Original article

Prediction of significant hyperbilirubinemia in term neonates by early non-invasive bilirubin measurement

Manish Jain, Akash Bang, Anju Tiwari, Shuchi Jain
Wardha, India

Background: **Neonatal jaundice is a common problem. We evaluated the utility and best cut-off values of 24- and 48-hour transcutaneous bilirubin indices (TcBI) in predicting subsequent significant hyperbilirubinemia and evaluated various associated maternal and fetal risk factors.**

Methods: **TcBI at 24 and 48 hours and serum bilirubin levels at 72 hours of age were obtained for healthy, term, appropriate for gestational age neonates. Neonates with prematurity, birth weight <2500 g, ABO or Rh incompatibility, onset of clinical jaundice <24 hours, clinical suspicion of septicemia, positive pressure ventilation at birth, admission in neonatal intensive care unit and contraindications for BiliChek were excluded. Twenty-four and 48-hour TcB indices were assessed as predictors of subsequent hyperbilirubinemia, defined as serum bilirubin >17 mg/dL after 72 hours of life and various cut-offs, and were evaluated by calculating sensitivity, specificity and predictive values.**

Results: **Of 500 newborns, 4.6% had significant hyperbilirubinemia, 27% had TcBI (mg/dL) <5 at 24 hours, and 27.4% had TcBI <8 at 48 hours. None of them had subsequent hyperbilirubinemia (100% negative predictive value). The percentage of newborns with subsequent hyperbilirubinemia increased from 3.4% to 13.2% as their 24-hour TcBI increased from 6 to above 9 mg/dL and from 4.2% to 7.4% as their 48-hour TcBI increased from 8 to above 11 mg/dL. The best cut-off value was TcBI (mg/dL) 7 (odd ratio=4.86, 95% confidence interval: 1.66-15.22) at 24 hours and 10 (odd ratio=2.87, 95% confidence interval: 1.04-8.29) at 48 hours. Area under the receiver operating characteristic curve for 24- and 48-hour measurements was 0.750 and 0.715, respectively. Maternal premature rupture of membranes, deep transverse arrest, post-date pregnancy, and fetal distress were significant risk factors for hyperbilirubinemia.**

Conclusions: **Twenty-four and 48-hour TcB indices are good predictors of subsequent hyperbilirubinemia. Twenty-four-hour TcBI had better predictive ability than 48-hour TcBI.**

World J Pediatr 2017;13(3):222-227

Key words: **hyperbilirubinemia;**
neonate;
transcutaneous bilirubin

Introduction

Neonatal jaundice is probably the most frequently encountered diagnostic and therapeutic problem in newborns, and affects nearly 70% of term and 80% of preterm infants.[1] It is a significant problem in the context of early discharge since the bilirubin level usually peaks between the third and fifth day of life in term newborns after discharge from the hospital.[2,3] If there is a higher bilirubin level, hyperbilirubinemia can cause irreversible neurological damage in newborns, and hence early detection is extremely important as neonatal jaundice can be treated with phototherapy or other methods and neurological damage can be prevented.[4-6] However, accurate assessment of hyperbilirubinemia requires a measurement of the serum bilirubin level. Thus, the development of a screening test that will reduce the necessity for laboratory analysis and is more reliable than visual inspection of skin color is desirable. Spectrophotometric measurement of the intensity of yellow color in the skin and subcutaneous tissue using reflectometry appears to be useful. Transcutaneous bilirubinometry is now one of the accepted methods for the assessment of severity of neonatal jaundice since Yamanouchi et al first reported its use in 1980.[7-12] This instrument is noninvasive, non-traumatic, compact, battery-powered, extremely simple, fast to operate, and gives an instant result. It is therefore handy and easy to operate.

Transcutaneous bilirubin (TcB) index usually

Author Affiliations: Department of Pediatrics (Jain M, Bang A, Tiwari A) and Department of Obstetrics & Gynecology (Jain S), MGIMS, Sevagram, Wardha Maharashtra, India

Corresponding Author: Manish Jain, Professor, Department of Pediatrics, MGIMS, Sevagram, Wardha Maharashtra 442102, India (Tel: 09822695195; Email: manish@mgims.ac.in)

doi: 10.1007/s12519-016-0067-1
Online First, November 2016

correlates well with the blood bilirubin concentration and there is a linear relationship between the two parameters.[9,10,13-16] In healthy term newborns, this method is however more effective than the eye or icterometer in detecting cases where a serum bilirubin test is required. Almost all cases of excessive hyperbilirubinemia can be diagnosed, thereby preventing the risk of bilirubin encephalopathy or nuclear jaundice. The major objective of this study was to find the incidence of hyperbilirubinemia [total serum bilirubin (TSB) >17 mg/dL], the utility of 24- and 48-hour TcB, the best cut-off values in predicting subsequent hyperbilirubinemia in healthy term neonates, and various maternal and fetal risk factors associated with the incidence.

