Estimation of Neonatal Jaundice from the Chest Images Captured with a Smartphone

Mekar Dwi Anggraeni[1*], Amin Fatoni[2], Eni Rahmawati[1] and Ismei Nartiningsih[3]

[1]*Department of Nursing, Faculty of Health Sciences, Universitas Jenderal Soedirman, Jl dr Soeparno 61, Purwokerto, Indonesia*
[2]*Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Jenderal Soedirman, Jl dr Soeparno, Purwokerto, Indonesia*
[3]*DR Goeteng Taroenadibrata Hospital, Purbalingga, Indonesia*
[*]*Corresponding author: mekar.anggraeni@unsoed.ac.id*

ABSTRACT

Hyperbilirubinemia is a common problem in neonatal for contact with the healthcare facilities. Several methods have been used to determine the bilirubin concentration. However, it is not easy to find the healthcare with the instrument to detect bilirubin, mainly in rural area. This research was aimed to develop a simple method for neonatal hyperbilirubinemia based on the chest images captured using a smartphone. A total of 31 randomly selected neonatal were studied, with the parental inform consent. The chest images have been capture using smartphone camera with the standard color chart besides the neonatal. The captured images were then analyzed by extracting the color intensity using ImageJ software. The bilirubin concentration obtained using standard method from the hospital were then analyzed to show the association of the chest color intensity with the bilirubin concentration. The result showed a high correlation between the blue color intensity and the blood bilirubin with the regression line of y = -0.466x + 162.84 (R^2 = 0.851). The result of this study indicated the smartphone camera images of neonatal chest could be used for a simple screening tool of neonatal hyperbilirubinemia. Further study could be performed for smartphone software development of the bilirubin prediction from the neonatal chest images.

Keywords: Hyperbilirubin, Neonatal jaundice, Self-care, Smartphone.

1. INTRODUCTION

Indonesia is one of the country in southeast Asia with the high of infant mortality rate [1] of about 26.9/1000 live birth [2]. One of the causes of the high IMR in Indonesia is hyperbilirubinemia in newborns [2]. About 60% of infant mortality occur in the range of 0-28 days after birth. Neonatal jaundice is one of factors affecting infant mortality rate. The neonatal jaundice is indicated by the high level of blood bilirubin. Almost 48% of neonatal showed hyperbilirubinemia [3].

The hyperbilirubinemia could be detected using standard protocol in the hospital of spectrophotometric method. The hyperbilirubinemia was also could be observed visually in case of spectrophotometric method is not immediately available, indicated by the yellowish color of the skin and sclera [4]. Physical examination needs an expert medical personnel or nurse, could be provides inaccurate data, is highly subjective and may give inaccurate results [5]. In another side, laboratory standard protocol using spectrophotometer provide accurate results of bilirubin determination, but the cost of equipment is expensive, requires special expertise, and primary health facilities are not always available. An alternative method is needed to determine or predict the neonatal jaundice with a good result, accurate, easy, low cost, portable and available in wide area including rural and remote villages.

Now day, almost everyone has smartphone with camera. The use of camera smartphone as alternative of visual observation or analytic instrumentation have been reported such as hemoglobin prediction [6], food safety[7], iron in water [8] and also and glucose[9]. The principle of using smartphone camera was the digital image had a color intensity and this value could be related to any analytes where the color change with the higher concentration of analytes such as in case of hemoglobin related to red color or hyperbilirubin related to yellow color. The neonatal skin color for hyper bilirubin prediction using smartphone could be used to replace the conventional method of visual examination of the inferior palpebral conjunctiva area [4]. The use of smartphone camera for early detection of hyperbilirubin could be used to improve the conventional method of visual examination. The proposed smartphone camera based observation would help early detection system, especially in developing country where the instrumentation for bilirubin determination is limited.

