Correlation between Transcutaneous Bilirubinometry and Measurement by Digital Photographic Yellow Level among Neonates

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ABSTRACT

Neonatal jaundice is a common medical problem among newborns. This study was conducted to evaluate the correlation among serum microbilirubin (SMB), transcutaneous bilirubinometry (TCB) and digital photographic yellow level (DPYL) among neonates. This research employed a quasi-experimental design. TCB and DPYL at chest level of 42 newborns were determined at more than 24 hours after birth in Ramathibodi Hospital. Digital photographs were taken at chest level of the newborns and were analyzed using Photoshop® computer program to determine the yellowish level of neonatal skin. The results of three methods were compared. Regression equation for the correlation between SMB and DPYL was SMB = 6.073 + 0.191(DPYL) mg/dL with $R^2 = 0.766$, ($p < 0.05$). The regression equation for the correlation between TCB and DPYL was TCB = 5.414+0.22 (DPYL) mg/dL with $R^2 = 0.935$, ($p < 0.05$). The results of DPYL could be used as a screening test for neonatal jaundice especially in locations where resources are limited.

Keywords: neonatal jaundice, serum microbilirubin (SMB), transcutaneous bilirubinometry (TCB), digital photographic yellow level (DPYL).

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Introduction

Neonatal jaundice or hyperbilirubinemia is one of the most common complications among newborns.[1] Often a harmless clinical condition as a result of normal adaptive physiological processes, it generally occurs between three and five days after birth and then resolves over the next seven to ten days. Normally, jaundice is first found on the newborn's face. Then it progresses to the trunk and extremities as serum bilirubin concentration increases.[2] Furthermore, extreme neonatal hyperbilirubinemia may result in bilirubin encephalopathy (kernicterus) causing irreversible brain damage to newborns.[3]

The incidence of neonatal jaundice or hyperbilirubinemia has been reported to be more than 30% among full term newborns and about 100% among premature infants.[4] Hyperbilirubinemia is more prevalent in Asian populations.[5] A study in Canada found that 6.7% of newborns (predominantly white) had jaundice with a peak total serum bilirubin (TSB) >230 μmol/L (13.5 mg/dL).[6]

The current gold standard to measure bilirubin levels is TSB and serum microbilirubin (SMB) determined from a blood sample, which can be obtained by venipuncture or skin capillary puncture at the sole of newborns. This invasive procedure is painful and may result in skin infection. Noninvasive methods of bilirubin measurements have been developed.[1] In 1980, Yamanouchi et al.[7] and the Minolta Camera Company developed one of the first clinically applicable transcutaneous bilirubin measurements. Then numerous technological advances have led to improved accuracy and reliability in determining jaundice. Currently, the two popular instruments for transcutaneous bilirubinometry, i.e., the BiliCheck and JM-103, have been validated through extensive study.[8] When screening by TCB significantly increases the risk of hyperbilirubinemia among neonates, serum bilirubin should be measured by the laboratory.[8-9] However, at present, the equipment to measure TCB is very expensive.

In 2009, Leartveravat S.[10] designed a new noninvasive method to measure jaundice levels of newborns using digital photography that could assess the yellow level of the skin using Photoshop®. He found good correlation between TSB and measurement of jaundice by digital photography (DPYL). This study aimed to evaluate the correlation between serum microbilirubin, TCB using the JM-103 and jaundice measurement by digital photography (DPYL) among neonates.

Materials and Methods

This research was approved by Committee on Human-Related Research Involving Human Subjects, Faculty of Medicine, Ramathibodi Hospital, Mahidol University. Forty-two newborns in Ramathibodi Hospital were recruited from August 15 to October 31, 2015.

Population

1. The inclusion criteria of the newborns are described below.

1.1) Newborns were born at gestational age ≥36 weeks.

1.2) Newborns visually presented jaundice and/or just before discharge (at 24 hours or later).

1.3) Newborns did not have complications both before and after delivery.

2. The exclusion criteria of the newborns are shown below.

2.1) Newborns had congenital anomalies.

2.2) Newborns had sepsis or shock.

2.3) Research participants refused or withdrew from the research.