Methods

It was a prospective study conducted in 2010 in a teaching hospital with 600 beds in rural central India with around 300 deliveries a month. After the study was approved by the Institutional Review Board, we consecutively selected 500 healthy neonates fulfilling the inclusion criteria as follows: 1) term, appropriate for gestational age newborns, as defined by neonates having birth weight between 2500 g to 4000 g for a gestational age of 37-42 weeks; 2) written informed consent given by the parents. The exclusion criteria were as follows: 1) preterm newborns (gestational age <37 weeks); 2) birth weight <2500 g; 3) presence of ABO or Rh incompatibility as indicated by blood group report; 4) onset of clinical jaundice <24 hours; 5) clinical suspicion of septicemia as decided by treating consultant; 6) positive pressure ventilation (PPV) at birth; 7) admission and treatment in NICU; 8) contraindications for using BiliChek: following exchange transfusion; excessive bruising, birthmarks, hematomas or excessive hairiness at the measurement site over the forehead.

The TcB indices were obtained by the BiliChek® Non-Invasive Bilirubin Analyzer which works by directing white light into the skin of the newborn and measuring the intensity of the specific wavelengths that are returned. A single device was used throughout the study to eliminate inter-device variability and was calibrated regularly as per the manufacturer instructions. Measurements were taken over the forehead of all the enrolled neonates at 24 and 48 hours. The site forehead was chosen to maintain the uniformity. All the measurements were obtained by trained postgraduates who underwent a short training in the standard procedures at the start of the study to ensure standardization and accurate test results. Serum bilirubin levels were obtained in all enrolled neonates at 72 hours by Random Access Analyzer XL 300, a multianalyser by using Diazo as reagent and Walter & Gerarde method.

Neonates with serum bilirubin >17 mg/dL after 72 hours were defined as significant hyperbilirubinemia as per American Academy of Pediatrics guidelines of considering phototherapy for TSB >17 mg/dL at 72 hours for a healthy term newborn.[13,17] The 24 and 48 hours TcB indices were evaluated as risk predictors for development of subsequent significant hyperbilirubinemia.

Various maternal risk factors, which include post date pregnancy, previous caesarean scar, premature rupture of membranes (PROM), pregnancy induced hypertension, cephalo-pelvic disproportion, oligohydramnios, polyhydramnios, severe anemia, primary infertility, gestational diabetes, meconium stained amniotic fluid, deep transverse arrest (DTA), hypothyroidism, previous perinatal loss, heart disease, and sickling positive, and fetal risk factors (e.g. fetal distress, cord around neck, breech presentation) were defined, and according to the definitions they were included in the study.[18]

Data were entered a predesigned proforma and recorded using the EPI info 6 software (Centers for Disease Control and Prevention, Atlanta, Georgia USA). Point estimates and the 95% confidence interval were calculated according to the standard methods for each of the sensitivity, specificity, positive and negative predictive values for the use of TcB index as a diagnostic test in the prediction of significant hyperbilirubinemia.

The best cut-off values for 24-hour and 48-hour TcB indices as predictors of significant hyperbilirubinemia were tried to be established by calculating these statistical values separately and plotting the receiver operating characteristic (ROC) curve for 24-hour and 48-hour TcB indices separately. The data were analyzed using the Microsoft Excel, EPI Info 6 software and Stata program release 10.0.

Results

The study population (n=500) had a mean birth weight of 2880±442 g. Out of 500 neonates, 289 (57.8%) were male. 485 (97%) neonates were appropriate for gestational age (AGA), while 15 (3%) were large for gestational age (LGA). Median bilirubin level for the entire study group was 12.14 mg/dL while it was 12.23 mg/dL for males and 11.94 mg/dL for females (P=0.14).