2. METHODS

2.1. Study design

Participants in this research were 31 newborn infants with hyperbilirubinemia who were hospitalized in the local district hospital. The inform consent as research participant has been signed by mothers. The chest images of the infant have been capturing during hospitalization where the blood bilirubin was also been analyzed by the hospital procedure both before and after treatment of the hyperbilirubinemia. The blood bilirubin has been analyzed without any interference from the researcher. The chest images were capture according to the timeline of the blood bilirubin determination by the hospital.

2.2. Newborn infant chest photo shoot

The chest photos have been captured using a smartphone camera (Redmi, Camera 13 MP, f/2.0, PDAF) under sufficient lighting without using camera flash. The photo capturing condition in the care room with white regular room light. A printed standard color chart as references [10] has been prepared and placed besides the newborn infant (**Fig. 1**). The photo capturing was performed at a distance of about 50-60 cm.
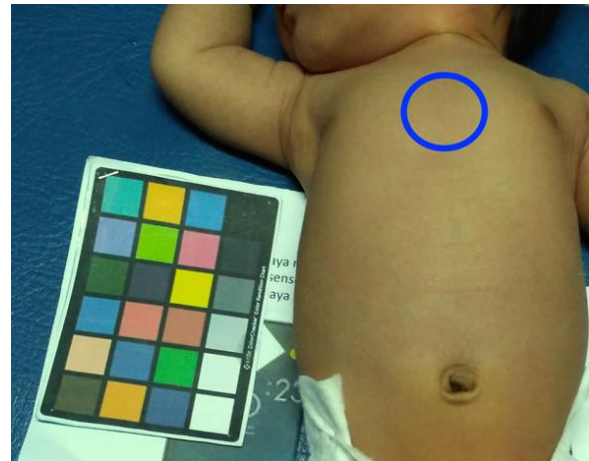

Figure 1. Smartphone camera could be used to predict the newborn blood bilirubin concentration. Observed site was marked in blue circle, standard color chart was prepared for correction.

2.3. Image analysis

Collected chest photos (digital images) have been transferred from smartphone to laptop (MacBook Air, Apple Inc.) for further image analysis. No image editing or processing in the smartphone prior to photo transferring. The chest digital images were analyzed using free software of ImageJ (ver. 1.52k, National Institute of Health, USA. http://imagej.nih.gov/ij). The ImageJ software was used to extract the color intensity of chest image into RGB color model to get the intensity of each red, green and blue. The RGB intensity could be record by simple hover the mouse over the chest image or using the line and the available RGB profile plot plugins. Three spots have been recorded their RGB intensity to get the representative sampling. The standard color chart has been used to correct the images from the possible different light condition and colored lamp effect.

2.4. Data analysis

The RGB of chest images have been collected for analysis. The color intensity data was first checking the light condition or colored lamp effect from the RGB data of standard color chart. The medical record of blood bilirubin and another possible affecting factor were also recorded. The color intensity was then analyzed using simple regression with blood bilirubin as X axis (independent variable) and RGB color as Y axis (dependent variable). The regression analysis would result regression line with the coefficient of determination. The color intensity of red, green or blue with the highest coefficient of determination was selected for further prediction of blood bilirubin concentration of newborn infant.

3. RESULTS DAN DISCUSSION

3.1. Study participants

The mothers of the participants in this study have an average age of 32 years, in the range of 19 to 41 years. The 31 newborns observed showed the birth weight of 1526 to 3900 g with gestational ages were 31 to 41 weeks. Among the newborn participants, 69% of them were cesarean birth and the rest were natural birth. About the hyperbilirubinemia of the participants, the blood bilirubin concentrations measured by the hospital method were 11 to 25.9 mg/dL with an average of 16.6 mg/dL. The hyperbilirubinemia symptoms reported from 2 days to 26 days from birth, with average of 6.9 days. The newborn data profile collected could be used for further analysis related to their hyperbilirubinemia.