The sample size: The sample was selected using purposive sampling and assignment by groups using the formula[11] shown below.

$$n = \frac{\sigma^2_D \, (Z_{\alpha/2} + Z_\beta)^2}{\mu^2_D}$$

n = number of subjects per group

$Z_{\alpha/2}$= level of significance was the critical value of the normal distribution at alpha 0.05 = 1.96

Z_β = power of test 80% was the critical value of the normal distribution at beta 0.20 = 0.84

σ_d = the difference in standard deviation between the two groups, the relative variability of the sample

μ_D = the relative difference in means between the two groups of subjects

The standard deviation and mean TcB and TcdB were obtained from the research of Leartveravat S.[10] using the formula:

$$n = \frac{(4.2-3.4)^2 \, (1.96+0.84)^2}{(12.55-12.92)^2}$$

$$= 37.65.$$

The sample size, calculated with the formula above, totaled 38 cases. To cover 10% of data loss or inadequate records, 42 subjects were recruited in this study.

At 48 hours or more after birth, serum microbilirubin level was measured and recorded. TCB was also evaluated using the JM 103 at chest level of the newborns and the results were recorded. Digital photographs were also taken by the researcher without using flash at chest level of the newborns and the yellow levels of the skin were analyzed using the Photoshop® Computer Program.

Steps used to evaluate the yellow level of the newborn skin by Photoshop® (Version 1998) are described below.

1) Standard colors of the RGB system

1.1) white color (red, green and blue were set at = 255)

1.2) black color (red, green and blue were set at = 0)

1.3) gray color (red, green and blue were set at = 128)

2) Automatic adjustment of white balance in the photograph using standard color paper.

3) Measurement of yellow level of newborn skin by calculating the different percentages between Y (yellow) color minus M (magenta) color at light setting at 70%.

Data were analyzed using the SPSS Program, Version 18 licensed for Mahidol University. Data were analyzed using percentage, mean and standard deviation. The Kolmogorov-Smirnov Test was used to evaluate normal distribution of data, while linear regression analysis was employed to test the hypothesis with significance set at level $p < 0.05$.

Results

General characteristics

Most mothers were 29 to 34 years old and mean maternal age was 32 ± 6.14 years. More than one half had obtained bachelor degree level of education or above. More than one half of mothers were primipara. 36% had an age of 37 weeks or more. In all, 43% had more than eight antenatal visits, 38% were O blood type and 31% were type B. Most mothers were not given oxytocin to augment labor before delivery. In total, 60% had delivery by caesarean section. Most newborns weighed between 2,501 to 3,500 gm at birth and mean weight was 3,027.14 $\pm$ 69.88 gm. Mean age at jaundice evaluation was 59.78 ± 18.32 hours after birth. Most newborns had an Apgar score of 9 at the first minute after birth and 71.4% had an Apgar score of 10 at 5 minutes after birth.

Table 1 Characteristics of Studied Mothers and Newborns

Characteristic	n=42 (100)
	No. (%)
Maternal Age (year)	
≤24	6 (14.3)
>24-29	10 (23.8)
>29-34	17 (40.5)
>35	9 (21.4)
$\bar{x} \pm$ SD 32 ± 6.14, Range 15-43	
Maternal Education	
High school or below	18 (42.9)
Bachelor degree or above	24 (57.1)

Table 1 Characteristics of Studied Mothers and Newborns (cont.)

Characteristic	n=42 (100)
	No. (%)
Gravida	
1	22 (52.4)
≥2	20 (47.6)
Gestational age (wk.)	
≤37	15 (35.7)
>37-38	13 (31.0)
>38	14 (33.3)
Antenatal Care (Visit)	
1-5	7 (16.7)
6-8	17 (40.5)
≥9	18 (42.9)
Maternal Blood group	
O	16 (38.1)
A	8 (19.0)
B	13 (31.0)
AB	5 (11.9)
Oxytocin	
No	25 (59.52)
Yes	17 (40.48)
Weight (grams)	
>3000 - 3500	15 (35.7)
>3500 - >4000	7 (16.7)
$\bar{x} \pm$ SD 3027.14 ± 452.86, Range 2180-4170	
Age of newborns (hour)	
≤48	15 (35.7)
>48-60	6 (14.3)
>60-72	12 (28.6)

The mean and standard deviation of SMB were 12.07 ± 1.649 mg/dL, TCB 12.33 ± 1.72 mg/dL and DPYL 31.46 ± 7.568%. The distribution of these three measurements analyzed using the Kolmogorov-Smirnov test showed normal distribution. Correlations among SMB, TCB and DPYL are shown in Figures 1 to 3. Regression equation for the correlation between SMB and TCB was SMB = 1.762 + 0.836(TCB) with R^2 = 0.761/(p <0.05). The regression equation for the correlation between SMB and DPYL was SMB = 6.073 + 0.191(DPYL) with R^2 = 0.766 / (p <0.05). The regression equation for correlation between TCB and DPYL was TCB = 5.414+0.22(DPYL) with R^2= 0.935 / (p <0.05).