The incidence of significant hyperbilirubinemia (TSB>17 mg/dL) at 72 hours was 4.6% (23/500). There was a male predominance (69.6%). In the neonates who later had significant hyperbilirubinemia, the median bilirubin level was 20.04 mg/dL (19.74 mg/dL for

males, 20.74 mg/dL for females, *P*=0.46) and all were AGA. The other group (*n*=477) that did not develop significant hyperbilirubinemia had a median bilirubin level of 11.84 mg/dL (12.04 mg/dL for males, 11.64 mg/dL for females, *P*=0.11).

The percentage of neonates having subsequent significant hyperbilirubinemia increased from 3.4% to 13.2% as their TcB index at 24 hours raised from above 6 mg/dL to above 9 mg/dL (Table 1). Similarly, the proportion of neonates having subsequent significant hyperbilirubinemia increased from 4.2% to 7.4% as their TcB index at 48 hours increased from above 8 mg/dL to above 11 mg/dL (Table 2). The odds ratios for the risk of developing significant hyperbilirubinemia at various cut-off TcB values at 24 and 48 hours are shown in Table 3.

TcB index of 6 mg/dL at 24 hours showed a NPV of 99%, a specificity of 39.8%, and chances of missing subsequent hyperbilirubinemia (1-sensitivity) about 8% (Table 3). With an increasing cut-off value, the specificity increased but the sensitivity and NPV decreased. At a cut-off value of 24 hour-TcB at 9 mg/dL, although the specificity increased to 87.6%, the NPV decreased to 96.8% and chances of missing subsequent hyperbilirubinemia increased up to 60%. Similarly as the cutoff value of 48 hour-TcB increased from 8 mg/dL to 11 mg/dL, the specificity increased to 73.8%, the NPV decreased to 96.4% and chances of missing subsequent hyperbilirubinemia increased up to 56%. On comparing the values at different cut-offs, the highest and best trade off in the sensitivity and specificity was obtained at a cut-off value of 7 mg/dL for 24-hour TcB index and 10 mg/dL for 48-hour TcB index. ROC curves plotted for 24-hour TcBI showed an area under curve of 0.750 and for 48-hour TcBI of 0.715 (Figs. 1&2).

In maternal risk factor analysis, 52.2% of the cases had some maternal risk factors and 3.8% of them developed subsequent significant hyperbilirubinemia (*P*=0.39). In individual risk factor analysis, only PROM (*P*=0.03), DTA (*P*=0.002), and post date pregnancy (*P*=0.05) were found to be statistically significant risk factors.

In fetal risk factor analysis, 8% of the cases had some fetal factors and 10% of them developed subsequent significant hyperbilirubinemia (*P*=0.55). Only fetal distress was found to be a statistically significant risk factor (*P*=0.02).

Table 1. Transcutaneous bilirubin (TcB) indices at 24 hour *vs* subsequent hyperbilirubinemia at 72 hours

TcB indices at 24 h	Total		Subsequent hyperbilirubinemia at 72 h			
			Present		Absent	
	n	%	*n*	%	*n*	%
< 5	135	27.0	0	0	135	100
5.1 to 6	57	11.4	2	3.5	55	96.4
6.1 to 7	87	17.4	3	3.4	84	96.5
7.1 to 8	90	18.0	4	4.4	86	95.5
8.1 to 9	63	12.6	5	7.9	58	92.0
>9	68	13.6	9	13.2	59	86.7

Table 2. Transcutaneous bilirubin (TcB) indices at 48 hours *vs.* subsequent hyperbilirubinemia at 72 hours

TcB indices at 48 hours	Total		Subsequent hyperbilirubinemia at 72 hrs			
			Present		Absent	
	n	%	*n*	%	*n*	%
<8	137	27.4	0	0	137	100
8.1 to 9	47	9.4	2	4.2	45	19.1
9.1 to 10	62	12.4	4	6.4	58	93.5
10.1 to 11	119	23.8	7	5.8	112	94.1
>11	135	27	10	7.4	125	92.5

Table 3. Predictive characteristics of 24- and 48-hour transcutaneous bilirubin indices (TcBI) at different cut-off points

