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Original Research Article

The smart phone study: assessing the reliability and accuracy of neonatal jaundice measurement using smart phone application

Srujana Swarna[1], Sekar Pasupathy[1], Balaji Chinnasami[1]*, Nirmala Manasa D.[2], Balaji Ramraj[3]

[1]Department of Pediatrics, [2]First year Medical student, [3]Department of Community Medicine, SRM Medical College, Hospital and Research Institute, Potheri, Kattankulathur, Chennai, Tamil Nadu, India

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***Correspondence:**
Dr. Balaji Chinnasami,
E-mail: balaji.ch@ktr.srmuniv.ac.in

ABSTRACT

Background: Current gold standard for bilirubin estimation in newborns is invasive while transcutaneous bilirubinometer which is a noninvasive option is costly. Smart phone applications can be used as an alternative to measure bilirubin. We did the study to evaluate "Biliscan" medical application for screening of neonatal jaundice.
Methods: During the first seven days, neonates with suspected jaundice were taken blood samples for serum bilirubin. Within two hours photographs were taken using Biliscan app by placing a colour calibration card over the chest. Bilirubin estimate obtained after colour balancing, feature extraction and machine learning regression were compared with blood values.
Results: There is a good correlation (0.6) between Biliscan bilirubin estimation and serum bilirubin levels ($p < 0.0001$) in the present study on 35 neonates. Biliscan thorax values correlated better than abdomen values (0.6 versus 0.551) with serum values. Hence chest is the preferred area for Biliscan measurement.
Conclusions: Biliscan app appears to be a good cheap option to screen for jaundice in newborns noninvasively.

Keywords: Bilirubin, Biliscan, Hyperbilirubinemia, Neonates, Transcutaneous bilirubinometry

INTRODUCTION

Jaundice which is yellowish discoloration of skin due to increased bilirubin is a common problem in new-born babies. Bilirubin may increase in few neonates to toxic levels and cause permanent damage to brain called kernicterus.[1] Hence detecting and monitoring serum bilirubin levels is a must to prevent such damages to developing brain. Measuring serum bilirubin by Diazo method is the gold standard but an invasive procedure and hence done only when clinical suspicion is high.[2] The current non-invasive option is a specialised equipment called transcutaneous bilirubinometer which is costly and not available in all centers. Hence, we often rely on direct visual assessment of skin colour for jaundice which is often unreliable.[3] There is a need for a cheap noninvasive screening system for monitoring neonatal jaundice regularly.

Recently smartphone applications for medical field like point of care diagnostics, heart beat monitoring; visions testing, etc. are being increasingly created. Portability, internet connectivity, easy availability and good computing power make smartphone devices good candidates for clinical use. One such application (app) is "Biliscan" which uses smartphone's inbuilt camera and a colour calibration card to detect new-born jaundice. However scientific literature on validity and accuracy of this application especially in Indian new-borns is lacking. We plan to do this study to assess the usefulness of this

"Biliscan" medical application as a screening tool for neonatal jaundice.

The objective of this study was to evaluate the accuracy of "Biliscan" medical application for assessing jaundice in neonates, by comparing with serum bilirubin (TSB) as the reference standard.

METHODS

This observational clinical study was done in the Department of Paediatrics, Neonatology division in our medical college from July 2017 to August 2017.

The study was started after getting the institutional ethical committee clearance (Ethics clearance number: 1198/IEC/2017). During that period after getting written informed consent from parents we could enrol 35 neonates for the study.

Exclusion criteria

- Sick neonates admitted in NICU
- Neonates already receiving phototherapy
- Parents not willing to give consent for the study.

Smart phone based sensing methodology

iPhone 6s smart phone with the "Biliscan" application installed was used for the study since the hardware is the most standardized among currently available brands. This medical application is available online free of cost. Neonates during their first week of life with visible jaundice and planned for serum bilirubin testing were included in the study. After recording gestational age, date of birth, gender, blood group two photo samples were taken, one over the chest and one over the abdomen. Serum bilirubin was taken within two hours of taking photo samples. The bilirubin value predicted by Biliscan algorithm was compared with blood levels of bilirubin which was taken as gold standard.

For taking photographs, the app first instructs to place a colour calibration card on the new-born and align the colour card with the frame provided by the app. Colour calibration card is used for colour balancing since skin colour varies with different lighting conditions. The colour card has a central larger aperture for skin colour assessment and twelve small squares surrounding it made of different colours like black, grey, green, blue, yellow, pink, white. The colour card provided by the Biliscan app developers is recommended to be printed by a colour ink jet printer made of Konica, Epson, Canon or HP.[4]

Since transcutaneous bilirubinometers which are also light-based instruments are placed on the upper part of sternum, we placed colour cards on the chest region as well as abdomen for taking images. After checking for image quality and appropriate lighting, the application auto snaps and collects images. The system uploads the data to a server through the phone's internet connection.

