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Non Invasive Haemoglobin Meter

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Abstract: Haemoglobin is the constituent of the red blood cell that combines with oxygen and consists of two parts, haemo and globin. Iron is an essential part of haemoglobin and when deficiency occurs due to dietary inadequacy or loss through chronic haemorrhage, anaemia results. In this paper a non invasive optical technique for haemoglobin measurement has been presented. At present it requires an invasive and painful needle stick to draw a blood sample from anemic and pregnant patients to test the level of haemoglobin content in blood. Frequent use of invasive method to get the blood samples, makes the testing a painful process for the patients. In order to minimize the pain of the patient and to have the measurements of blood haemoglobin level in frequent intervals, in the newly developed system, principle of pulse oximetry is used to find the haemoglobin content in the blood. Oxygenated and deoxygenated haemoglobin absorbs different amount of red light at two wavelengths 660nm and 940nm. Red and IRLED are used for the particular wavelengths. Transmitted light from the patch of skin on finger was detected by transimpedance amplifier. Then received signal strength can be calibrated in terms of Haemoglobin content in blood and the proposed technique show promising results.

Key words: Haemoglobin · Non invasive · Pulse Oximetry

INTRODUCTION

Anaemia, a common blood disorders, occurs when the level of healthy red blood cells in the body becomes too low. Anaemia can be a result of drop in Hb level in blood, which in turn can be due to deficiency of Iron, Vitamin B12 or Folic acid. Of these, anaemia due to Iron deficiency is normally prevalent. Iron in Hb is helps blood to carry oxygen from the lungs to various parts of body through blood. Hence, reduction in iron level will result in decrease in oxygen carrying capacity of blood, which can have adverse effect on the health of the individual. To overcome this unhealthy condition as anaemia, it is essential to estimate the level of Hb in in the blood of the patient. There are different methods of evaluation of Haemoglobin in blood namely, pallor test or filter paper test. In the non-invasive method, namely the pallor test, the color of the patient's conjunctiva is observed and the haemoglobin level is guessed and it is subjective. It also does not give the value of haemoglobin in precise and crisp form. Hence, there is a requirement for simple method and more accurate method to measure the haemoglobin content of blood.

The physiology of haemoglobin is elaborated in this paragraph. Haemoglobin is the constituent of the red blood cell that combines with oxygen and consists of two parts, haem and globin. The complex of a porphyrin ring is called haem and iron in the ferrous (Fe2+) state. Iron is a crucial part of haemoglobin and when deficiency occurs due to dietary inadequacy or loss through chronic haemorrhage, anaemia is caused. Haem is conjugated with globin, a polypeptide, which consists of four subunits. Adult haemoglobin (HbA) comprises two alpha (α) and two beta (β) polypeptides. Differences in the polypeptide chains account for a number of haemoglobin variants, which alter the body's capacity for transporting oxygen [1].

Haemoglobin plays important role for transporting oxygen from the lungs to the other peripheral tissue of body and exchange oxygen for carbon- dioxide and then carry carbon dioxide back to lungs where it is exchange for oxygen.

The structure of haemoglobin consists of four protein molecules, called globulin chains as shown in the Figure 1.1. Each globulin chain contains an important central structure called the heme molecule. Embedded within the

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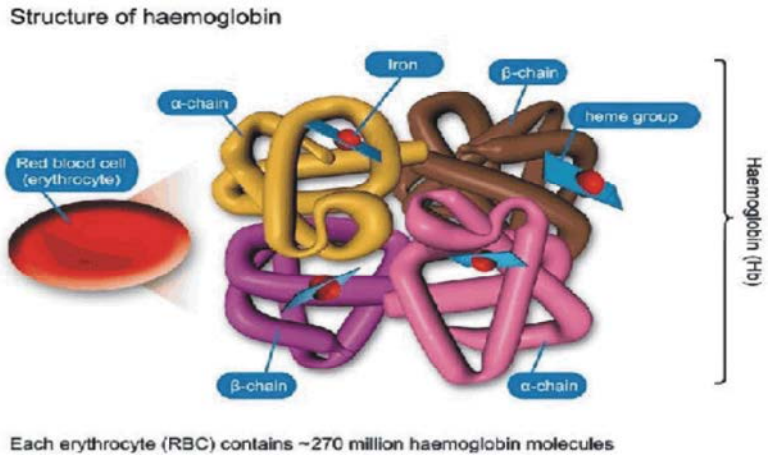