Predictive TcBI		Outcome: subsequent significant hyperbilirubinemia (TSB >17 mg/dL at day 3)		Predictive characteristics				
TcB indices as risk demarcator	Number of babies (Total=500)	Present	Absent	Sensitivity% 95% CI	Specificity% 95% CI	PPV% 95% CI	NPV% 95% CI	Odds ratio 95% CI
24-h TcBI								
>9	68	9	59	39.1 (20.5, 61.2)	87.6 (84.3, 90.4)	13.2 (6.6, 24.1)	96.8 (94.5, 98.1)	4.55 (1.73, 11.83)
<9	432	14	418					
>8	131	14	117	60.9 (38.8, 79.5)	75.5 (71.3, 79.2)	10.7 (6.2, 17.6)	97.6 (95.3, 98.8)	4.79 (1.89, 12.34)
<8	369	9	360					
>7	221	18	203	78.3 (55.8, 91.7)	57.4 (52.9, 61.9)	8.1 (5.0, 12.8)	98.2 (95.6, 99.3)	4.86 (1.66, 15.22)
<7	279	5	274					
>6	308	21	287	91.3 (70.5, 98.5)	39.8 (35.4, 44.4)	6.8 (4.4, 10,4)	99 .0(95.9, 99.8)	6.95 (1.55, 43.4)
<6	192	2	190					
At 48 h								
>11	135	10	125	43.5 (23.9, 65.1)	73.8 (69.6, 77.6)	7.4 (3.8, 13.6)	96.4 (93.8, 98.0)	2.17 (0.86, 5.43)
<11	365	13	352					
>10	254	17	237	73.9 (51.3, 88.9)	50.3 (45.7, 54.9)	6.7 (4.1, 10.7)	97.6 (94.5, 99)	2.87 (1.04, 8.29)
<10	246	6	240					
>9	316	21	295	91.3 (70.5, 98.5)	38.2 (33.8, 42.7)	6.6 (4.3, 10.1)	98.9 (95.7, 99.8)	6.48 (1.45, 40.46)
<9	184	2	182					
>8	363	23	340	100 (82.2, 100)	28.7 (24.7, 33.0)	6.3 (4.1, 9.5)	100 (96.6, 100)	Not calculable
<8	137	0	137					

TSB: total serum bilirubin; PPV: positive predictive value; NPV: negative predictive value; CI: confidence interval.

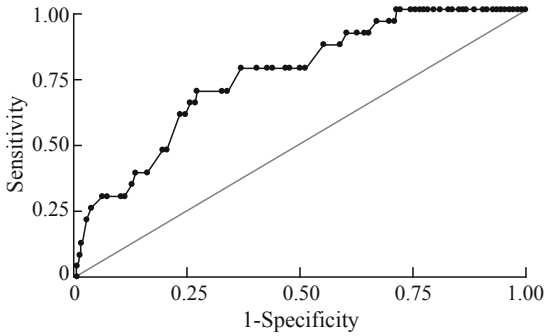

Fig. 1. Receiver operating characteristic (ROC) curve for 24-hour transcutaneous bilirubin indices. Area under ROC curve is 0.7500.

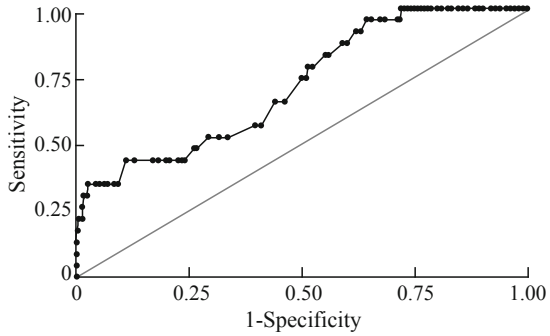

Fig. 2. Receiver operating characteristic (ROC) curve for 48-hour transcutaneous bilirubin indices. Area under ROC curve is 0.7150.

Discussion

Neonatal hyperbilirubinemia in healthy neonates has always been a concern for parents as well as for pediatricians, being the commonest abnormal physical finding in the first week of life and affecting nearly 70% of term and 80% of preterm infants.[1] Early discharge of healthy newborn infants, particularly those in whom breastfeeding may not be fully established, may be associated with delayed diagnosis of significant hyperbilirubinemia. Thus, effective screening and surveillance are essential to ensure that infants with severe hyperbilirubinemia are not missed. Importantly it is still unknown at what level bilirubin can cause a significant risk of brain damage; however, TSB over 26 mg/dL has been associated with kernicterus in term infants with comorbidities such as sepsis or hemolysis. More recent recommendations support the use of less intensive therapy in healthy term newborns with jaundice. Preventative, screening and management strategies therefore remain a significant practice issue during the early postnatal period. This protocol was developed to screen for significant hyperbilirubinemia and reduce the need for invasive and painful blood tests through the use of new generation bilirubinometers.