Discussion

Jaundice among newborns is one of the most common conditions and requires medical attention. The yellowish coloration of the skin and sclera among newborns is the result of the accumulation of unconjugated bilirubin. Among newborns, unconjugated hyperbilirubinemia reflects a normal transitional phenomenon. However, among some newborns, serum bilirubin levels may increase excessively, which can be a cause for concern because unconjugated bilirubin is neurotoxic and can cause death or lifelong neurologic sequelae among the newborns who survive (kernicterus).[4] For these reasons, diagnostic evaluation of neonatal jaundice is important and necessary to prevent neonatal morbidity and mortality.[7]

Quantification of serum bilirubin based on visual assessment on the depth of jaundice is subjective and inaccurate and can be confounded by skin color and hemoglobin. Various methods have been developed to aid noninvasive diagnosis of hyperbiliruneamia and serum bilirubin.[12]

Since 1980, noninvasive measurement of bilirubin level, i.e., TCB, was proposed by Yamanouchi et al. as a screening test for SMB to evaluate neonatal jaundice.[8, 13] The common equipment of TCB are the BiliCheck or JM 103, which are options for universal screening of neonatal jaundice. When TCB screening indicates that a neonate is at increased risk for clinically significant hyperbilirubinemia, SMB should be followed. Being aware that TCB appears to underestimate bilirubin concentrations at 206 to 240 mmol/L or 12 to 14 mg/dL is also important and should be confirmed by a clinical laboratory[1]. The available literature has demonstrated excellent linear correlation between SMB and TCB for these two devices among term and late preterm neonates. The JM-103 and BiliCheck reach almost 100% sensitivity in predicting hyperbilirubinaemia.[8, 13] However, both instruments are expensive and cannot be afforded by some hospitals especially in the rural areas.

DPYL was proposed by Leartveravat S. in 2009.[10] He used a Sony Cyber-shot® camera and found that digital photography with the aid of a computer program could be used to measure the yellow level of neonate skin (DPYL). DPYL was found to be well correlated and could be used in place of TCB.

Digital cameras have become popular for use in daily life and are not very expensive. Photoshop® is also a popular computer program as a high end image editor for Macintosh® and Windows®. The original Mac versions were the first to bring affordable image editing down to the personal computer level in the late 1980s. Since then, Photoshop has become the de facto standard in image editing. Although it contains a large variety of image editing features, one of Photoshop's most powerful capabilities is layers, which allows images to be rearranged under and over each other for placement. Photoshop is designed to read form and convert to a raft of graphics formats, but uses its own native format for layers. It can also determine the components of color in the picture.

This study showed good correlation between DPYL with TCB and SMB. DPYL could be used in hospitals in rural areas where SMB and TCB are unavailable.

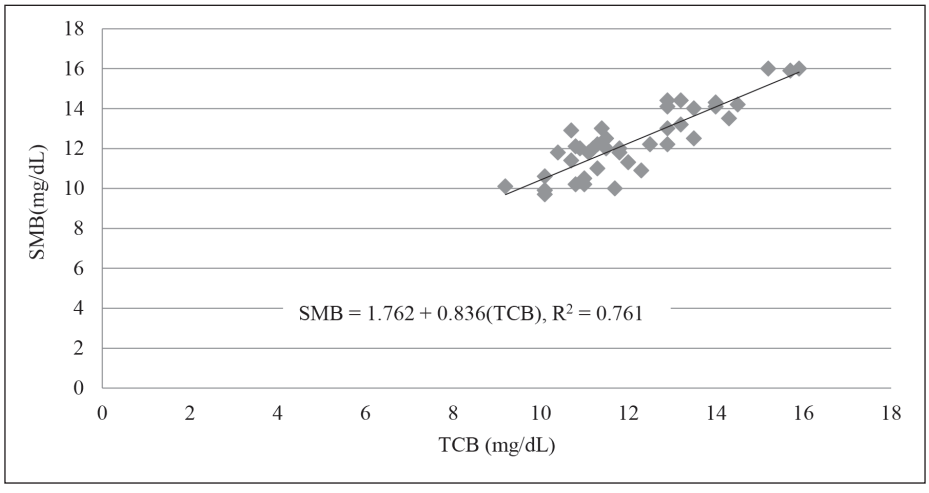

Figure 1 Scatter Plot between Serum Microbilirubin and Transcutaneous Bilirubinometry, (n=42)

