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Research paper

Non-Invasive Total Hemoglobin Measurement by Forehead Oximetry.

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Abstract

More than half a percentage of women across the world of reproductive age suffer from anemia. Low level of hemoglobin and partial pressure of oxygen plays a vital role in monitoring the level of anemia. The parameters of Spo_2, total hemoglobinbin count,and heart rate have to be monitored when required to avoid various kinds of health complications. Finger oximetry and a blood test is the ideal and traditional method for monitoring Spo_2 and measuring total hemoglobin count. If a patient is experiencing the severe anemic condition, an accurate measure of the above mentioned physiological parameters is necessary which are not done by the Traditional methods. So, the hardware is designed to measure these parameters with utmost accuracy. Recent works in forehead oximetry convey that it gives more accurate value than finger oximetry avoiding noise and motion artifacts. This idea comes up with measuring the Spo_2, total hemoglobin count and heart rate over the forehead region by the optical method of using four different wavelengths and a heart rate sensor interfaced with the ARDUINO UNO Board to process the output and display it in the LCD. Non-Invasive monitoring of Spo_2, total hemoglobin count,and heart rate is essential to know the oxygen saturation level in the body at any instant of time compared to standard biochemical test.

Keywords: *Total hemoglobin count; noninvasive method; Spo_2&heart rate; forehead oximetry.*

1. Introduction

According to a recent survey of WHO across 140 countries in the world, about 51 percent of women of reproductive age suffer from anemia. A blood test is an ideal and traditional method for measuring total hemoglobin count. However, this method needs skin to be pricked to draw blood and takes time for the result. Meanwhile, the hemoglobin level may change until test results. So, an instant and noninvasive device would be better to overcome these problems. Nowadays finger oximetry is the widely used method to measure oxygen saturation. However, there are several drawbacks of pulse oximeter includes-(I)incapability of sensing poor perfusion state(showing normal saturation level even if there is inadequate blood flow),(II) ineffectiveness in calculating the anemia level(inadequate hemoglobin levels),(III)carboxyhemoglobin, and methemoglobin interference(amount of hemoglobin molecules converted to methemoglobin or carboxyhemoglobin),(IV)skin pigmentation(V) color interference and(VI) the motion artifacts form the challenging part in producing accurate values in the measurement of Spo_2 from a pulse oximeter in finger probe[9]. Reflectance mode of pulse oximeters has advantages over transmittance mode of oximeters in the situation of low perfusion rate and motion artifacts. [7]. Many studies have proved accurate means of measuring Spo_2 by comparing different regions of interest – probe,fingerprobe(transmittance mode and reflectance mode) and forehead oximeter. The comparison of the measurements taken in finger and forehead is depicted in a graph which clearly says the higher accuracy level found in taking measurements from the forehead. The response time in detecting the increase or decrease is faster while measuring from forehead (100 % re-saturation response time were 23.2 seconds for the forehead probe and 28.9 seconds for the finger probes).[7]. The measurement of saturation level is measured in various parts of the body like wrist, sternum, forehead,and ear using the green wavelength of LED and IR wavelengths, and is found that (I). Forehead gives the best measure of saturation level in blood. (II) IR wavelength is found to give good results in the forehead. [5]. Even a small position change in reflectance oximetry in wrist shows inaccurate readings[18].Forehead pulse oximetry, when recorded in supine position gives more accurate values than sitting position. Headband avoids the motion and noise artifacts which significantly reduces the reading errors. [3]. The saturation level varies in different parts of the body as rSO2 values for the brain, liver,and heart varies as measured by Near InfraRed Spectroscopy (NIRS). That the forehead region gives the more accurate and IR wavelength is more favorable to measure the parameter [2]. It is found that forehead oximeters are 10% more accurate, 40%more easy to use and 30% longer durability than finger probe oximeters. [17]. even though there is fluctuation in pressure inside Reduced Oxygen Breathing
Device (ROBD) subjected to patients for ten minutes, forehead reflectance oximeter showed faster and accurate readings than finger probe oximeter.[15]. Thus this work aims to design hardware to measure the physiological parameters such as Spo_2, total hemoglobin count and heart rate using forehead pulse oximetry in reflection mode which gives more accurate results at

different altitudes.

2. Working of the System

2.1. Block Diagram Description

The idea is implemented successfully by building the prototype using hardware circuit designed. LEDS of four different wavelengths are used to measure the physiological parameters,and the programming in the ARDUINO USB Board is done with the help of ARDUINO software. The working hardware is then preceded with few subjects by connecting the designed head band over the forehead region. The head band is placed over the forehead region of the subject in the supine position as this position overcoming all the artifacts and gives more accurate results compared to all the other positions. The reflected rays of the LED are detected by the photodetector. The output of the photodetector is given to the ARDUINO Board to process the output according to the programmed value and display the digital signal in the LCD Display.

The below-mentioned block diagram (Fig.1) represents the working of the non-invasive total hemoglobin measurement by forehead oximetry. By using the ARDUINO UNO BOARD (ATMEGA 328), the hardware can set the LED wavelengths to be administered to the patient regardingnanometer to measure the Spo_2, hemoglobin count,and heart rate. The LEDs are placed in a head band of the adjustable type which can be properly pressurized and reduces the error such as motion artifacts and noise artifacts which significantly reduces the reading errors. The different wavelength from the various LED analyses various parameters. The wavelengths used in this hardware are 660nm, 940nm, 545nm,and 525nm to measure oxygenated blood, deoxygenated blood,and total hemoglobin count respectively. The wavelength is infused in the forehead region, and a photodiode is used to detect the reflected as our study says that reflection mode gives the more accurate result. An operational amplifier OP-AMP LM358 is attached to the headband. The OP-AMP internally built with five filters internally in which four of them are passive filters,and one is an active filter. These filter process the 660nm, 940nm and 546nm signals for noise elimination and amplification. An LCD is used to display the digital output processed by the ARDUINO UNO Board from the photodiode.

