Accuracy of Transcutaneous Bilirubinometry Compare to Total Serum Bilirubin Measurement

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Background: *Neonatal hyperbilirubinemia leads to bilirubin neurotoxicity. Noninvasive transcutaneous bilirubin (TcB) levels can be used as a screening tool for total serum bilirubin (TSB) levels.*
Objective: *To evaluate the correlation of TcB for TSB levels before, during and after phototherapy and find the most reliable cutoff values of TcB levels with the highest sensitivity and specificity for TSB levels.*
Design: *Diagnostic study.*
Material and Method*: In this research, forehead TcB measurement was measured by the transcutaneous bilirubinometer (Minolta Airshilds Jaundice Meter, JM 103). The 224 paired TcB-TSB specimens from 74 term and nearterm newborns were study from September 2007 to October 2008. The mean postnatal age at the time of measurement was 57.85 $\pm$ 22.15 hours. The mean gestational age was 38 $\pm$ 1.29 weeks and mean body weight was 2,864.65 $\pm$ 262 g.*
Results*: The TcB and TSB values had linear correlation with significant correlation coefficient (r 0.81, p < 0.001). The correlation equation was TSB = 0.88 + 0.89 x TcB (r^2 = 0.65). TcB levels tended be higher than TSB with mean difference of 0.44 mg/dL (95% CI: 0.7433-0.1323 mg/dL) and SD:1.64. TSB confirmation was recommended when TcB cutoff values greater than 9, 12, 13, 15 mg/dL at 24 (TSB:8 mg/dL), 36 (TSB:10 mg/dL), 48 (TSB:12mg/dL) and 72 (TSB:15mg/dL) hours' postnatalage, respectively.*
Conclusion*: The TcB levels can accurately predict TSB with the different cutoff points at various postnatal ages before phototherapy.*

Keywords*: Total serum bilirubin, Transcutaneous, TcB, TSB, Noninvasive, Bilirubin, Neonatal jaundice, Hyperbilirubinemia, Bilirubinometer, Minolta, Newborn*

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Hyperbilirubinemia is one of the most common neonatal problems with a distinctly high incidence of 25%-50%. From the clinical point of view, physical examination is not a reliable assessment of total serum bilirubin (TSB) though newborns can appear jaundiced when their serum bilirubin level is above 5 mg/dL. While high level of bilirubin was left and untreated, manifestations of kernicterus may occur as a consequence of neuronal injury from unconjugated bilirubin directly damaging to the brain[1]. Accordingly, irreversible encephalopathy and disability will be inevitable in those infants. Although, serum bilirubin measurement to monitor a disease progression and severity is essential to perform at prior, during and post-treatment with phototherapy. TSB was fundamentally measured by heel puncture or venous blood sampling which increased the risk of infection and produced pain in the baby as well as anxiety to the parents[2,3]. Since 1925 the non-invasive bilirubin measurement using transcutaneous bilirubin (TcB) has been developed and decrease the used of the conventional TSB[4]. Although, several published studies revealed this new TcB could be substituted TSB with satisfactory correlation but the cutoff values of hyperbilirubinemia in each specific age range using TcB are not well mentioned.

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Objective

To evaluate the accuracy of the transcutaneous bilirubinometer for the TSB level estimation prior

to, during and after phototherapy and find the most appropriate TcB cutoff values with the highest sensitivity and specificity for TSB levels.

Material and Method

This correlational study design approved by the university ethical committee, including all the neonates at gestational age of 35 weeks or greater at HRH Princess Maha Chakri Sirindhorn Medical Center, Srinakharinwirot University, Nakorn Nayok, Thailand. When the newborns had jaundice, blood was taken from the heel for TSB measurement (ERMA Inc, Japan). Transcutaneous bilirubin measurement was also performed within 5-10 minutes by bilirubinometer (Minolta AirShilds Jaundice Meter, Model JM 103). The fiber optic probe was placed at the newborn's forehead in supine position repeatedly 3 times' measurement was performed and the mean bilirubin levels were obtained in order to reduce the measurement errors[5]. The bilirubin in mg/dL, gestational age, body weight, sex and postnatal age (in hour) were also recorded. In the mornings, the calibration of both serum and transcu-taneous bilirubinometers were performed.