The collected images first undergo image segmentation and an algorithm identifies various colour patches based on their respective Hue and Saturation values. This is followed by white balancing where the observed red, green and blue (RGB) values of the colour calibration card are adjusted to the RGB values of the skin. After colour balancing, multiple features of the skin patch are obtained by Biliscan through a process called "feature extraction". Various regression algorithms are applied by the software to obtain separate estimates of the total bilirubin. Then the outputs of all regressions are combined to give a single value of bilirubin level.[5]

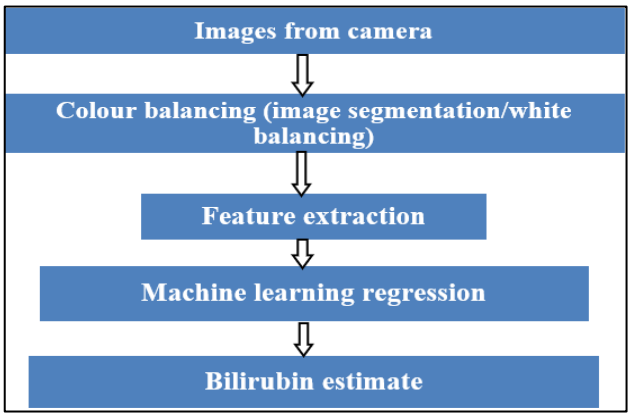


Figure 1: Steps of bilirubin estimation by "biliscan" medical application.

Measurement of serum bilirubin levels

For estimation of serum bilirubin in neonates, venous blood samples were collected and immediately sent to central laboratory for analysis using diazo-coupling method.[6] Sample collection was performed within 2 hours of taking picture.

Statistical analysis

Data was entered and statistical analysis was done using SPSS version 21. Continuous measures were summarized using mean and standard deviation. Categorical variables were summarized using percentages. Pearson's correlation was used to identify the relationship between Biliscan measurement values and serum bilirubin values. p-value less than 0.05 was considered significant

RESULTS

The study was conducted among 35 neonates delivered in our hospital located in Chennai. The clinical characteristics of the enrolled neonates (birth weight, gender, gestational age, day of life, blood group incompatibilities) are given in Table 1.

Table 1: Clinical characteristics of study population.

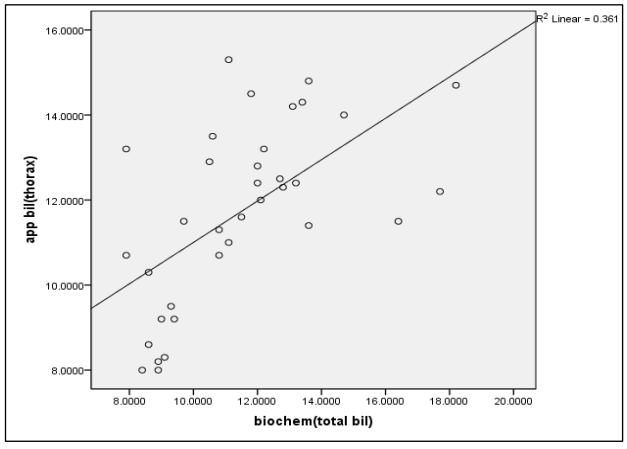
Characteristics		Number (n)	(%)
Birth weight	>2500	28	80
	1500-2500	5	14.2
	<1500	2	5.7
Gestational age	Term ≥37 weeks	30	85.7
	Preterm ≤36 weeks	5	14.3
Postnatal day of measurement	1-2 days	12	34.3
	3-7 days	22	62.8
	>7 days	1	2.8
Baby and mother blood group	Incompatibility yes	14	40
	No incompatibility	21	60
Gender	Male	20	57.1
	Female	15	42.8

The table suggests that neonates enrolled for the study were mostly term (85.7%), less than 1 week old (97.1%), birth weight more than 2500 grams (80%), with representation from both boys and girls (57.1% versus 42.8%). Table 2 gives the mean (95% CI) levels of serum bilirubin, Biliscan measured bilirubin values over sternum and abdomen. The mean values and 95% CI values were almost similar for all three measurements.

Table 2: Summary table of bilirubin measurements.

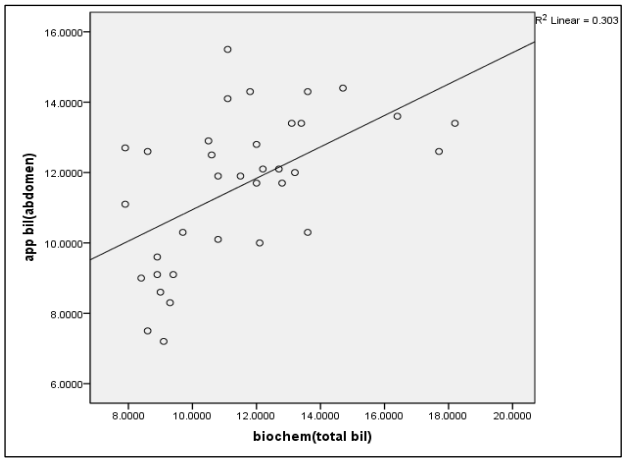
Variable	N	Mean	SD	95% CI of mean
Serum Bilirubin	35	11.47	2.62	10.6-12.34
Biliscan-sternum	35	11.72	2.12	10.99-12.40
Biliscan-abdomen	35	11.60	2.12	10.89-12.30

The pearson correlation coefficients in comparison with the gold standard serum bilirubin are given in Figures 2 and 3.



