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Comparison of Non-Invasive Bilirubin Detection Techniques for Jaundice Prediction

Nainika Saini[1], Ashok Kumar[2]

M.Tech Scholar, Department of Electronics and Communication Engineering,

Ambala College of Engineering and Applied Research , Ambala, India[1]

Head of Department, Department of Electronics and Communication Engineering,

Ambala College of Engineering and Applied Research, Ambala, India[2]

Abstract: Hyperbilirubinemia is mostly found in newborn babies as a result of increase in the bilirubin content measured in the body. Neonates with hyperbilirubinemia often needs medical evaluation and involvement to detect hyperbilirubinemia, an elevated level of bilirubin in the blood and jaundice, yellowing of skin that usually accompanies it, are common in the first week of life. Three methods commonly used to estimate the bilirubin levels in the neonates are visual assessment, transcutaneous bilirubin measurement and blood serum analysis.

Keywords: Hyperbilirubinemia, Non-invasive, Transcutaneous Bilirubinometer, Transcutaneous Serum Bilirubin.

I. INTRODUCTION

Hyperbilirubinemia is a condition in which there is an excessive amount of bilirubin in the blood. When blood platelets breakdown, a substance called bilirubin is formed. Neonates are not ready to effortlessly dispose of the bilirubin and it can develop in the blood and different tissues and fluids of the infant's body which is called hyperbilirubinemia. Since bilirubin has a coloring pigment which causes yellowing of the baby's skin, eyes, and other tissues. This condition is called jaundice. Jaundice which is also known as icterus, is a condition in which the skin and the conjuctival membranes over the sclerae (whites of the eyes) gets to be yellow, urine darkens and the color of stool gets to be lighter than ordinary. One of the first tissues to change color in jaundice is the conjunctiva of an eye which is sometimes referred to as scleral icterus. The term jaundice is derived from French word jaune, which means yellow. Although jaundice is not a disease but a noticeable indication of a hidden sickness process.

In adults, jaundice can be caused by a variety of medical conditions, some of which are serious and possibly life-threatening. Any grown-up who develops jaundice needs to experience a comprehensive medical evaluation in order to determine its reason. Jaundice in newborns, called neonatal jaundice [12] is caused by the breakdown of Red Blood Cells. If the cell breakdown occur at the rate faster than the usual then it results in the increased level of bilirubin in the body and causes jaundice. Jaundice is typically seen when the level of bilirubin in the blood exceeds 2.5-3 mg/dL (milligrams per deciliter). Newborn children with high blood levels of bilirubin, called hyperbilirubinemia [6], builds up the yellow color when bilirubin aggregates in the skin. Most babies have physiologic jaundice, which happens because a baby's organs aren't yet ready to dispose of abundant bilirubin extremely well. In very few cases, jaundice may be an indication of another condition for example, an infection, a digestive system problem or blood group incompatibility with the mother.

This paper comprises of four sections where Section II. consists of Literature Survey and Section III. describes the Performance Analysis.

II. REVIEW

Extensive research work has been reported over past few years in the area of jaundice prediction through bilirubin detection using non-invasive technique.

A. Transcutaneous Bilirubinometers

Neonatal jaundice is a common problem and appears in about 60% of newborns. Occasionally, the rate of bilirubin production may surpass the capacity of the body to eliminate bilirubin resulting in imbalance between the processes that may prompt hyperbilirubinemia. The significance in the prevention of extreme hyperbilirubinemia may therefore lie equally in the resolute post-release follow-up of all neonates as in following guidelines for the institution of phototherapy or performing of exchange transfusion [4]. Distinct countries or geographic areas may have local traditions or customs with the potential of either worsening or dampening the risk of hyperbilirubinemia.