2.2. Measurement of Physiological Parameters

The whole system functions depend on finding these parameters. The parameters considered showing the working of heart and lungs in oxygen saturation of blood are

1) Spo_2– stands for peripheral capillary oxygen saturation and gives the amount of oxygen in the blood. Normal Spo2 ranges between 95 and 100% and Spo_2 levels lower than 90% is hypoxemia which causes heart diseases, obesity hyperventilation syndrome, sleep apnoea, shortness of breath and another related disease.

2) Total Haemoglobin count – The total hemoglobin count gives the amount of hemoglobin, oxygen-carrying pigment in grams per deciliter of whole blood. The normal count in an adult male is 14-18g/dl and inthe adult female is 12-16g/dl. Total hemoglobin count less than the normal range causes anemia,and higher than normal range causes lung diseases, tumors, polycythemia, etc.

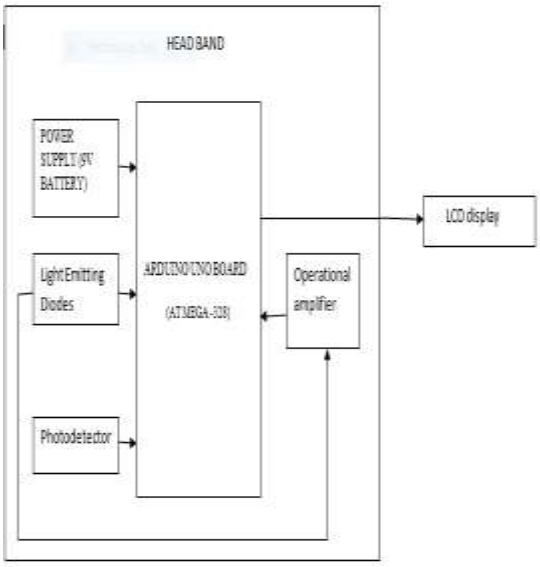

Figure.1: Block diagram representation of the Non-invasive total hemoglobin measurement by forehead oximetry.

3) Heart rate- The normal heart rate ranges between 60 and 100 beats a minute. The heart rate less than 60 is called Bradycardia causing a congenital disability, thyroid disease, obstructive sleep apnoea, etc. The heart rate more than 100 is Tachycardia causing high blood pressure, coronary artery disease, cardiomyopathy, tumors or infections.

3. Software Implementation

The analog output of the hardware assembled is checked with the software PC scope. This software enables one to check the analog signal and proceed the prototype to produce the output in digital form. The hardware is connected to the PCScope by using the USB cable. Then the hardware is run to see the analog output of the different parameters in PCScope window. The programming part of the hardware is done in the ARDUINO UNO Board using the ARDUINO Software. The main task in the programming part is to program the relationship between the optical density and the hemoglobin. The microcontroller is programmed by using two wavelengths ratio and deriving the below equation of the relationship between optical property and the hemoglobin by using the output produced by the photodetector as the input value.

$$\text{Ratio}=\frac{AC660/DC660}{AC940/DC940} \quad [20]$$

$$OD=\text{Log}\,(10/I) = \square cL \quad [21]$$

4. Hardware Implementation

The block diagram designed after the studyis implemented as the prototype using the ARDUINO UNO Board and Microcontroller ATMEGA328.

Components used in Non-Invasive Total haemoglobin measurement by Forehead oximetry are, A headband is used to place the designed embedded circuit to measure the parameters of oxygenated blood, deoxygenated blood and total hemoglobin count from the forehead region, Four different LED's are used to measure the oxygenated blood, deoxygenated blood and total hemoglobin which are of 660nm, 940nm, 525nm and 545nm of SMD LED. The photodetector used in this circuit is FDS100- Si Photodiode to detect the photons from all the four LED's and the operational amplifier are used to amplify signals. LCD Display

model is a very basic module and is very commonly used in various circuits. In this LCD each character is displayed in the 5x7 pixel matrix. The hardware is powered by the Power supply is the major component, with a regulated power supply 9V circuit board and an Arduino board for programming. Also,16*2 LCD Display for digital output.

5. Analysis and Results

On the whole, it is seen that monitoring of the parameters such as Spo_2, total hemoglobin count and heart using the non-invasive method measurement over the forehead region in supine position gives more accurate measure. This model resulted in incorporating the values of the photodiode output with the relationship formula stored in the microcontroller to process the output and display in the LCD Display. A study of fifteen subjects was analyzed.Relevant results were obtained from 525nm.The student T-Test was performed between total hemoglobin count measured from 525nm wavelength LED in forehead oximeter and the total hemoglobin count from a traditional blood test. The statistical student T-Test was done to compare the hemoglobin count obtained from both methods. The significant value obtained from student T-Test was 0.06 which indicates that both the hemoglobin count values taken from two different methods are the same.

Fig.3: LED with Photodetector

6. Conclusion

Modern technology is applied to automate the process of measuring the Spo_2, total hemoglobin,and heart rate; it replaces the work of the Biochemical test and gives more accurate result in less time. Non-Invasive total hemoglobin measurement by Forehead oximetry gives more accurate result in the supine position. Furthermore testing and calibration of the system has to be done with subjects and biochemical tests.

7. Future Enhancements

The device can be further extended to measure other clinical parameters like carboxyhemoglobin, methemoglobin,and HbA1c. The response of the system for measuring the parameters can sobe reduced by improving the hardware.

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