO}_2]\} L$$

Light absorbance at two different wavelengths:

$$[\text{HbO}_2] = \frac{\epsilon_{\text{HHb}}^{\lambda_2} \cdot OD^{\lambda_1} - \epsilon_{\text{HHb}}^{\lambda_1} \cdot OD^{\lambda_2}}{L(\epsilon_{\text{HHb}}^{\lambda_2} \cdot \epsilon_{\text{HbO}_2}^{\lambda_1} - \epsilon_{\text{HHb}}^{\lambda_1} \cdot \epsilon_{\text{HbO}_2}^{\lambda_2})}$$

$$[\text{HHb}] = \frac{\epsilon_{\text{HbO}_2}^{\lambda_2} \cdot OD^{\lambda_1} - \epsilon_{\text{HbO}_2}^{\lambda_1} \cdot OD^{\lambda_2}}{L(\epsilon_{\text{HbO}_2}^{\lambda_2} \cdot \epsilon_{\text{HHb}}^{\lambda_1} - \epsilon_{\text{HbO}_2}^{\lambda_1} \cdot \epsilon_{\text{HHb}}^{\lambda_2})}$$

The clinically measured hemoglobin value vs. noninvasively measured absorbance ratio of 660nm and 940nm wavelengths are plotted to get a prediction curve.

4. References

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