Accuracy of Transcutaneous Bilirubin Measurement in Term Newborns

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Objective: *1) To evaluate the accuracy of transcutaneous bilirubin (TcB) compared with serum bilirubin (TsB) in full-term infants, 2) To compare the accuracy of TcB reading from two, three, and four measurements and, 3) To compare the accuracy of TcB measured at the forehead and sternum.*

Material and Method: *Full term infants who were diagnosed neonatal jaundice and underwent blood tests for TsB were eligible for enrollment. Infants who were born at gestational age less than 37 weeks, unstable, previously received phototherapy, or exchange transfusion were excluded. TcB was measured at forehead and sternum two, three, and four times at each site. TcB measurements were done within 30 minutes before or after blood sampling for TsB.*

Results: *The authors obtained 294 paired TcB-TsB from 257 full-term infants. TsB ranged from 1.60 to 21.18 mg/dL (mean 11.03, SD 2.73). The correlation coefficients between TcB at forehead and TsB were significant for two, three, and four measurements (r = 0.812, 0.800, and 0.800 respectively). TcB measured at sternum also had significant correlation with TsB (r = 0.829, 0.844, and 0.823 for two, three, and four measurements). TcB tended to underestimate TsB. Measurements at the sternum seemed to have better correlation with TsB than at the forehead.*

Conclusion: *TcB has good correlation coefficient to TsB. Two measurements have enough accuracy to estimate TsB level and measurement at the sternum gives better correlation with TsB than at forehead.*

Keywords: *Neonatal hyperbilirubinemia, Transcutaneous bilirubin, forehead, sternum*

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Neonatal jaundice is one of the most common problems in neonatal care. Approximately 60% of full-term infants and nearly 80% of preterm infants have jaundice during the first week of life[1,2]. Eight to ten percent of full-term and near-term infants develop severe hyperbilirubinemia[3], which can cause devastating consequences such as bilirubin encephalopathy, hearing loss, delayed development, and even death. To prevent these complications, early diagnosis and treatment must be provided to these infants.

Visual estimation has been used to screen the degree of neonatal jaundice. Kramer LI et al[4] reported correlation of the progression of visualized skin color from head to toe with serum bilirubin level. Gosset[5] used an Ingram icterometer, a yellow strip on a plastic ruler, to estimate the level of serum bilirubin. Nonetheless, the accuracy of these methods is low. In general practice, the authors use total serum bilirubin (TsB) to diagnose and follow-up the severity of neonatal jaundice. However, blood sampling is painful and may cause complication, such as infection at the puncture site. Transcutaneous bilirubin (TcB) measurement is a good choice for neonatal jaundice screening which can reduce adverse events.

Although many studies have reported good correlation between TcB and TsB[6-14], most of the studied populations were white. Asian infants are different from white populations in skin color, genetics, incidence of neonatal jaundice, and glucose-6-phosphate dehydrogenase (G-6-PD) deficiency[15-20]. In addition, they have more rapidly rising bilirubin, longer durations of jaundice, and a greater risk of developing bilirubin encephalopathy. A number of studies reported good correlation between TcB and TsB in Asian infants[21-29]. There were also several studies in Thai infants that reported good correlation of TcB and TsB[25-29]. However, the method and device differ from those in the present study.

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Material and Method

The authors performed a prospective, cross-sectional study on full-term newborn infants who were diagnosed neonatal jaundice by the attending physician and underwent blood tests for total serum bilirubin level in neonatal ward at Chiang Mai University Hospital between June and December 2009. The authors excluded infants whose gestational age was less than 37 weeks, clinically unstable, previously received phototherapy, or exchange transfusion. Written consents were obtained from the parents. The present study was approved by the Ethics Committee of Faculty of Medicine, Chiang Mai University (study code: PED-06-08-15A-08).

The authors recorded demographic data, age at testing (hours), and TcB and TsB levels. Blood was taken by heel stick and collected in sodium-heparinized capillary tubes, shielded from light exposure, spun at 20,000 Hz and analyzed for serum bilirubin level by Roche/Hitachi Automatic Analyzer 902 in our hospital clinical laboratory. Trained personnel performed TcB measurement by Minolta Air-Shield Jaundice Meter JM-103 within 30 minutes before or after blood sampling. The device's optical probe was cleaned then placed on the infant's forehead and sternum and gently pressed until there was light from the probe. Two, three, and four measurements were performed on each site. The average value displayed by the device showed TcB level (mg/dL). Both devices were calibrated before daily use as recommended by the manufacturers.

