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Working mechanism and utility of pulse oximeter

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Abstract

Oximetry is a medical diagnostic procedure, deals with the study of blood oxygen level of patients and to identify the need of medical assistance. The pulse oximeter measures the oxygen saturation in the blood. Understanding the working method of oximeter is helpful for the easy and conventional utility of oximetry in critically ill conditions to interpret the pathology. In recent days there are different types of oximeter available used in various conditions. For the enhanced study of oximeter, it requires a thorough knowledge of physics and basic electronics. Oximeter can be used by healthy sports professionals as well as many pathologic conditions like critical care units of health centers.

Keywords: Oximetry, Pulse oximeter, Oxygen saturation, Electronics.

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INTRODUCTION

Amount of Oxygen content along with the hemoglobin in the blood to the total hemoglobin containing saturated and unsaturated called Oxygen saturation. The hemoglobin containing oxygen is called oxygenated while without oxygen is called deoxygenated hemoglobin. Peripheral oxygen saturation [1] can be measured through pulse oximeter which is a noninvasive method of monitoring.

Pulse oximeter provides a simple, convenient and non-invasive method for continuous monitoring of hemoglobin saturated with oxygen and heart rate [2]. It has virtually replaced the transcutaneous monitors. The oxygen saturation in the blood can be determined by measuring the absorption of two selected wavelengths of light.

Non -invasive method of pulse oximetry makes use of red and infra -red LEDs for illumination of light at different wavelengths [3]. Absorption of infrared or red-light can be decided based on the type of haemoglobin and their optical property and hence the other will be passed through. The amount of light that is transmitted will be passed through photo detector and is measured and separate normalized signals are produced for each wavelength. The ratio of red light measurement to the infra -red light measurement represents ratio of oxygenated hemoglobin to deoxygenated hemoglobin which is converted to SpO_2 based on 'Beer–Lambert law'.

METHODOLOGY

Pulse oximetry makes use of principle of Photo-plethysmography (PPG).

It is one of noninvasive method used to measure proportional quantity of blood change using light absorbtion phenomina in biological tissues.When fingertip is illuminated by red and infra red light,depending on the oxygenenated blood content either red or infra red light is detected by photodetector.

Oxygenated hemoglobin absorbs more infrared light while deoxygenated hemoglobin absorbs more red light. Because of their different asorption spectra [4], at 660nm red light absorption coefficient and at 940nm infra-red light coefficients can be obtained [5]. Ultimately the amount of oxygen bounded with hemoglobin can be decided based on the absorption coeffients.

There are certain factors affecting absorbance phenomina [6]. They are

1) The path by which light travels : As the artery narrowers, light takes shorter paths and for wider artery light path will be long [7,8].

2) Concentration of the absorbing substance: More the number of molecules attract to light, more will be the absorbtion.

3) Oxyhaemoglobin and deoxyhaemoglobin: Since wavelength spectra of oxyhemoglobin and deoxyhaemoglobin are different,their absorption capacity also different.

According to Beer's law, absorption of light is entirely related to the property of the material and also on which path the light travels [7]. The Fig.1, shows absorption spectra of red and infrared at different wavelegths. Wavelengths of two lights red light and infrared light are 650nm and 950nm respectively.

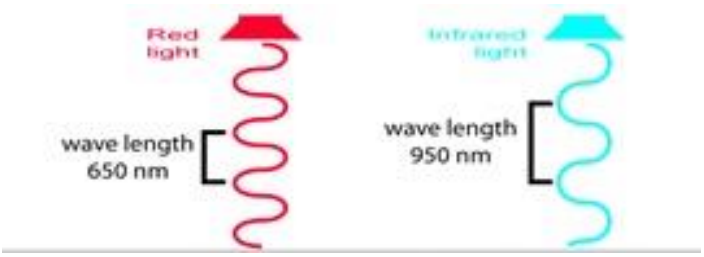

Fig 1: showing the red light and infra -red light with wavelength

Pulse oximeter calculates oxygen saturation based on the difference in the absorption spectrum of hemoglobin. In the non-invasive technique, it makes use of two leds –red and infrared. Deoxyhaemoglobin absorbs more light at 660nm and at 940nm oxygenated haemoglobin absorbs more light. Light illuminated by red and infra-red led passes through fingertip and by observing the transmitted light, oxygen saturation can be calculated.

Design:

Pulse oximeter system consists of a SpO_2 sensor, MPM (Multi Parameter Monitoring) module, ADC (Analog to Digital Converter) and MATLAB [9].