The exclusion criteria were the newborns with the history of previous phototherapy, blood transfustion, sepsis, biliary tract obstruction and other critically-illed conditions.

Statistic parameters were analyzed by SPSS, version 11.5. Pearson Linear Regression was used to assess the correlation between TcB and TSB. Receiver Operating Characteristic (ROC) curve was performed for TcB cutoff values.

Results

There were 74 term and near-term newborns enrolled in this study from September 2007 to October 2008. The number of male and female newborns was equal. The mean of gestational age, postnatal age, body weight was 38 $\pm$ 1.9 weeks (35-39 weeks), 57.85 $\pm$ 22.15 hours (24 to 130 hours) and 2,864.65 $\pm$ 262 grams (2,408-3,350 grams), respectively.

The pairs of TSB and TCB levels prior to, during and after phototherapy were 113, 72 and 39 pairs, respectively. Unspecified neonatal jaundice was found to be the most common cause in this study (67.57%) and 52 newborns (70.27%) were also required for phototherapy as described in Table 1.

Before phototherapy, the linear correlation between TcB and TSB values was TSB = 0.88 + 0.89 x TcB with statistical significance (r 0.81, $p < 0.01$). This equation was able to predict TSB 65% correctly (r^2 = 0.65). Transcutaneous bilirubin levels tended to over-

Table1. Demographic Characteristics

Characteristics		n	(%)
Gender:	Male	37	50.00
	Female	37	50.00
Sample:	Total (TSB-TcB pairs)	224	
	Before phototherapy	113	50.45
	During phototherapy	72	32.14
	After phototherapy	39	17.41
Body weight:	< 2,500 g	3	4.05
	2,500-4,000 g	71	95.95
GA:	35-37 week	2	2.70
	37-39	72	97.30
Underlying of jaundice:			
	Physiologic jaundice	12	16.21
	Unspecified jaundice	50	67.57
	ABO incompatibility	2	2.71
	Enclosing hemorrhage	3	4.05
	Breast feeding jaundice	7	9.46
Treatment:			
	Phototherapy	52	70.27
	Non phototherapy	22	29.73

TcB = transcutaneous bilirubin levels, TSB = total serum bilirubin levels

estimate TSB, with mean difference of 0.44 mg/dL (95% CI: 0.7433-0.1323 mg/dL).

During and after phototherapy, the linear correlation between TcB and TSB values were TSB photo = 6.84 + 0.46 x TcBphoto and TSBoff = 8.55 + 0.16 x TcBoff. These equations were able to predict TSB during phototherapy 42% ($r^2 = 0.42$) and after phototherapy 22% ($r^2 = 0.22$) correctly (Fig. 1).

From the hour-specific serum bilirubin nomogram, the zone of high risk was considered when TSB levels were more than 8,10,13 and 15 mg/dL at the age of 24,36,48 and 72 hours, respectively[6-8]. TcB cutoff values for screening before phototherapy at 9,12,13 and 15 mg/dL had the most sensitivity and specificity for TSB levels at 8,10,13,and 15 mg/dL, respectively. If the TcB levels were more than the values mentioned above, the TSB level measurement was recommended to confirm before intervention (Fig. 2 and Table 2).

