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IOT based Non-Invasive Transcutaneous Bilirubinometer for Jaundice Prediction

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ABSTRACT – IOT based Non-Invasive Transcutaneous Bilirubinometer is the device that measures the yellowness of the skin (jaundice) by analysing the spectrum of the light reflected from the newborn's skin based on transcutaneous bilirubin (TcB) where the amount of bilirubin is measured. Jaundice is always occur in infants or newborn where the condition of the infants or newborn like the skins, eyes and other tissues of the baby becomes yellowish. The overall process involved are development of non-invasive bilirubin meter device, the method of non-invasive test conducted for transcutaneous bilirubin then the monitoring process of bilirubin level with automatic data storage of patient in smartphones. This IOT based Non-Invasive Transcutaneous Bilirubinometer device also used infrared (LED green and blue 455-575nm), photodiode (BPW21R) and colour sensor (TCS3200) that can detect the bilirubin level in the blood through the surface skin of the newborn without giving them any discomfort and pain. This device has a new upgradation system by using the MIT software application and IOT Android system that can give the result of the test conducted. The data from the test will be stored on the phone automatically and the user can keep monitoring the condition of the newborns via the phone continuously.

KEYWORDS : Jaundice, Transcutaneous Bilirubin, Colour Sensor (TCS3200), Photodiode Sensor (BPW21R), MIT Software, IOT

1.0 INTRODUCTION

The development of new technology that introduce the different method and product to detect jaundice or hyperbilirubinemia in newborns is by using non-invasive technique. Hyperbilirubinemia or jaundice occurs in 60% of healthy infants and 80% of premature infants due to elevation of unconjugated bilirubin in red blood cells [1]. Jaundice in a newborns happens due to the increased production of bilirubin and limited ability of the undeveloped liver to collect and excrete bilirubin and normally it occurs during the first week after birth. Although jaundice is not painful, serious complications may occur if elevated bilirubin level is not treated in a timely manner. The worst case that may happen to jaundice infants is severe hyperbilirubinemia that causes toxicity to the nervous system and potentially causing kernicterus or brain damage [2].

Non-invasive, transcutaneous, point of care measurement of transcutaneous bilirubin (TcB) pre discharge by multi wavelength spectral analysis, using a portable devices is clinically equivalent to measurement of TsB in a diverse, multiracial term, and near-term newborn population and predictive of subsequent hyperbilirubinemia. Hence, non-invasive bilirubin meter can overcome the problem which is the pain inflicted and discomfort to the newborns through needle prick when withdrawn the blood from the newborns. Besides, non-invasive transcutaneous bilirubinometer measures the yellowness of the skin by analysing the spectrum of light reflected by the newborn's skin using blue and green LED (455 nm & 575 nm), photodiode sensor, and RGB colour sensor with IR filter. The measurement of the bilirubin level is based on transcutaneous bilirubin (TcB) where the amount of bilirubin is measured at two different wavelength that are first, at the wavelength of 455 nm which is the maximum absorption amount of bilirubin and the absorption of haemoglobin at both wavelength, 455 nm and 528 nm.

By non-invasive transcutaneous bilirubinometer that connects via smartphone, the result of the test can be displayed instantly and it can avoid delay with discharge and indicate the need for formal SBR testing. However, this non-invasive transcutaneous bilirubinometer must be calibrate to avoid from false readings and wrong indicator.

2.0 JAUNDICE PHENOMENAL TO NEWBORN

Hyperbilirubinemia is also known as jaundice among people nowadays. Jaundice is a common problem in the first week of life to the newborn infants. This phenomenal increase in the anxiety of the parents. Haemoglobin, the red pigment in red blood cells, must undergo a succession of changes before the body can dispose of it. Specific enzymes from the body in human great processing centre, the liver, carry out each step. Bilirubin which is the yellow pigment responsible for jaundice, is a normal component in the breakdown of haemoglobin. Adults often turn yellow when they have hepatitis because their livers aren't able to process the bilirubin. The presence of enough bilirubin for the yellow pigment to be visible is called jaundice [7].

Jaundice occurs in about 60% of healthy term infants and 80% of those born prematurely. Jaundice has two different types which are physiological jaundice and pathological jaundice [6]. By definition, physiological jaundice appears between 24 to 72 hours of age, peaks by 4 to 5 days in the term and 7th day in preterm neonates and then, disappears by 10 to 14 days of life. Approximately, the level of bilirubin of newborn infants does not exceed 15 mg/dL but in some cases, if the newborn infants have 17 to 18 mg/dL of serum bilirubin, they still considered as healthy newborn. In this regard, physiological jaundice disappears spontaneously without having any special treatment. Pathological or also known as non-physiological jaundice appears in the first 24 hours and serum bilirubin is rising beyond 5 mg/deal per day. The peak level might be greater than the expected normal range. Thus, the higher readings of jaundice can lead the infants to a severe hyperbilirubinemia and can affect the newborn's health in a long period of time. They can be exposed to a liver failure problems and cerebral palsy.