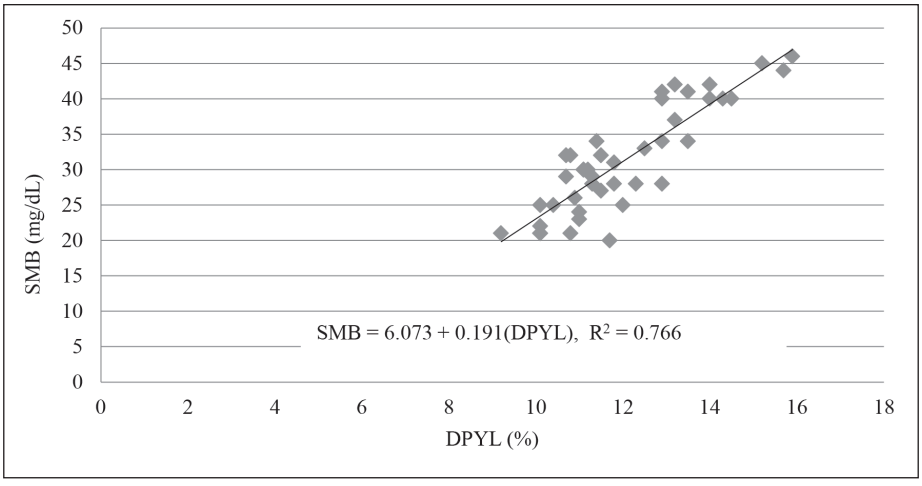

Figure 2 Scatter Plot between Serum Microbilirubin and Digital Photo Graphic Yellow Level, (n=42)

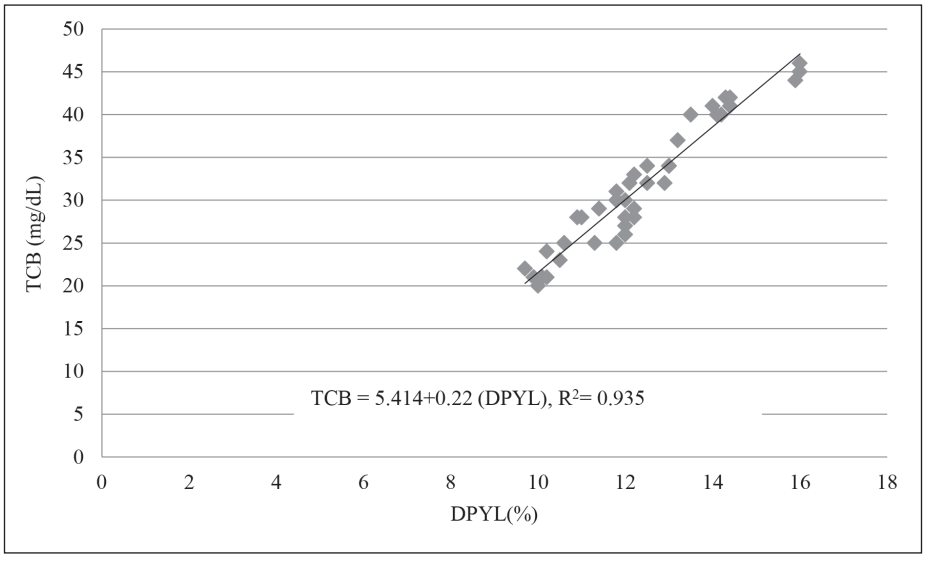

Figure 3 Scatter Plot between Transcutaneous Bilirubinometry and Digital Photo Graphic Yellow Level, (n=42).