When newborns had been on the phototherapy, the TcB values had high errors in prediction of

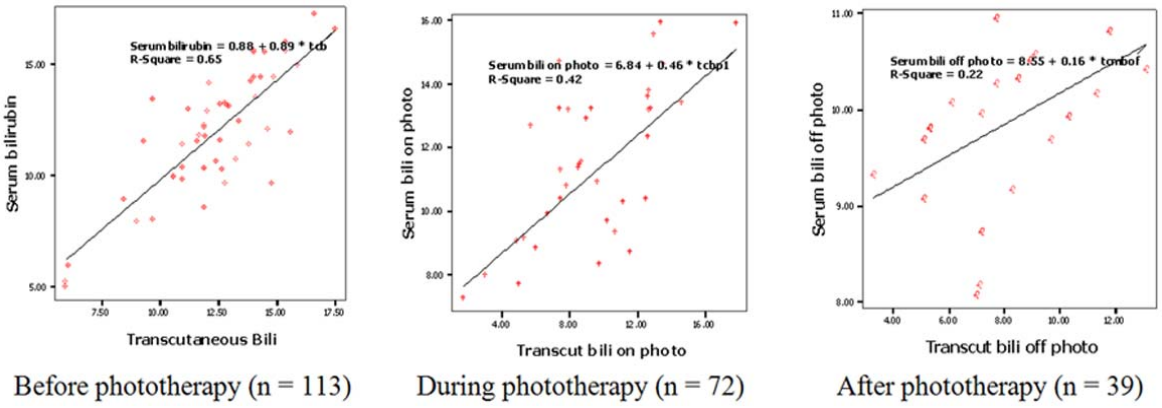

Fig. 1 The Correlation Between Transcutaneous Bilirubin (TcB) and Total Serum Bilirubin (TSB) Levels

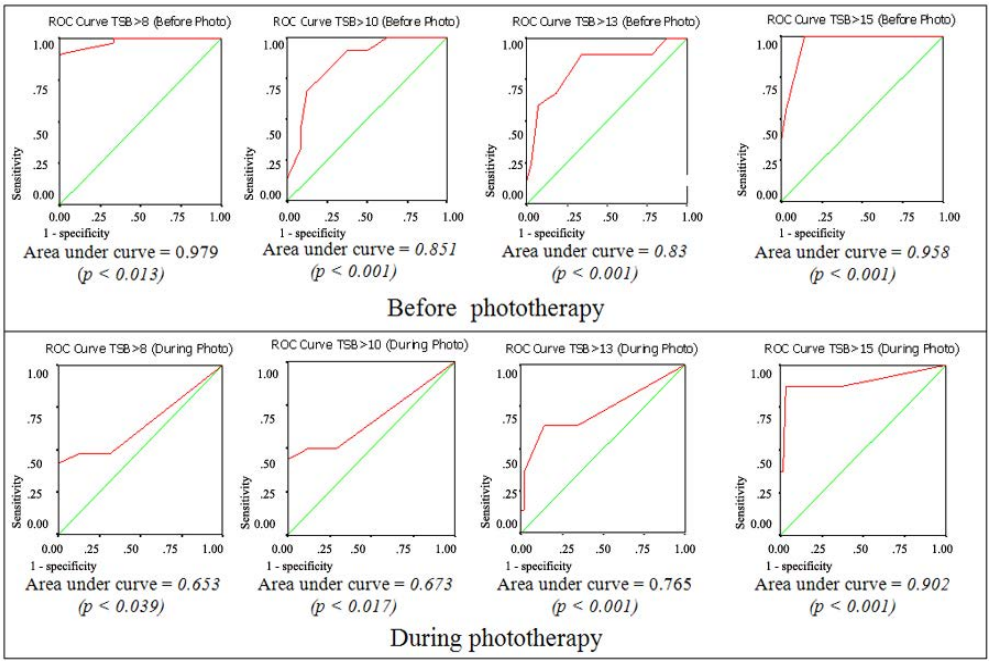

Fig. 2 The ROC Curve of Transcutaneous Bilirubin (TcB) level at Different Total Serum Bilirubin (TSB) Levels

Table 2. The Cutoff Values of Transcutaneous Bilirubin at Different Total Serum Bilirubin Levels Before and After Phototherapy