3.2. Chest image capture and analysis

Chest image of newborn participants have been captured with smartphone camera under the approving of their mothers. The research assistant explained the research objective and procedure prior to chest newborn image capturing. Participants in this study were voluntary, there was no compulsion from the researcher nor the hospital. Previous study reported the chest was the best site for bilirubin determination using BiliCheck™ compare to another body site of the infant [11], therefore, we use the chest image of the newborn infant to predict the bilirubin concentration using smartphone camera. The chest images have been captured several times to get the best picture position and lighting.

The camera image could be interfered with environmental such as light condition and colored lamp. Several strategies have been reported to compensate the environmental effect such as the use of software correction [12], red label based white balance [13], white paper [6] and standard color chart [10]. The standard color chart was used in this research to correct the images by adding or reducing the color intensity, when the value of color intensity of white and yellow color was significantly (more than 3 point) different with another images.

The standard color chart of the white box color intensities was red of 201.5, green of 237.5 and blue of 239. The yellow color box in the standard color chart was also used as reference with the observed color intensities of red of 202, green of 200.7 and blue of 0.8.

3.3. Regression analysis

The newborn infant chest images color intensity was plotted to the corresponding blood bilirubin concentration. Among the red, green and blue color intensity, the blue color showed the best sensitivity and correlation (highest coefficient of determination) compare to that of red and green color intensities (**Fig. 2**). Therefore, the yellowest chest image, the lowest blue color intensity, the highest corresponding bilirubin concentration.
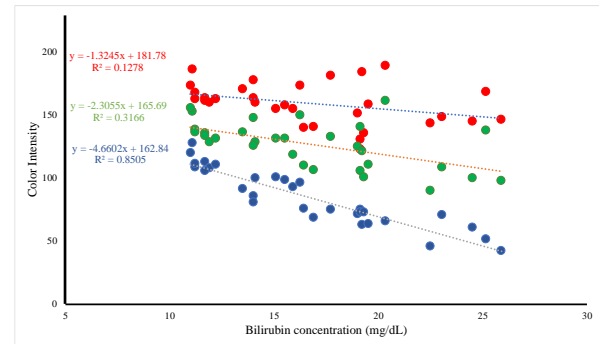

Figure 2. Relationship between newborn chest images color intensity and blood bilirubin obtained by hospital laboratory (n=31). Dotted line represents best fit by linear regression.

3.4. Neonatal jaundice etiology

Neonatal jaundice is characterized by yellow color of newborn skin and sclera. The yellow color occurs because the high level of blood bilirubin of the newborn. Neonatal jaundice common event occur in the first week of birth [14] and it is common reason of infant hospitalization. The excess of bilirubin is cause by imbalance of bilirubin metabolism, where the production of bilirubin is greater than the excretion of bilirubin. The imbalance of metabolism due to the immature liver for rapid breakdown the red blood cells due to several factors [15], such as gestational age [15]. Neonatal born before 38 weeks may not be able to process bilirubin quickly compare to full term infant. The premature infant also may feed less and fewer bowel movement, resulting less bilirubin elimination [16]. The newborn participants in this research showed that the average of gestational age was 37.8 weeks, with the minimum of 31 weeks and maximum of 41 weeks. Induced labor was also reported slightly increase the neonatal jaundice incidence [16]. The result of data analysis in the participants showed the 43,5% neonatal from the induced labor.

4. CONCLUSION

Newborn chest images obtained by smartphone camera could be used to estimate the blood bilirubin concentration. The blue color intensity of chest images showed the best correlation with the blood bilirubin concentration compare to the red and green color intensity. Obtained regression equation of y = -0.466x + 162.84 used to estimate the blood bilirubin concentration in infant, with y was blue color intensity and x was bilirubin concentration (mg/dL). The use of camera

smartphone would help for neonatal jaundice in rural area with limitation of medical instrumentation to determine the blood bilirubin in infant.

AUTHORS' CONTRIBUTIONS

All authors, MDA, AF, ER, and IN, have contributions about CONCEPT, METHOD, and ANALYSIS. All authors (MDA, AF, ER, and IN) provided feedback, discussed result and contributed to the final manuscript.

ACKNOWLEDGMENT

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