Fig. 1.1: Structure of Haemoglobin

heme molecule is iron that is vital in transporting oxygen and carbon dioxide in the blood. An iron contained in haemoglobin is responsible for the red color of blood. If haemoglobin level crosses the critical limits then problem occurs such as anaemia which is low haemoglobin level and polycythemia, also called as high haemoglobin level [2].

Oxygen Content of Blood: The amount of oxygen the blood carries is described as the oxygen content of blood. Although the vast majority of oxygen is carried bound to haemoglobin, a very small amount is dissolved in the plasma. The total amount of oxygen carried can be calculated by adding these two amounts. Under normal circumstances, as blood leaves the lungs, haemoglobin is almost fully saturated with oxygen and each gram of haemoglobin contains 1.39ml of oxygen. However, by the time it reaches the systemic circulation this has fallen slightly due to the addition of a small volume of venous blood from the pulmonary and coronary circulations. Therefore in the arterial circulation, one gram of haemoglobin is around 98% saturated and contains 1.34ml of oxygen. The amount of oxygen dissolved in the blood is proportional to the partial pressure. At 37 degrees Celsius, 0.23ml oxygen dissolves in each litre of blood per kPa. Therefore the oxygen content of blood can be calculated from the equation [1] and highlights the multiple factors required to optimize the ability of the blood to carry oxygen [3,4].

Oxygen content of Blood (l)

= (Hb x 1.34 x SaO2) + (0.23 x PaO2)
=(150 x 1.34 x 98%) + (0.23 x 13)
˜20.3 ml/l

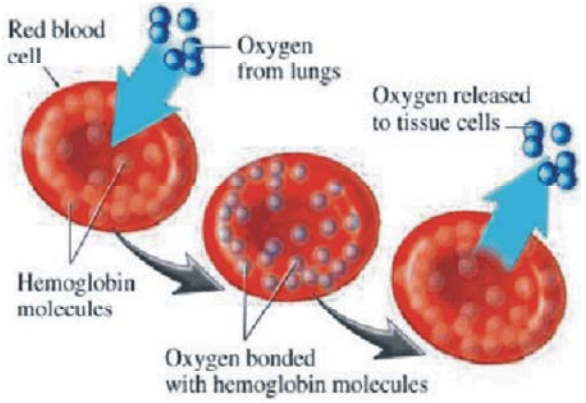

Fig. 1.2: Formation of Oxyhaemoglobin and Deoxyhaemoglobin

Oxyhaemoglobin and Deoxyhaemoglobin: The form of haemoglobin isloosely combined with oxygen, present in arterial and capillary blood is bright red in color. The form of haemoglobin without oxygen i.e., after releasing it to the tissues and it is purple blue is shown in Figure 1.2 Formation of Oxyhaemoglobin and Deoxyhaemoglobin.

Oxygen combines reversibly with the ferrous ion in the haemoglobin molecule to form oxyhaemoglobin as given in the equation (2).

$$Hb + O2 = HbO2 \quad (2)$$

In the lungs, where the partial pressure of oxygen is high, the forward reaction oxygenating haemoglobin is favored. In the tissues where the partial pressure of oxygen is low the reverse reaction reducing haemoglobin is favored. Thus haemoglobin combines with oxygen in the lungs and releases it at the level of the tissues as both the oxygenation and reduction of haemoglobin are