TSB level (mg/dL)	TcB level (mg/dL)	Before phototherapy		During phototherapy	
		Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
>8 (Age 24 hr.)	8	100.0	00.0	100.0	00.0
	9	100.0	66.7$	48.0	68.2
	10	97.1	66.7	48.0	86.4
	11	90.3	100.0	42.0	100.0
	12	87.4	100.0	18.0	100.0
>10 (Age 36 hr.)	8	100.0	00.0	100.0	00.0
	9	100.0	25.0	50.0	70.1
	10	100.0	37.5	50.0	87.5
	11	92.0	50.0	43.8	100.0
	12	92.0	62.5*	18.8	100.0
	13	67.0	88.0	8.3	100.0
>13 (Age 48 hr.)	8	100.0	00.0	100.0	00.0
	9	100.0	8.6	63.6	66.0
	10	100.0	12.9	63.6	74.0
	11	90.5	21.4	63.6	86.0
	12	90.5	25.7	36.4	98.0
	13	90.5	65.7*	13.6	98.0
	14	66.7	88.0	13.6	100.0
>15 (Age 72 hr.)	10	100.0	9.4	87.5	68.7
	11	100.0	19.8	87.5	78.1
	12	100.0	22.9	87.5	96.9*
	13	100.0	52.1	37.5	99.0
	14	100.0	74.0	37.5	100.0
	15	100.0	85.4*	00.0	100.0
	16	60.0	97.0	00.0	100.0

*p-value < 0.001, $p-value < 0.013, TcB = transcutaneous bilirubin levels, TSB = total serum bilirubin levels

TSB levels and this study revealed that the TcB levels at more than 12 mg/dL had the best sensitivity (87.5%) and specificity (96.9%) in prediction of TSB at 15 mg/dL. However, the finding has no practical benefit for any follow-up during phototherapy. In addition, this study confirm that no correlation between the TcB and TSB after phototherapy.

Discussion

Generally, normal newborns may appear jaundiced at serum bilirubin levels more than 5 mg/dL[9]. Transcutaneous bilirubinometer has been developed by various types such as Bili Check (multiwavelength, USA), Minolta, JM103 (dual wavelength, Japan) and Bilitest BB 77™ (Italy). All types of equipment have little different accuracy in screening before phototherapy[10-13]. Minolta AirShilds Jaundice Meter, JM 103 was used in this study. The linear correlation between TcB and TSB values before phototherapy was found with statistically significance (r 0.81, $p < 0.01$). This correlation (r) was within the range of previous studies ($0.63 < r < 0.956$)[14-17]. The correlation equation was TSB = 0.88 + 0.89 x TcB. The chance of this equation to predict TSB was 65% correctly ($r^2 = 0.65$). Transcutaneous bilirubin levels in this study tended to overestimate TSB, with the mean difference of 0.44 mg/dL (95% CI: 0.7433-0.1323 mg/dL) which was within the range of $\pm$ 1.5 mg/dL of the recent studies[18-20]. This was due to the standard of instruments and methods of TcB measurement. From the agespecific nomogram for specific serum bilirubin values, the cutoff values of TSB that needed intervention were 8 mg/dL, 10 mg/dL, 13 mg/dL and 15 mg/dL at 24, 36, 48 and 72 hours, respectively. From the result of this study, the most appropriate cutoff values of TcB before phototherapy were not more than 9, 12, 13 and 15 mg/dL at 24, 36, 48

and 72 hours, respectively. TSB confirmation was recommended if the TcB values were higher than the cutoff values because of their low sensitivity and specificity.

There was less correlation between TcB and TSB during and after phototherapy. We found that the correlation equation during phototherapy was TSB photo = 6.84 + 0.46 x TcB photo (r^2 = 0.42) and after phototherapy was TSBoff = 8.55 + 0.16 x TcBoff (r^2 = 0.22). This result confirmed that the colour of skin was not able to predict the degree of jaundice after phototherapy from the skin bleaching technique[21-23].

Conclusion

Our data demonstrated that the noninvasive TcB measurement (Minolta AirShilds Jaundice Meter, JM 103) was useful as a screening tool before phototherapy in healthy newborn infants. The cutoff values of TcB that needed TSB confirmation were more than 9, 12, 13, 15 mg/dL at 24, 36, 48 and 72 hours of postnatal age, respectively.