Yamanouchi et al[19] introduced transcutaneous bilirubinometry in 1980 as a non-invasive screening tool in the management of neonatal jaundice. By the year 2000, the situation changed with the introduction of a new generation of TcB measuring instruments that promised a superior performance through minimizing the disturbance in reflectance caused by skin pigmentation and other chromogens.[20] The non-invasive nature of the TCB determination and the immediacy of the test result availability made it a highly desirable investigative tool.

Bhutani et al[9] suggested non-invasive pre-discharge assessment to determine the need for additional follow-up. But the visual assessment (coefficient of correlation of 0.6-0.74) has well documented unreliability. An hour specific pre-discharge TSB facilitates monitoring, risk designation, targeted interventions and follow-up.[21,22] However, as serum bilirubin sampling is painful, and takes time for the report. Cord bilirubin has also been suggested for prediction. However, the predictive ability of TSB prior to 12 hours of age has not been useful because of poor sensitivity and specificity.[21] On the other hand, TcB measurement is handy, easy to perform, pain free and provides rapid results. Its correlation with lab bilirubin (0.86-0.95) and its linear relationship has been well documented. It also reduces the number of blood tests needed.[22-25]

In the present study we aimed to evaluate predictive ability of early transcutaneous bilirubin values at 24 hours and 48 hours for significant hyperbilirubinemia (TSB >17 mg/dL at 72 hours) against the gold standard of TSB. As the measurement of TcB was likely to be used, primarily as screening technique for prediction of hyperbilirubinemia, we calculated the point estimates of sensitivity, specificity, PPV and NPV along with 95% confidence interval. The incidence of significant hyperbilirubinemia in our study population was 4.6%. This is similar to expected incidence of hyperbilirubinemia in normal babies.[26]

In 1996, Ruchala et al conducted a pilot study aimed at determining the use of transcutaneous bilirubinometry as a screening device in the home to identify the cases of significant hyperbilirubinemia.[27] They found a high correlation (Rs=0.85; P>0.01) between the visual assessment and the transcutaneous bilirubin index. TcB was tested against the visual assessment, which itself is not very reliable method of diagnosing jaundice. In the present study, utility of TcB was tested against the serum bilirubin level which is the gold standard for the diagnosis of jaundice.

In 1998, Carbonell et al[28] conducted a study to establish the correlation between TcB and TSB and its predictive value for significant hyperbilirubinemia ≥17 mg/dL. The study was carried out in two phases.

The incidence of significant hyperbilirubinemia (≥17 mg/dL) was 2.95% in phase I and 3.2% in phase II respectively. They found a good correlation between TSB and TCB, and concluded that in infants with TSB≥6 mg/dL at 24 hours or TSB≥9 mg/dL or transcutaneous readings ≥13 mg/dL at 48 hours, a TSB test must be performed after 48 hours of life.

In the period of 2003-2005, Bhatt et al[22] assessed the utility of 24-hour and 48-hour TcB index for predicting subsequent significant hyperbilirubinemia in healthy term neonates. In their study they studied 461 healthy term neonates with a mean birth weight of 2949 g (±390 g). The incidence of significant hyperbilirubinemia was 17.6%. Sensitivity and specificity were optimized at TcB value (in mg/dL) of 7 for 24 hours and 10 for 48 hours. C-statistics for 24- and 48-hour measurements were 0.838 and 0.836 respectively. They concluded that 24 and 48-hour indices are predictive for subsequent significant hyperbilirubinemia and can guide clinicians in early discharge of healthy term newborns.

The results of the present study were very much comparable with Bhatt et al's study and sensitivity and specificity had the best trade off at the cut-off values (in mg/dL) of 7 for 24-hourTcBI and 10 for 48-hour TcBI. Area under ROC curves for 24- and 48-hour measurements were 0.750 and 0.710, respectively. We conclude that 24-hour indices are better predictors than 48-hour indices for subsequent significant hyperbilirubinemia. However, the incidence of significant hyperbilirubinemia was lower than that of the above mentioned study because serum bilirubin level was measured in all enrolled neonates while it was measured on some specific indications in previous studies.