Jaundice occurs due to breakdown red blood cells, the breakdown process is known as hemodialysis. If the cell breakdown rate occur at faster rate than usual, it increased the level of bilirubin in the body and causes jaundice to the infants [8]. Bilirubin concentration can be detected by using two different techniques which are invasive method and non-invasive method. Bilirubin is the yellowish pigment that is the byproduct of heme catabolism. Bilirubin is responsible for the yellow colour of the urine. When the cell is died, haemoglobin is release from the cell, which is breakdown into heme and globin, Heme is finally converting into bilirubin, an orange yellow pigment. Bilirubin is an endogenous anion derived from haemoglobin degradation from the red blood cell [3]. Bilirubin is altered by exposure to light so serum and plasma samples must be kept in dark before measurements are made. When the liver function tests are abnormal and the serum bilirubin levels more than 17 μmol/L suggests underlying liver disease.

Total bilirubin is also known as total serum bilirubin. In other words, total bilirubin also termed as any form of a yellowish pigment made in the liver when red blood cells are broken down and normally excreted with the bile. Total bilirubin is measured as the amount, which reacts in 30 minutes after addition of alcohol. Normal range is 0.2-0.9 mg/dl (2-15μmol/L). It is slightly higher by 3-4μmol/L in males as compared to females. Other than that, total bilirubin and direct bilirubin levels are measured directly in the blood of the newborn baby [9]. Direct bilirubin or also known as conjugated bilirubin is a bilirubin that is made by the liver from indirect bilirubin and can be dissolve in water. It is also measured directly in the blood. This is the water soluble fraction. Besides that, a small portion, termed delta bilirubin is the covalent conjugated bilirubin that bound to albumin. The measurement of direct bilirubin estimated the total concentration of the conjugated bilirubin and delta bilirubin [10]. This is measured by the reaction with diazotized sulfanilic acid in 1 minute and the normal range obtained is 0.3mg/dl (5.1 μmol/L). Indirect bilirubin also known as unconjugated bilirubin or hyperbilirubinemia (albumin bound) which usually results from increased production, impaired hepatic uptake, and decreased conjugation of bilirubin [11]. This fraction is calculated by the difference of the total and direct bilirubin and is a measure of unconjugated fraction of bilirubin. Unconjugated hyperbilirubinemia will arises in newborn if one of the three major pathophysiologic conditions or a combination of them occur. The three major pathophysiologic conditions are the increased bilirubin production, impaired bilirubin uptake, and impaired bilirubin conjugation.

3.0 METHODOLOGY

IOT based Non-invasive Transcutaneous Bilirubinometer design has been made in obtaining the proper accurate readings of hyperbilirubinemia. In this section, several components of the device and more detail explanation about the design and flow of constructing the IOT based Non-invasive Transcutaneous Bilirubinometer are discussed. The device's design is based on two aspects that are hardware and software. For the software part, there will be a system that will be built by using Massachusetts Institute Technology (MIT) Software [12] which is the MIT software will be the main part that will connect and synchronize the hardware and software. Besides, this device also will be connected wirelessly to the phone and the programming for data storage will be add on in this device for the upgraded point. For the hardware part, the Arduino Nano, will integrate with the software and hardware part to make sure that the both parts is connected so that the input can communicate and program to the output application.

The hardware part of the device that contain infrared sensor (blue and green LED 455 nm – 575 nm), color sensor TCS3200, photodiode sensor (BPW21R) with Arduino Nano will be tested on the newborn with jaundice. Then, the reading of the bilirubin level will be displayed on the smartphone via wireless connection. Figure 2 shows how the Recent Intelligence Non-Invasive Transcutaneous Bilirubinometer is functioned. The battery act as the source that connect with Arduino Nano. The input is LED with two different wavelengths, 455nm and 575nm, photodiode sensor and color sensor will be attached to the skin. The Arduino Nano that indicate with the input will process all the data receive from the input like the wavelength of the bilirubin level through the skin reflectance. The result then will be displayed at the LCD and also the smartphones where the smartphones will connect wirelessly with the Arduino Nano and the data of patient will be storage at cloud storage.