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ความแม่นยำของการตรวจระดับบิลิรูบินทางผิวหนังเปรียบเทียบกับการวัดระดับบิลิรูบินจากซีรั่ม

จันทนา พันธ์บูรณะ, ศุภวัชร บุญกษิดิ์เดช, สุดารัชต์ ฤกษ์ใหญ่

ระดับซีรั่มบิลิรูบินที่สูงในทารกแรกเกิดมีอันตรายต่อเซลล์สมอง ซึ่งอาจใช้การตรวจทางผิวหนังเพื่อหาระดับบิลิรูบินในซีรั่มได้

วัตถุประสงค์*: เพื่อตรวจความแม่นยำของเครื่องมือที่ใช้วัดระดับบิลิรูบินทางผิวหนัง (Minolta Airshilds Jaundice Meter, JM 103) เทียบกับระดับซีรั่มบิลิรูบินทั้งก่อนและหลังการส่องไฟรักษา และหาค่าของระดับบิลิรูบินทางผิวหนังที่น่าเชื่อถือที่สุดในระดับซีรั่มบิลิรูบินต่างๆกัน*

วัสดุและวิธีการ*: วัดระดับบิลิรูบินทางผิวหนัง (TcB) บริเวณหน้าผากทารกด้วยเครื่อง Minolta Airshilds Jaundice Meter, JM 103 หลังจากตรวจซีรั่มบิลิรูบิน (TSB) ภายใน 5-10 นาที ทำการศึกษาในทารกแรกเกิดที่อายุครรภ์มากกว่าหรือเท่ากับ 35 สัปดาห์ จำนวน 74 ราย โดยตรวจระดับบิลิรูบินทางผิวหนังเทียบกับในซีรั่ม 224 คู่ ตั้งแต่ เดือนกันยายน พ.ศ. 2550 ถึง ตุลาคม พ.ศ. 2551 ทารกมีอายุเฉลี่ย 57.85 $\pm$ 22.15 ชั่วโมง อายุครรภ์เฉลี่ย 38 $\pm$ 1.9 สัปดาห์ น้ำหนักแรกเกิดเฉลี่ย 2,864.65 $\pm$ 262 กรัม*

ผลการศึกษา*: ระดับบิลิรูบินทางผิวหนัง (TcB) และซีรั่มบิลิรูบิน (TSB) มีความสัมพันธ์กันอย่างมีนัยสำคัญแบบเส้นตรง (r 0.81, p < 0.001) ตามสมการ "TSB = 0.88 + 0.89 x TcB" ซึ่งมีโอกาสที่จะทำนายได้ถูกต้องร้อยละ 65 (r^2 = 0.65) โดยระดับบิลิรูบินทางผิวหนังมีแนวโน้มสูงกว่าซีรั่มบิลิรูบินประมาณ 0.44 มก/ดล 95% CI: 0.7433-0.1323 และ SD: 1.64 มก/ดล จากการศึกษาพบว่าระดับบิลิรูบินทางผิวหนังเกิน 9, 12, 13, 15 มก/ดล เมื่อทารกอายุ 24 (TSB: 8 mg/dL), 36 (TSB: 10 mg/dL), 48 (TSB: 13 mg/dL) และ 72 (TSB: 15 mg/dL) ชั่วโมงตามลำดับ ควรต้องตรวจซีรั่มเพื่อยืนยันด้วยขณะให้การรักษา และหลังจากโดยวิธีส่องไฟแล้วไม่สามารถใช้ค่าบิลิรูบินทางผิวหนังทำนายระดับระดับบิลิรูบินในซีรั่มได้*

สรุป*: ระดับบิลิรูบินทางผิวหนังมีความสัมพันธ์กับระดับบิลิรูบินในซีรั่มก่อนการส่องไฟรักษาโดยมีค่าของระดับบิลิรูบินทางผิวหนังที่น่าเชื่อถือในแต่ละอายุที่ต่างกัน*