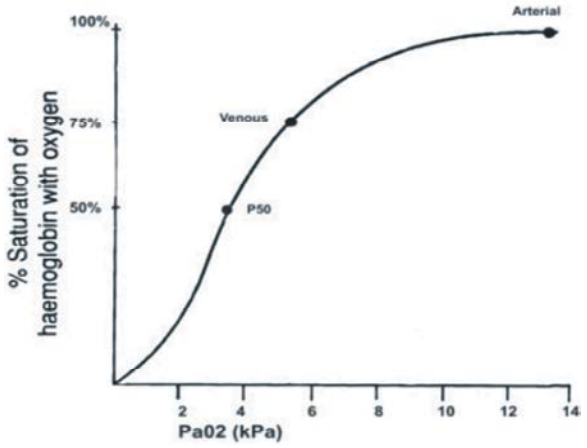

Fig. 1.3: Dissociation curve

extremely rapid reactions taking less than 0.01 seconds. The relationship between the saturation of haemoglobin and the partial pressure of oxygen in the blood is described by the oxygen dissociation curve, is shown in Figure 1..3

Dissociation Curve: The curve demonstrates that at a normal PaO2 (13kPa) haemoglobin level is approaching 100% saturation. The curve has a sigmoid shape owing to the cooperative binding of haemoglobin with oxygen. When one molecule of oxygen binds to the ferrous iron, steric reactions cause movement of the globin polypeptide chains. This facilitates the binding of further oxygen molecules. Thus at low oxygen tensions it is initially difficult for haemoglobin to combine with oxygen but this process gets much easier as more oxygen is available and as more oxygen combines with haemoglobin i.e. at the higher oxygen tensions available in the lungs. This is evident by the steep rise in the curve, until it plateaus as it approaches 100% saturation. The steep section of the curve is extremely important as it demonstrates that below 92% saturation the drop in saturated haemoglobin falls very quickly per unit partial pressure of oxygen [5,6].

A number of important points are shown on the curve. At 13kPa, the partial pressure of oxygen in the arteries, haemoglobin is nearly 100% saturated. At 5.3kPa, the partial pressure of oxygen in venous blood, haemoglobin is only 75% saturated. The thirdpoint demonstrated on the curve is the P50 value. This equates to the partial pressure of oxygen in the blood at which 50% of the haemoglobin is saturated. Under normal conditions this is 3.6kPa. It is useful when looking at how certain conditions affect the oxygen dissociation curve.

The dissociation curve can be shifted to the right or left by a number of factors. The curve is displaced to the right by increased hydrogen ions (reduced pH), increased carbon dioxide, increased temperature and increased DPG

A right shift in the curve means that haemoglobin releases its oxygen relatively easily. This occurs during an acidosis. Deoxyhaemoglobin binds more actively with hydrogen ions than oxyhaemoglobin, thus as the hydrogen ions rise and the pH consequently falls, haemoglobin's affinity for oxygen also falls. The reverse also occurs. There will also be a rise in the P50 value, as only 50% of the haemoglobin molecules are saturated at a higher partial pressure compared to normal. Carbon dioxide has a similar effect on the position of the dissociation curve, increases shifting it to the right and decreases to the left. This comes about as a result of an increase in PCO2 causing an increase in hydrogen ions (decrease in pH) and also a decreased affinity of haem for oxygen. In the lungs, the converse is true. The influence of hydrogen ions and CO2 on haemoglobin affinity for oxygen is known as the Bohr Effect.Diphosphoglycerate (DPG) is formed in red blood cells as a product of glycolysis. It is a highly charged ion and when it combines with the beta chain of haemoglobin, it displaces oxygen and again shifts the curve to the right. The conditions that cause a rightward shift in the curve thus encouraging the unloading of oxygen at relatively low partial pressures of oxygen can be summarized by thinking about the exercising muscle. During exercise there is an increase in temperature, hydrogen ions, CO2and DPG in the tissues, all the conditions associated with a rightward shift in the curve to help deliver oxygen to the active muscles [7].

Proposed Methodology

Working Principle: At the optical characteristics of blood. Oxygenated and deoxygenated haemoglobin absorbs different amount of light at two wavelength 660nm and 940nm. Red and IR LED are used for these particular wavelengths. Transmitted light from an area of the skin on the finger was detected by a photodiode. Ratio of pulsating to non-pulsating component of both red and IR signal after normalization is calculated for determination of Hb. Signal acquisition by this method is totally non-invasive. This method minimizes the need for reagents different wavelengths absorption coefficient of blood differs [8]. The Figure 2.1 shows the block diagram for non invasive haemoglobin meter.