After analyzing the data, we found the sensitivity and NPV keep on decreasing as the cut-off value for a 24-hour TcB index increasing from 6 to 9 and 48-hour TcB increased from 8 to 11 (in mg/dL). Simultaneously, specificity and PPV keep on increasing. Use of any screening test (eg. blood glucose test strips) has some limitations and will lead to some false positive determinations. Nevertheless it is quite possible to keep false negative determinations (failure to identify high serum bilirubin levels) close to zero. Sensitivity and specificity showed the best trade off at TcB value (in mg/dL) of 7 for 24 hours and 10 for 48 hours. C-statistics for 24- and 48-hour measurements were 0.750 and 0.710 respectively. Thus the use of TcB indices can be recommended for the prediction of significant hyperbilirubinemia in healthy term neonates. 24-hour TcB indices seem to be more useful in predicting significant hyperbilirubinemia than 48 hours values. Though 7 mg/dL was the best cut-off value for 24-hour TcB, clinically pediatricians may choose slightly lower threshold especially in the light of the electricity outages and poor quality of phototherapy in many facilities in low and middle income countries. Also, since there was no external quality assurance scheme for monitoring consistency and bias performance of TcB devices, there is no certainty that similar TcB devices elsewhere would have the same cut-off values as those proposed in this paper. Hence newborns with TcB indices between 5 to 7 at 24 hours of age can be discharged with a follow-up strategy. A proper follow-up strategy is needed because missing even a single neonate with possibility for later hyperbilirubinemia is clinically unacceptable. For TcB indices >7 at 24 hour and >11 at 48 hours it is prudent to withhold discharge as chances of developing hyperbilirubinemia are high. Retaining them in the hospital would facilitate continued monitoring, early intervention and reduce bilirubin related to neurological dysfunction. The c-statistics of predictive TcB model was found to be fair.[29] Finally, further research may focus on the high risk newborns and see how well this model predicts significant hyperbilirubinemia and further outcomes in them.

In conclusion, jaundice is a major concern in the context of early discharge. The practice of early postnatal discharge increases the risk of not detecting cases of significant neonatal hyperbilirubinemia, since the bilirubin level peaks after the infant is discharged. In the present study, the utility of TcB indices is demonstrated. However, the cut-off values need to be defined for individual population. Thus, we recommend that early non-invasive bilirubin measurement by TcBI may be used for prediction of subsequent significant hyperbilirubinemia and according to that a policy can be made for the discharge of neonates.

Funding: None.
Ethical approval: The Institutional Ethics Committee approved the protocol. Written informed consent was taken from the parents.
Competing interest: None.
Contributors: JM conceived the idea. JM, BA, TA, JS wrote the protocol. TA collected the data. JM, BA, TA analyzed the data. TA wrote the first draft of manuscript. JM, BA, TA, JS read, edited, and approved the final manuscript. JM is the guarantor.

References

1 Randev S, Grover N. Predicting neonatal hyperbilirubinemia using first day serum bilirubin levels. Indian J Pediatr 2010;77:147-150.
2 Lee K-S, Perlman M, Ballantyne M, Elliott I, To T. Association between duration of neonatal hospital stay and readmission rate. J Pediatr 1995;127:758-766.
3 Bhutani VK, Johnson L, Sivieri E. Predicative ability of a pre-discharge hour-specific serum bilirubin for subsequent significant