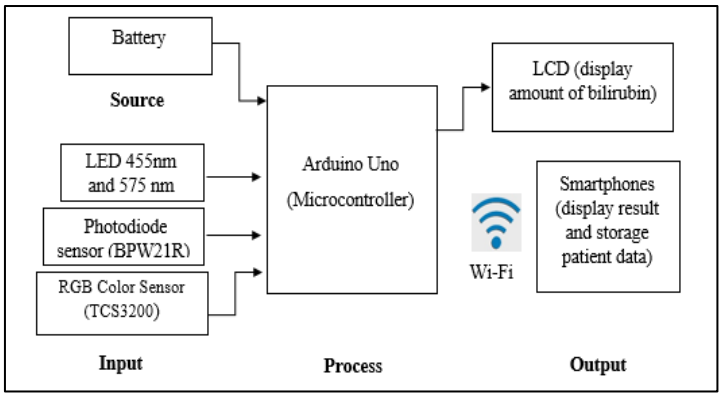

Figure 2. Block diagram of IOT based Non-Invasive Transcutaneous Bilirubinometer

Figure 3 shows the design of the IOT based Non-Invasive Transcutaneous Bilirubinometer. The design shows the picture on how the IOT based Non-Invasive Transcutaneous Bilirubinometer device will be tested on the patient and the result then will appear on the smartphone. With the use of IOT, all of patient's data will appear and can be save automatically in the smartphone.

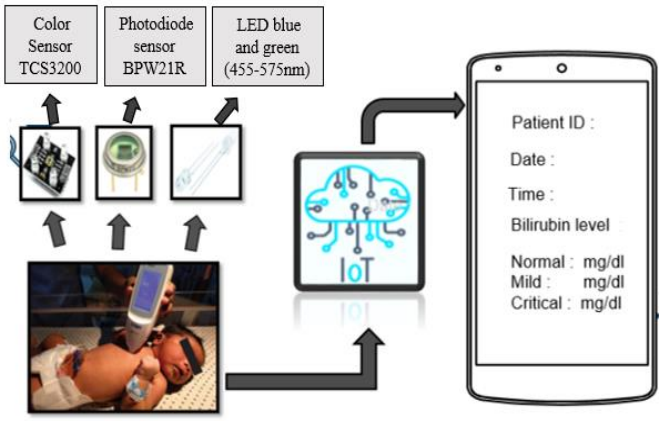

Figure 3. Design of IOT based Non-Invasive Transcutaneous Bilirubinometer

Table 1 shows the reading parameter of bilirubin level in newborns as reference for the result of IOT based Non-Invasive Transcutaneous Bilirubinometer device when being tested to the newborn in different area of the body and classified in five level for each range of bilirubin.

Table 1. Reading of bilirubin in newborns

Area of the Body	Level	Range of Serum Bilirubin	
		µmol/L	mg/dL
Head and Neck	1	68-133	4-8
Upper trunk (above umbilicus)	2	85-204	5-12
Lower trunk and thighs (below umbilicus)	3	136-272	8-16
Arms and lower legs	4	187-306	11-18
Palms and soles	5	≥306	≥18

3.0 RESULT AND ANALYSIS

The analysis of device is by referring to the research [13] that using a colour detection to detect jaundice in newborn which is the concept is similar to IOT based Non-Invasive Transcutaneous Bilirubinmeter device. The result from the research is taken as a reference for this project in testing section. Based on the research, the device is being tested on the colour sample of jaundice and each colour sample has different value of bilirubin. Thus, through the result, the amount of bilirubin in newborn and the condition of the newborn whether it is normal, severe or critical can be known. Table 2,3 and 4 are used as references and describe the level of bilirudin and jaundice. Table 2 shows the range of bilirubin level in newborn that determine whether the newborn is in normal condition or having a jaundice. The table is used as a reference to determine the bilirubin level in newborn by using the IOT based Non-Invasive Transcutaneous Bilirubinometer device. Table 3 and Table 4 each shows the result of bilirubin level based on jaundice and non-jaundice colour sample. Through this result, the stage of jaundice in newborn can be predicted and determined by referring to the Table 2.

Table 2. Reading of bilirubin level and the stage of jaundice in newborn.

Bilirubin level (mg/dL)	Stage of Jaundice
Bilirubin level < 4	Normal
4 < Bilirubin level ≤ 10	Mild
10 < Bilirubin level ≤ 20	Severe
20 < Bilirubin level	Critical

Table 3. Response for jaundiced sample.

Sample No.	Extracted skin colour of jaundiced sample	Estimated bilirubin level (mg/dl), State of Jaundice
1		17.36 Severe
2		15.23 Severe
3		9.92 Mild

Table 4. Sample colour of non-jaundice and the scale of jaundice for normal condition.