Statistical analysis

Descriptive data is presented as mean ± standard deviation (SD). Pearson correlation coefficients between TcB and TsB were calculated by using of linear regression techniques. Error distribution was performed by Bland-Altman method.

Results

Two hundred ninety four paired TcB and TsB samples were obtained from 257 infants, 48% were male. Their mean gestational age was 38.44±1.29 weeks, mean birth weight was 3,043±473.98 grams and most of the infants (81%) were born vaginally. Age at the time of bilirubin measurement ranged from eight to 147 hours (mean±SD; 59.67±18.38). TsB levels ranged from 1.60 to 21.18 mg/dL (mean±SD; 11.03±2.73). Twenty samples (6.8%) had level exceeding 15 mg/dL. Sixty-one infants received phototherapy during their admissions. One infant had exchange transfusion. He started to have jaundice at 20 hours old and was diagnosed glucose-6-phosphate dehydrogenase (G-6-PD) deficiency.

Table 1. Correlation coefficients between TsB and TcB measured at forehead and sternum

Numbers of measurements	Correlation coefficient (r)	
	Forehead	Sternum
2	0.812	0.829
3	0.800	0.844
4	0.800	0.823

Correlation coefficients between TsB and TcB measured at the forehead are all significant for two, three, and four measurements (r = 0.812, 0.800 and 0.800 respectively). Coefficient correlations of those measured at the sternum for two, three, and four measurements are all high (r = 0.829, 0.844 and 0.823 respectively).

There was no difference in correlation when using two, three, and four measurements at the forehead or sternum. Measurements at the sternum seem to have better correlation than at forehead as shown in Table 1.

TcB tends to underestimate TsB as shown in Fig. 1. Mean differences of TcB to TsB for two, three, and four measurements at forehead are 0.93±1.69, 0.99±1.73, and 0.88±1.76 respectively. Mean differences ± SD for sternal measurements are 0.97±1.55, 1.12±1.47, and 1.17±1.57 for two, three, and four measurements respectively.

Discussion

The transcutaneous bilirubinometer was introduced in the 1980s[6] and was thoroughly studied