B. Instruments Used for Measuring TcB

Among the devices used for non-invasive bilirubin measurement, first was the ColorMate III. It is based on the color of the skin and estimates the serum bilirubin from skin reflectance [9]. This type of transcutaneous bilirubinometer used a Xenon flash tube and light sensors to measure the wavelengths from 400nm to 700nm. A major requirement of this device was the necessity for a

baseline TSB reading on each newborn baby, regardless of its risk for developing hyperbilirubinemia. When an initial baseline skin color measurement was performed in neonates, the correlation coefficient measured in the clinical laboratory with TSB was greater than 0.95.

Another sophisticated instrument for non-invasive bilirubin measurement was the Minolta/Air Shields Jaundice Meter [1], which works by assessing the light reflected from the skin (after emmited from a photo tube). It uses two wavelengths (460 and 550nm) along with dual optical path framework to measure bilirubin transcutaneously. The original model of jaundice meter JM-101 and JM-102 gave readings as a numerical index that required an initial correlation to the TSB. Newest version of the meter, JM-103 determines the bilirubin from the subcutaneous tissue of neonate by determining the difference in the optical densities of reflected light at 450nm and 550nm by the infant skin. JM-103 showed much better correlation with TSB than the earlier JM-101 and JM-102 models. The usefulness of JM-103 in Taiwanese neonates [3] was evaluated and the paper recommended routine TcB measurements for newborn babies before discharge in order to effectively decrease the recurrence of blood sampling and prevent severe neonatal hyperbilirubinemia. Acoording to J.M.C Uwurukundo [8], the accuracy of one of the bilirubinometer JM-102 was evaluated in dark skin term and preterm neonates old under two weeks compared to the gold standard which is the estimation of serum bilirubin(SBR) and the most useful value of transcutaneous bilirubinometer (TcB) in terms of specificity and sensitivity [2] was identified.

Recently, a transcutaneous bilirubinometer, BiliChek was developed which measures the bilirubin transcutaneously by using the visible light (380-760nm) reflected by the skin. The light absorption of the interfering factors, such as haemoglobin and melanin, is subtracted to obtain the biliubin concentration. Although BiliChek was recognized as a huge improvement over the older transcutaneous devices but a clean and disposable tip is required for each measurement which substantially increases the cost of the test. Kaynak-Turkmen M. investigated that the BiliCheck, point-of-care device, which performs transcutaneous estimation of bilirubin by multiwavelength spectral analysis was evaluated and the results obtained with the BiliCheck are compared with bilirubin concentrations in blood samples measured by three ways: bilirubinometer, diazo [5] methods and HPLC [7].

Clinicians estimate the blood concentration of bilirubin with either a TSB or TcB. A Total Serum Bilirubin (TSB) test directly estimates the bilirubin from a blood sample whereas Transcutaneous Bilirubinometer (TcB) is a specialized meter that indirectly measures bilirubin levels from skin reflectance. Since TSB requires repeated blood sampling and TcB costs several thousands of dollars thus a low cost system, BiliCam has been developed to assess newborn jaundice. It is a smartphone based medical device that uses the embedded camera and a paper based color caliberation card to monitor newborn jaundice. This non-invasive solution requires no additional hardware other than the smartphone and color caliberation card. A rank order correlation of 0.85 is yielded by BiliCam with the gold standard blood test.

Smartphones have been shown to improve and automate point-of-care diagnosis, which require visually analyzing test results from blood or urine samples on specialized materials. BiliCam, a smartphone-based medical device that uses an embedded camera and a paper-based color alignment card to monitor newborn jaundice, operates by performing following steps: color balance the images, obtain intensities of various reflected wavelengths and both chromatic and achromatic properties from the skin and estimate bilirubin levels using machine learning [12].

III. PERFORMANCE ANALYSIS

The current gold standard to detect bilirubin levels is total serum bilirubin concentration (TSB) determination from a blood sample obtained by invasive blood sampling. Although over the years this method has been turned out to be successful in preventing kernicterus, it has its drawbacks. Invasive blood sampling is stressful and painful for the neonate, resulting in blood loss and infections at the site of sampling. In addition, the method is laborious and time consuming, lacking the possibility for immediate diagnosis. Table1. compares the performance of various devices used for non-invasive bilirubin detection. The parameters in the table can be further summarized using numeric values as follows: 0-Low, 1-Medium and 2-High thus Table 2. Shows the simplified form of the comparison discussed in Table1. Based on this comparison, smartphone based device BiliCam seems to be much better than any of the Transcutaneous Bilirubinometers and Total Serum Bilirubin methods.