Sample No.	Extracted skin colour of jaundiced sample	State of Jaundice Estimated bilirubin level (mg/dl)
4a		Normal (<4mg/dl)
4b		
5		

The IOT based Non-Invasive Transcutaneous Bilirubinometer device readings is based on bilirubin level in range form. For IOT based Non-Invasive Transcutaneous Bilirubinometer device, the output is based on the value of intensity of blue LED and green LED of TCS3200 RGB color sensor. The value is measured and collected in the form of range to represent the range of value measured using IOT based Non-Invasive Transcutaneous Bilirubinometer device is equivalent to the range of bilirubin level (mg/dl). The stage of jaundice that are normal, mild, severe, and critical can be recorded based on the value of the intensity of blue and green LED appeared during testing the device that fits into the range of bilirubin level that had been measured. Table 5 shows the value obtained the IOT based Non-Invasive Transcutaneous Bilirubinometer device testing compared to the bilirubin color card. The device is tested at least 3 times for each color of bilirubin color card and from the result, the average value is obtained. Comparison analysis between the average value for each color of bilirubin color card is equivalent to the estimated range of bilirubin level tested by IOT based Non-Invasive Transcutaneous Bilirubinometer.

Table 5. Sample colour of non-jaundice and the scale of jaundice for normal condition.

Jaundice Colur of Newborn Image	Estimated Range of Bilirubin Level using Recent Intelligence Non-Invasive Transcutaneous Bilirubinometer	Stage of Jaundice
	29853	Mild
	43524	Severe
	53442	Severe

4.0 CONCLUSION

The IOT based Non-Invasive Transcutaneous Bilirubinometer design aims to be easy to use, efficient, economical and most importantly, not giving any pain or discomforts to the patient. Invasive method is a good technique in measuring and detecting the jaundice in early age of newborn. However, due to the risk factor on doing the blood test on the baby, the new device using latest technology and without painful is designed in determined jaundice which is by using the Intelligence Non-Invasive Transcutaneous Bilirubinometer that is more preferable and painless for testing the newborn with jaundice. By using this IOT based Non-Invasive Bilirubinometer, it can save time, user friendly, painless without any pricking needle (blood test) is needed to determine the level or readings of the jaundice among baby. The proposed device shows excellent results, generating control with a low computational cost.

REFERENCES

[1] J. A. J. I. B. S. S. E. M. C. Zulkarnay Z., "An Overview on Jaundice Measurement and Application in Biomedical : The potential of Non-Invasive method," *2015 2nd International Conference on Biomedical Engineering (ICoBE),* 2015.

[2] A. K. I. &. P. K. Ankan Gupta, "Jaundice Prediction through Non-Invasive Techniques: Issues and Challenges," *IEEE INDICON 2015 1570170877,* 2015.

[3] A. K. Nainika Saini, "Comparison of Non-Invasive Bilirubin Detection Techniques for Jaundice Protection," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation, and Control Engineering,* vol. 4, no. 5, 2016.

[4] P. C. Health, "Guidelines for Detection, Management and Prevention of Hyperbilirubinemia In Term and Late Preterm Newborn Infants (35 or more weeks' gestation)-Summary," *Paediatrics Child Health,* 2007.

[5] Z. J. a. S. H. Rasool Panahi, "The Relationship between the Behavioral Hearing Thresholds and Maximum Bilirubin Levels at Birth in Children with a History of Neontal Hyperbilirubinemia," *Iranian Journal of Otorhinolaryngology,* pp. 127-134, 2013.

[6] K. R. a. M. H. Sana ULLAH, "Hyperbilirubinemia in Neonates: Types, Causes, Clinical Examinations, Preventive Measures and Treatments: A Narrative Review Article," *Iranian Journal of Public Health,* 2016.

[7] N. J. a. P. Jaundice, ""What Causes Jaundice?"," pp. 1-29, 2016.

[8] T. Jewell, "Healthline," Healthline, 17 September 2018. [Online]. Available: https://www.healthline.com/health/high-bilirubin. [Accessed 11 March 2020].

[9] M. P. Charles Patrick Davis, "MedicineNet," MedicineNet, 7 December 2019. [Online]. Available: https://www.medicinenet.com/bilirubin_and_bilirubin_blood_test/article.htm. [Accessed 11 March 2020].

[10] M. P. R. M. a. T. B. N. M. M. Adam Rahn Davis, "Interpreting Conjugated Bilirubin Levels in Newborn," *The Journal of Paediatrics,* pp. 562-565, 2011.

[11] I. J. Anand Singh, Unconjugated Hyperbilirubinemia, StatPearls Publishing LLC, 2019.

[12] "Information Systems and Technology," Massachusetts Institute of Technology , [Online]. Available: https://ist.mit.edu/. [Accessed 11 March 2020].

[13] S. D. R. G. Ajay Kumar Chowdhary, "Neonatal Jaundice Detection using Colour Detection Method," *International Advanced Research Journal in Science, Engineering and Technology(IARJSET),* vol. Vol.4, no. issue 7, 2017.