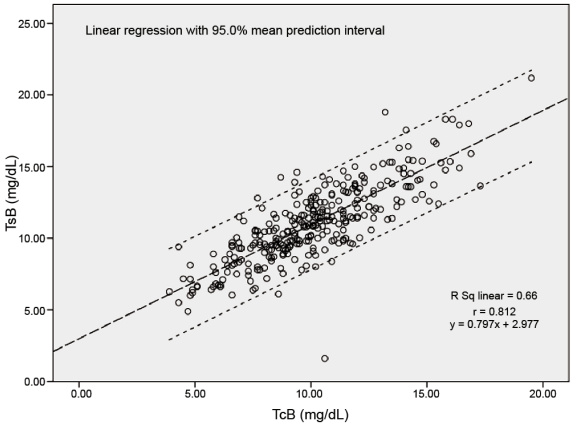


Fig. 1 Correlation between 2 times measurement of TcB at forehead and TsB

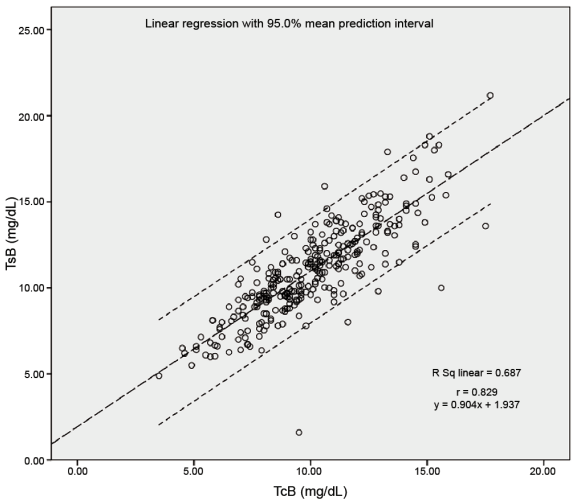
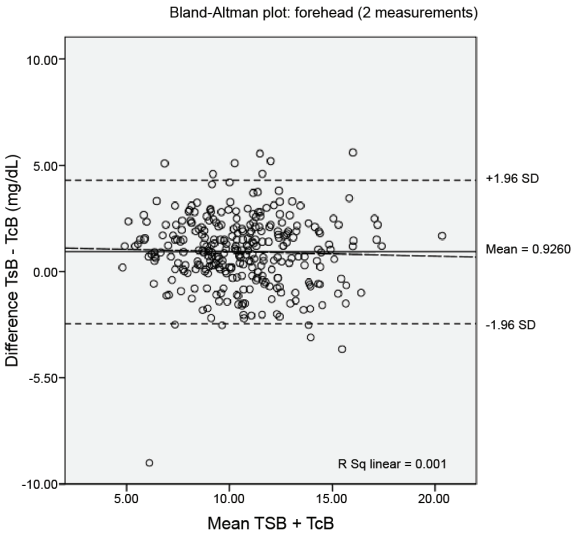
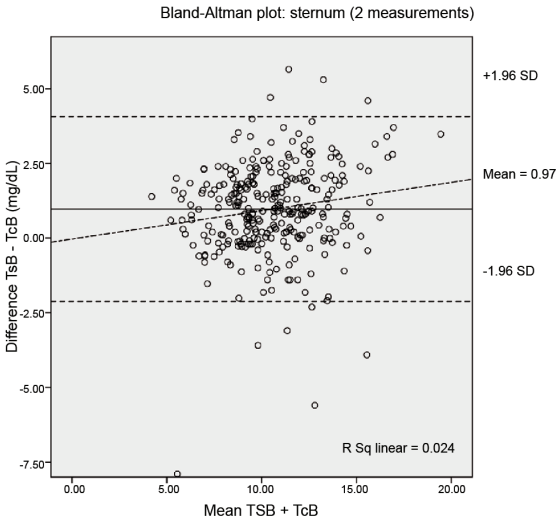


Fig. 2 Correlation between 2 times measurement of TcB at sternum and TsB



A. Forehead: 2 measurements



B. Sternum: 2 measurements

Fig. 3 Bland-Altman plots (mean and 95% CI)

to evaluate its accuracy in neonates. Many studies showed good correlation of TcB and TsB and recommended using TcB for neonatal jaundice screening. The original models of transcutaneous bilirubinometer have some disadvantages. The accuracy of readings was influenced by skin pigmentation, hemoglobin level, and gestational age[30-31]. Moreover, it displayed a TcB index that must be converted to a serum bilirubin level in each hospital.

The newer models, BiliCheck® and JM-103 Jaundice Meter, are claimed to reduce these limitations[7-9,30-33]. BiliCheck® estimates serum bilirubin by measuring optical densities at multi-wavelength regions. It reports mean TcB from five replicated measurements. Many studies showed that TcB readings from this device had good correlation with TsB[7-9,11,26,32].

The authors used the JM-103 Jaundice Meter in the present study. This device determines bilirubin concentration by measuring difference of optical densities at two wavelength regions (450 nm and 550 nm) and converted to bilirubin level. Studies in the Asian population showed significant correlation as the studies in White populations with correlation coefficients range from 0.79 to 0.94[25-27,29-30,34,35]. The present study also shows significant correlation of TcB measured at the forehead and sternum with TsB ($r = 0.800$ and $r = 0.844$ respectively), which is similar to Sanpavat et al. study ($r = 0.804$)[25]. However, the correlation in Thai babies seems to be less than those of Yasuda et al and Maisels et al[30-31]. This may be due to differing laboratory TsB measurements and ethnicity. Yasuda et al[30] used unbound bilirubin analyzer to measure serum bilirubin and reported that this method had significant linear correlation with high-performance liquid chromatography (HPLC), which is gold standard. The authors' clinical laboratory used the Diazo method to determine TsB, the same method as Maisel et al[31]. There has been no reported study to compare the accuracy of Diazo method and unbound bilirubin analyzer.

TcB in the present study underestimated the TsB level at a mean difference of 0.89 to 0.99 at the forehead and 0.97 to 1.12 at the sternum, which is similar to previous studies[30-34].

The JM-103 can be set to take up to five measurements and automatically average the results. This averaging may help reduce user error. The authors found that there was no difference in the correlation coefficients of TcB and TsB obtained by two, three, and four measurements at either the forehead or the sternum. The mean differences between TsB and TcB from by two, three, and four measurements were also not significantly different. The present result is similar to previous studies, that midsternal TcB has better correlation with TsB than TcB measured at the forehead[35]. This difference may be explained by less exposure of the skin at sternum to light compared with the forehead. Thus, it may be inferred that using two, three, and four measurements of TcB is equally accurate. Sternal measurement seems to be better than measurement at the forehead.