Table1. Comparison of Different Non Invasive Detection Devices .

Serial No.	**Measuring Device → Parameters ↓**	**JM-103**	**BiliChek**	**BiliCam**
1.	Design	Uses two wavelengths and a dual optical path system.	Uses multiple wavelengths and spectrometer for measuring bilirubin.	Uses a paper based color caliberation card and an embedded camera.
2.	Detection Level	Can detect bilirubin concentration upto 14mg/dl.	Can detect bilirubin concentration upto 14mg/dl.	Can exactly detect bilirubin concentration upto 17mg/dl.
3.	Rank Correlation	0.85	0.83	0.85

4.	Sensitivity (%)	100	99	100
5.	Specificity (%)	60	66	50
6.	Standard Deviation (µmol/l)	29.46	24.3	41.60
7.	Cost	Less Expensive	More Expensive	Least Expensive
8.	Time Consumption	Less	More	Least

Table 2. Simplified Comparison of Non Invasive Detection Devices.

Serial No.	**Measuring Device → Parameters ↓**	**JM-103**	**BiliChek**	**BiliCam**
1.	Detection Level	1	1	2
2.	Rank Correlation	2	1	2
3.	Sensitivity (%)	2	1	2
4.	Specificity (%)	1	2	0
5.	Standard Deviation (µmol/l)	1	0	2
6.	Cost	1	2	0
7.	Time Consumption	1	2	0

Figure1. represents this comparison in the form of chart. According to it, BiliCam can detect the level of bilirubin with high sensitivity within less time. Its low cost and simple hardware makes it easily affordable for a common man.

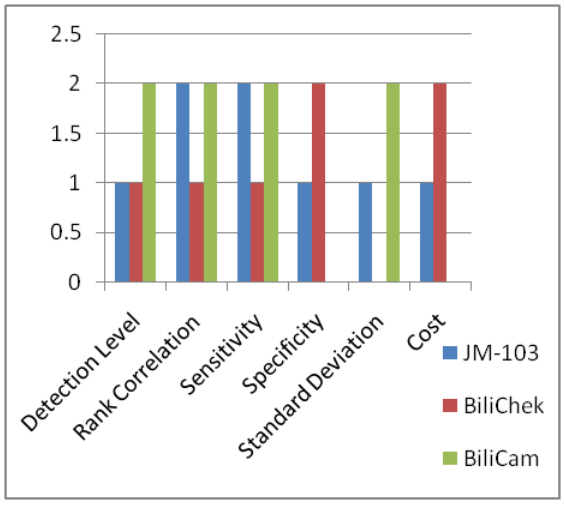

Fig 1. Comparison of Three Non Invasive Detection Devices using Bar Graph.

IV. CONCLUSION

Bilirubin can be detected through invasive and non-invasive techniques for jaundice prediction in neonates. Invasive techniques are painful for the infants and stressful for the parents. In invasive techniques, blood samples are taken and bilirubin concentration is detected by taking these samples to laboratory which is a long process and require many hours for detection. This time delay causes delay in the treatment of child. To avoid these drawbacks, non invasive techniques are used that are not painful and provide result in lesser time as compared to invasive techniques. In non-invasive techniques, bilirubin concentration can be determined by placing bilirubinometer at sternum or forehead but these devices are costly. So, there is need to develop a technique, which can be used to detect jaundice without the need to go to laboratory and without causing pain and stress. Now-a-days, smartphones are common in homes and usability of smartphone increases by the rate of 67%. An app for smartphone can be designed for early and easy detection of jaundice in neonates.

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