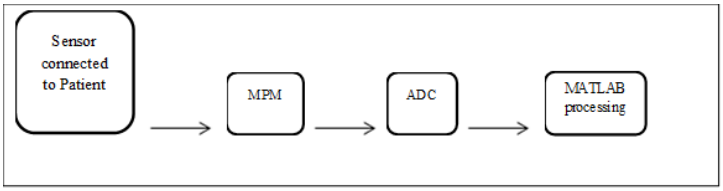

Fig 2: Showing the design of the instrument

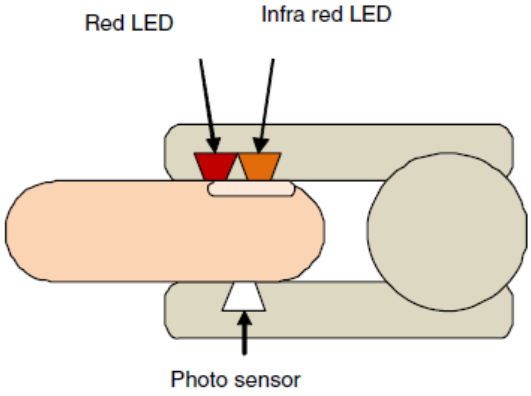

Fig 3: Pulse oximeter sensor fixed to the finger[10]

Pulse Oximeter Sensor: It consists of red and infrared LEDs and photo detector for light absorption detection. Two lights illuminated and passed through fingertip, and the signals transmitted through skin and received signals sensed back using photo detector.

MPM Board: An affordable and efficient MPM Board enables physician to monitor heart rate, SpO_2 rate, respiratory rate, perspiration rate, body temperature and blood pressure. MPM acquires the SpO_2 signals filters and amplifies weak signal and to convert digital value it passed to Analog to Digital Convertor.

Microcontroller C8051F380: The amplified and filtered signals from MPM Board are fed to microcontroller which is programmed to convert analog data into digital data .Universal Asynchronous Receiver Transmitter allows data exchange between PC and serial devices which is attached with [9].

MATLAB: Matrix Laboratory is a multi- paradigm numerical computing environment. The acquired data from ADC unit stored and transmitted from the microcontroller through UART serial communication. Further acquired signal processed in MATLAB to calculate SpO_2 value. To calculate the oxygen saturation, AC peak to peak voltage is measured for both red and infrared signals by calculating the difference between maximum and minimum peaks on the waveform [9].

The calculation in the process is done by the following formula [10-12]

$$SpO2 = (10.0002*R^3)-(52.887*R^2)+(26.871*R)+98.283$$

R is calculated using the formula

$$R = \frac{(Vmax(Red)-Vmin(Red))*Vmin(Infrared)}{(Vmax(Infrared)-Vmin(Infrared))*Vmin(Red)}$$

Utility

Oximeter are of 4 varieties, namely pulse oximiter, handheld oximiter, fetal oximiter and bedside oximeter [13].

Pulse oximeter is the most portable and can be used in home to observe oxygen saturation. It is in the shape of an alligator clip and has to be put on the finger or earlobe. The display screen is on the clip. Infrared light is passed through the veins and this can measure the difference between oxygenated and deoxygenated blood cells. Pulse oximeter may not give the right reading if there is a blood clot or the hand is cold.

A handheld oximeter is used in medical institutions and hospitals. The machinery is slightly more sophisticated. The screen is not attached to the clip. Instead there is a cable attaching the clip to the screen. The screen shows more than just the level of oxygenated blood like pulse rate, blood pressure. This assists doctors in making the right diagnosis. The clip of this device in emergency cases can even be attached to the toe to get a reading.

Fetal pulse oximeter is used in critically ill babies. The usual oximeter may be hard to use in new born baby. The device has a probe which is put on the baby's head in order to get a reading from the skull by the passing of light rays. The physician can be alerted of complications of newborn early.

A bedside oximeter is typically used in stationary medical facility and suited for non-ambulatory patients such as those who are chronically ill.

Oximeter used in the diagnosis of disorders like hypoxia, sleep apnea, hypertension. The portable version of it helps to monitor the conditions even at home.

Pulse oximeter probe is used on a finger, ear, or other tissue. The derived saturation should be independent of skin pigmentation, and many other variables, such as hemoglobin concentration, excessive movements, nail polish, dirt, and jaundice [14].

Arterial oxygen saturation should be maintained between 90- 95% for acute conditions and 85- 90% for chronic situations in the patients [15]. Shock and peripheral vasoconstriction is associated with unreliable display of SpO_2.

In case of vasoconstriction and hypothermia low perfusion states results difficulty for sensor to differentiate true signal from background noise.

CONCLUTION

Pulse oximetry found to be one of the important respiratory monitoring method.Technical aspects has been studied over the past 15 years , and these degree of accuracy combined with ease of operation of most instruments, made pulse oximetry to be used successively for monitoring the patients in the ICU.

Accuracy of commercially available oximeters may vary,because it depends on which algoritham it is designed.Most of the conventinal oximeters use two leds to estimate oxygen saturation based on the absorbtion coeffients of oxyhemoglobin and deoxyhemoglobin.

In this method it is possible to determine the percentage of oxygen saturated with hemoglobin but when other possible factors like carboxy hemoglobin (COHb) and methemoglobin (MetHb) are present,then to detect those factors need to use four wavelengths to determine the 'fractional SpO_2'.

Oximeter has a number of limitations which may lead to in accurate readings. Carboxy hemoglobin, methemoglobin, anemia, dyes, nail polish, ambient light, False alarms, motion artifact, skin pigmentation, low perfusion state are the different factors which effects the reading in oximetry.

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