The non invasive haemoglobin meter as shown in the Figure 2.1 has a sensor module which contains a signal generator. The function of signal generator is to produce

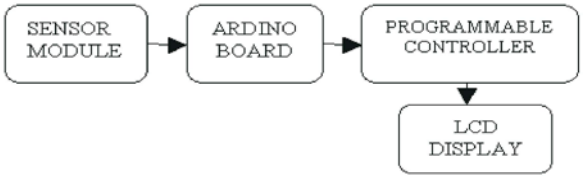

Fig. 2.1: Block diagram non invasive haemoglobin meter

a signal that alternatively switches the red led and infrared led in a predefined interval. Now the led setup alternatively passes red light and IR light into the patient's finger [9-12]. The light passes through the finger where it is absorbed by the haemoglobin content of the blood to some extent. The varied light is absorbed by the photo sensor. The output of the photo sensor is in the form of current which is proportional to the variation of light due to the absorbance [13,14].

Arduino is a tool which is an open-source physical computing platform based on a simple microcontroller board and it contains a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors and controlling a variety of lights, motors and other physical outputs [15-17].

The current from the photo sensor is converted into voltage by using a transimpedance amplifier. Now the analog signal is filtered and amplified which is then converted to a digital signal using A/D converter. Now the digital value is given to the microcontroller for mathematical calculations. Now the value is displayed using the LCD display which is the required total haemoglobin content [17-20].

RESULTS

The hardware part contains the sensor probe, Arduino board and I/O interface. The sensor probe contains two LEDs namely RED AND IR LED. The change in LED value is captured by the photodiode in the probe.

Fig. 3.1: Measuring Haemoglobin using non invasive haemoglobin meter

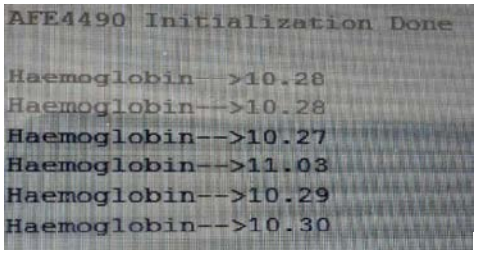

Fig. 3.2: Obtained haemoglobin value using non invasive method

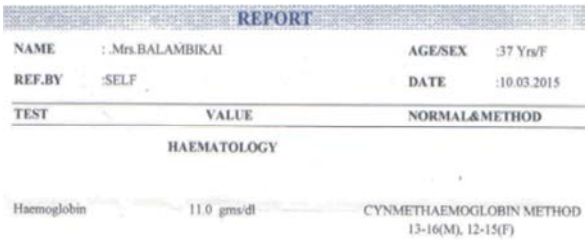

Fig. 3.3: Obtained haemoglobin value using non invasive method

The output of photodiode is current which is fed to the I/O interface, where the current is processed and the mathematical analysis is done in the microcontroller of the Arduino board. The probe is connected to the forefinger of the leg as shown in Figure 3.1 to measure the haemoglobin value.

The program is fed into the microcontroller using software "Arduino version 1.6.3". The haemoglobin meter is initialized and the value of haemoglobin is displayed in the serial monitor as shown in Figure 3.2.

The following figure 3.3 indicates the measured value of the haemoglobin using invasive method done in a hospital.

DISCUSSION

The haemoglobin measurement of the author is shown in the results. The non invasive method takes 3 seconds after initialization to show the haemoglobin value. The noninvasive haemoglobin measurement gives a near by value to the haemoglobin value obtained by the invasive method. This prevents the frequent invasive tests carried to test the patients for anaemia and the haemoglobin content for pregnant ladies.

The fingertip will have a set of arteries and vein along with capillaries. The capillaries are the end of the arteries and the beginning of the veins. The capillaries run longitudinally under the nail bed and in the pulp on the palmer side of finger. In the fingertip, it is seen that the light energy penetrates skin to a depth depending on the

wavelength of the source and the concentration of Hb and other ingredients of blood and this concept has been applied to measure the haemoglobin in non invasive method among the patients in a satisfying way.

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