hyperbilirubinemia in health term and near-term newborns. Pediatrics 1999;103:6-14.
4 Atkinson LR, Escobar GJ, Takyama JI, Newman TB. Phototherapy use in jaundiced newborns in a large managed care organization: do clinicians adhere to the guideline. Pediatrics 2003;111:e555-e561.
5 Petersen JR, Okorodudu AO, Mohammad AA, Fernando A, Shattuck KE. Association of Transcutaneous Bilirubin Testing in Hospital with Decreased Readmission Rate for Hyperbilirubinemia. Clin Chem 2005;51:540-544.
6 Bhutani VK, Johnson LH. Newborn jaundice and Kernicterus--Health and societal perspectives. Indian J Pediatr 2003;70:407-416.
7 Engle WD, Jackson GL, Sendelbach D, Manning D, Frawley WH. Assessment of a Transcutaneous Device in the Evaluation of Neonatal Hyperbilirubinemia in a Primarily Hispanic Population. Pediatrics 2002;110:61-67.
8 Karolyi L, Pohlandt F, Muche R, Franz AR, Mihatsch WA. Transcutaneous bilirubinometry in very low birth weight infants. Acta Paediatrica 2004;93:941-944.
9 Bhutani VK, Gourley GR, Adler S, Kreamer B, Dalin C, Johnson LH. Noninvasive measurement of total serum bilirubin in a multi-racial pre-discharge newborn population to assess the risk of hyperbilirubinemia. Pediatrics 2000;106:E17.
10 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;107:1264-1271.
11 Ozkan H, Oren H, Duman N, Duman M. Dermal bilirubin kinetics during phototherapy in term neonates. Acta Paediatr 2003;92:577-581.
12 Tan KL, Dong F. Transcutaneous bilirubinometry during and after phototherapy. Acta Paediatr 2003;92:327-331.
13 American Academy of Pediatrics Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. Pediatrics 2004;114:297-316.
14 Maisels MJ, Ostrea EM Jr, Touch S, Clune SE, Cepeda E, Kring E, et al. Evaluation of a new transcutaneous bilirubinometer. Pediatrics 2004;113:1628-1635.
15 Ip S, Chung M, Kulig J, O'Brien R, Sege R, Glicken S, et al. An evidence-based review of important issues concerning neonatal hyperbilirubinemia. Pediatrics 2004;114:e130-e153.
16 Szabo P, Wolf M, Bucher HU, Haensse D, Fauchere JC, Arlettaz R. Assessment of jaundice in preterm neonates: comparision between clinical assessment, two transcutaneous bilirubinometers and serum bilirubin values. Acta Paediatrica 2004;93:1491-1495.
17 American Academy of Pediatrics. Provisional Committee for Quality Improvement and Subcommittee on Hyperbilirubinemia. Practice parameter: management of hyperbilirubinemia in the healthy term newborn. Pediatrics 1994;94:558-565.
18 Dutta DC, Text Book of Obstetrics including perinatology and contraception. Calcutta: New Central Book Agency (P) Ltd, 2004.
19 Yamanouchi I, Yamauchi Y, Igarashi I. Transcutaneous bilirubinometry: preliminary studies of noninvasive transcutaneous bilirubin meter in the Okayama National Hospital. Pediatrics 1980;65:195-202.
20 Ebbesen F, Rasmussen LM, Wimberley PD. A new transcutaneous bilirubinometer,BiliCheck,used in the neonatal intensive care unit and maternity ward. Acta Paediatr 2002;91:203-211.
21 Bhutani VK, Johnson L, Sivieri E. Predicative ability of a pre-discharge hour-specific serum bilirubin for subsequent significant hyperbilirubinemia in health term and near-term newborns. Pediatrics 1999;103:6-14.
22 Bhatt YR, Rao A. Transcutaneous bilirubin in predicting hyperbilirubinemia in term neonates. Indian J Pediatr 2008;75:119-123.
23 Lodha R, Deorari AK, Jatana V, Paul VK. Non-invasive estimation of total serum bilirubin by multi-wavelength spectral reflectance in neonates. Indian Pediatr 2000;37:771-775.
24 Mahajan G, Kaushal MK, Sankhyan N, Sharma RL, Nakra M. Transcutaneous bilirubinometer in assessment of neonatal jaundice in Northern India. Indian Pediatr 2005;42:41-45.
25 Harish R, Sharma DB. Transcutaneous bilirubinometry in neonates:evaluation of Minolta Airshields Jaundicemeter. Indian Pediatr 1998;35:264-267.
26 Maisels MJ, Conrad S. Transcutaneous bilirubin measurements in full term infants. Pediatrics 1982;70:464-467.
27 Ruchala PL, Seibold L, Stremsterfer K. Validating assessment of neonatal jaundice with transcutaneous bilirubin measurement. Neonatal Netw 1996;15:33-37.
28 Carbonell X, Botet F, Figureras J, Riu-Godo. Prediction of hyperbilirubinemia in the healthy term newborn. Acta Paediatr 2001;90:166-170.
29 Tape TM. Interpreting diagnostic tests. University of Nebraska Medical Centre [10 screens]. Available from: URL:http://gim.unmc.edu/dxtests/Default.htm (accessed September 16, 2004).

Received December 3, 2014
Accepted after revision May 13, 2015