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References

1. Bhutani VK, Gourley GR, Adler S, Kreamer B, Dalin C, Johnson LH. Noninvasive measurement of total serum bilirubin in a multiracial pre-discharge newborn population to assess the risk of severe hyperbilirubinemia. Pediatrics 2000; 106(2): 17.
2. Moerschel SK, Cianciaruso LB, Tracy LR. A practical approach to neonatal jaundice. Am Fam Physician 2008; 77(9): 1255-62
3. Bosschaart N, Kok JH, Newsum AM, Ouweneel DM, Mentink R, van Leeuwen TG, et al. Limitations and opportunities of transcutaneous bilirubin measurements. Pediatrics 2012; 129(4): 689-94.
4. Chowdhury AD, Hussey MH, Shortland DB. Critical overview of the management of neonatal jaundice in the UK. Public Health 2007; 121(2): 137.
5. McKiernan PJ. The infant with prolonged jaundice: investigation and management. Curr Pediatr 2001; 11(2): 83-9.
6. Watchko JF. Identification of neonates at risk for hazardous hyperbilirubinemia: emerging clinical insights. Pediatr Clin North Am 2009; 56(3): 671-87.
7. Yamanouchi I, Yamauchi Y, Igarashi I. Transcutaneous bilirubinometry: preliminary studies of noninvasive transcutaneous bilirubin meter in the Okayama National Hospital. Pediatrics. 1980; 65(2): 195-202.
8. O'Connor MC, Lease MA, Whalen BL. How to use: transcutaneous bilirubinometry. Arch Dis Child Educ Pract Ed 2013; 98(4): 154-9.
9. Maisels MJ, Ostrea EM, Jr., Touch S, Clune SE, Cepeda E, Kring E, et al. Evaluation of a new transcutaneous bilirubinometer. Pediatrics 2004; 113(6): 1628-35.
10. Leartveravat S. Transcutaneous bilirubin measurement in full term neonate by digital camera. Med J Srisaket Surin Buriram Hospital 2009; 24(1): 108-18.
11. Kaewkawan C, Singhasanon P. Sample Size in Clinical Trials. In: Pitisuttithum P, Picheansoonthon C, editors. Textbook of clinical research. Bangkok: Business Amarin Printing and Publishing Public, 2011: 107-44.
12. Mansouri M, Mahmoodnejad A, Taghizadeh R, Gharibi F. A comparison between Transcutaneous Bilirubin (TcB) and Total Serum Bilirubin (TSB) measurements in term neonates. International Journal of Pediatrics 2015; 3(3.1): 633-641.
13. Rubaltelli FF, Gourley GR, Loskamp N, Modi N, Roth-Kleiner M, Sender A, et al. Transcutaneous bilirubin measurement: a multicenter evaluation of a new device. Pediatrics 2001; 107(6): 1264-71.

ศึกษาความสัมพันธ์ระหว่างการวัดระดับบิลิรูบินทางผิวหนังด้วยเครื่องและการวัดความเหลืองโดยใช้กล้องถ่ายรูปแบบดิจิตัลในทารกแรกเกิด

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บทคัดย่อ

ทารกแรกเกิดตัวเหลืองเป็นปัญหาที่พบบ่อย จึงศึกษาความสัมพันธ์ระหว่างระดับบิลิรูบินในเลือด (Serum Microbilirubin; SMB), วัดระดับบิลิรูบินทางผิวหนังด้วยเครื่อง (Transcutaneous Bilirubinometry; TCB) และวัดระดับความเหลืองด้วยการถ่ายรูปดิจิตอล (Digital Photo Graphic Yellow Level; DPYL) ในทารกแรกเกิด วิจัยกึ่งทดลองวัดระดับบิลิรูบินทางผิวหนัง(TCB) และการวัดระดับความเหลืองด้วยการถ่ายรูปดิจิตอล (DPYL) ที่บริเวณหน้าอกของทารกแรกเกิด 42 รายที่มีอายุมากกว่า 24 ชั่วโมงในโรงพยาบาลรามาธิบดี หลังจากถ่ายรูปบริเวณหน้าอกทารกแรกเกิดด้วยกล้องดิจิตัล และนำมาประมวลผลหาความเหลืองโดยโปรแกรมคอมพิวเตอร์สำเร็จรูป Photoshop® (DPYL) แล้วเปรียบเทียบผลทั้งสามแบบ ทดสอบการถดถอยเชิงเส้นที่ระดับนัยสำคัญทางสถิติที่ 0.05 ระหว่างบิลิรูบินในเลือดกับระดับความเหลืองด้วยการถ่ายรูปดิจิตอล พบว่า บิลิรูบินในเลือด เท่ากับ 6.073 + 0.191 ระดับความเหลืองด้วยการถ่ายรูปดิจิตอล มิลลิกรัม/เดซิลิตร (R^2 = 0.766) การทดสอบการถดถอยเชิงเส้นที่ระดับนัยสำคัญทางสถิติที่ 0.05 ระหว่างระดับบิลิรูบินทางผิวหนังด้วยเครื่องเท่ากับ 5.414+0.22 ระดับความเหลืองด้วยการถ่ายรูปดิจิตอล มิลลิกรัม/เดซิลิตร (R^2= 0.935) จากผลการศึกษาพบว่า การวัดระดับความเหลืองด้วยการถ่ายรูปดิจิตอล สามารถนำไปใช้คัดกรองทารกตัวเหลืองในสถานที่ที่ขาดแคลนทรัพยากรได้

คำสำคัญ: ทารกแรกเกิดตัวเหลือง, ระดับบิลิรูบินในเลือด, ระดับบิลิรูบินทางผิวหนังด้วยเครื่อง, ระดับความเหลืองด้วยการถ่ายรูปดิจิตอล

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