The limitation of this study is that serum bilirubin was not measured by high-performance liquid chromatography (HPLC), which is the gold standard method.

Conclusion

Transcutaneous bilirubin is a noninvasive test and has good correlation with serum bilirubin. It can be used to screen for neonatal jaundice in Thailand. Measurement at the sternum gives better correlation with TsB than at forehead, and two measurements have enough accuracy to estimate the TsB level.

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ความแม่นยำของการใช้เครื่องวัดบิลิรูบินทางผิวหนังแก่ทารกแรกเกิดครบกำหนดในโรงพยาบาลมหาราชนครเชียงใหม่

ฉานิกา โกษารัตน์, วรางค์ทิพย์ คูวุฒยากร

วัตถุประสงค์: *1) เพื่อหาความแม่นยำของการวัดค่าบิลิรูบินทางผิวหนังเปรียบเทียบกับค่าบิลิรูบินในซีรัม 2) เปรียบเทียบความแม่นยำของการวัดบิลิรูบินทางผิวหนังที่อ่านได้จากการวัด 2, 3 และ 4 ครั้ง และ 3) เปรียบเทียบความแม่นยำของการวัดบิลิรูบินทางผิวหนังที่อ่านได้จากการวัดที่หน้าผาก และบริเวณหน้าอกของทารก*

วัสดุและวิธีการ: *ทารกคลอดครบกำหนดสุขภาพแข็งแรงที่ได้รับการวินิจฉัยภาวะตัวเหลืองในทารกแรกเกิด และแพทย์ผู้รักษาสั่งเจาะเลือดตรวจ TsB จะได้รับการวัดค่า TcB ที่บริเวณหน้าผากและหน้าอกภายในเวลา 30 นาที ก่อนหรือหลังการเจาะเลือดโดยวัดค่า TcB 2, 3 และ 4 ครั้ง ในแต่ละตำแหน่ง คัดทารกที่คลอดก่อนอายุครรภ์ 37 สัปดาห์ หรือ มีอาการไม่คงที่ หรือ ทารกที่ได้รับการรักษาภาวะตัวเหลืองโดยการส่องไฟหรือเปลี่ยนถ่ายเลือดมาก่อนออกจากการศึกษา*

ผลการศึกษา: *จากทารกคลอดครบกำหนด 257 ราย ได้ตัวอย่างค่าบิลิรูบินทางผิวหนัง (TcB) และบิลิรูบินในซีรัม (TsB) 294 คู่ ค่าบิลิรูบินในซีรัมอยู่ระหว่าง 1.60 ถึง 21.18 มก./ดล. (ค่าเฉลี่ย 11.03±2.73 มก./ดล.) TcB ที่อ่านได้จากการวัดจำนวน 2, 3 และ 4 ครั้ง ที่หน้าผากกับ TsB มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติ (ค่าสัมประสิทธิ์สหสัมพันธ์เท่ากับ 0.812, 0.800 และ 0.800 ตามลำดับ) ค่า TcB ที่อ่านได้จากการวัดจำนวน 2, 3 และ 4 ครั้ง ที่หน้าอกกับ TsB ก็มีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติเช่นกัน (ค่าสัมประสิทธิ์สหสัมพันธ์เท่ากับ 0.829, 0.844 และ 0.823 ตามลำดับ) ค่า TcB ที่วัดได้มีแนวโน้มต่ำกว่าค่า TsB และค่าที่วัดจากบริเวณหน้าอกมีความสัมพันธ์กับ TsB มากกว่าค่าที่วัดจากหน้าผาก*

สรุป: *การวัดค่าบิลิรูบินทางผิวหนังทั้งสองวิธีมีความแม่นยำเมื่อเทียบกับบิลิรูบินในซีรัม การวัดทางผิวหนังจำนวน 2 ครั้ง มีความแม่นยำเพียงพอในการประมาณค่าบิลิรูบิน และค่าที่วัดได้จากบริเวณหน้าอกมีค่าใกล้เคียงกับซีรัมมากกว่าค่าที่วัดได้จากหน้าผาก*