Pearson correlation: 0.600; P <0.0001

Figure 2: Correlation graph serum bilirubin versus Bilicam over chest



Pearson correlation: 0.551; P <0.001

Figure 3: Correlation graph of serum bilirubin vs Biliscan bilirubin over abdomen

For Biliscan sternum values correlation was 0.6 (R^2=0.361) while Biliscan abdomen had a correlation of 0.55 (R^2=0.303). The correlation was highly significant for Biliscan sternum vales (P<0.0001) and significant for Biliscan abdomen values (P<0.001).

DISCUSSION

Hyperbilirubinemia is an important cause of damage to the developing brain leading to kernicterus and cerebral palsy.[1] This can be prevented by serial monitoring of jaundice and providing phototherapy at the right time before it rises to alarming levels. Most of the samples for bilirubin estimation are taken by venepuncture which can be painful and can even cause infection.[7]

Non-invasive method of screening for jaundice will be the preferred one for serial monitoring as it is simple, cost effective. Currently transcutaneous bilirubinometry is the most widely used noninvasive method of screening.[8] There has been up to 50% reduction in samples collected if transcutaneous bilirubinometer was used. Transcutaneous bilirubinometer assessment of neonatal jaundice in northern India yielded a correlation of 0.9 versus serum bilirubin values.[9] But cost of bilirubinometers are high hence not available in many hospitals especially in small clinics run by primary care physicians. Moreover, TcBs are unreliable at higher values (>14.5 mg/dl).

Visual assessments are commonly used by clinicians and parents to identify jaundice. But evidence suggest that even experienced doctors are underestimating the severity of jaundice based on visual assessment alone.[3] There is a need for cheap, noninvasive method of monitoring jaundice. Since smart phones with internet connectivity are available with almost everyone, mobile phone based health sensing can be a solution to this problem. Smart phones have already been evaluated in studies to measure pulmonary function, to monitor coughing episodes, nasal

symptoms, smart phone camera for detecting heart rate abnormalities, screen eyes for abnormalities.[12-16]

Similarly, few studies have been published on usage of smartphones in predicting jaundice in neonates. Taylor JA et al used "Bilicam", a low-cost system using imaging by smart phone to detect neonatal jaundice. Their evaluation on 530 neonates yielded overall correlation of 0.91 with serum bilirubin test. Using two decision rules their sensitivities in identifying high TSB levels were 84.6% and 100% respectively, specificities were 75.1% and 76.4% respectively.[17]

Rong ZH et al used an automated image based bilirubin (AIB) testing technique for predicting jaundice in two hundred and fifteen neonates.[18] They found no significant difference between AIB and serum bilirubin values with 82% sensitivity and 60% specificity.

Aydin M et al used advanced image processing techniques to analyse images taken by smart phones.[19] The bilirubin estimation by machine learning regressions was consistent with serum bilirubin tests with a compliance rate of 85%.

But studies evaluating the use of smart phone apps for detecting bilirubin among Indian neonates has not been done so far. We aim to do study one such app "Biliscan" and if found accurate, it can be very useful for noninvasively monitoring jaundice among Indian neonates in a cost-effective manner.

Present pilot study on 35 neonates was able to demonstrate moderately positive correlation between Biliscan and serum bilirubin measurements. The correlation was highly significant for Biliscan thorax values and significant for Biliscan abdomen values. Hence Biliscan measurements should be preferably taken over chest.

Taylor JA et al in their study with Bilicam software obtained an overall correlation of 0.91.[17] The probable difference in findings may be due to the usage of different software and on different ethnic groups. But Bilicam app is still a research tool and is not available for public usage. Biliscan app is currently the only app available free of cost for download and usage by general population.

Biliscan app may not correlate as strongly as transcutaneous bilirubinometry. But definitely its better than visual assessment of jaundice in newborns. Riskin et al has shown high interobserver variation and 61.5% of babies were clinically misclassified.[20] Biliscan gives objective values which are uniform without interobserver variations.

For a clinician a variation of 1 to 2 mg per dl in bilirubin detection is acceptable. With regards to detection of bilirubin levels, biliscan app was accurate by 60% for a 1mg/dl variation and 70% of occasions with 2mg/dl variation. Seven out of ten parents have an opportunity to know their correct baby's bilirubin values at the comfort of home. This will definitely reduce the need for needle pricks and damage caused by hyperbilirubinemia not picked up at an early stage.

We could collect thirty plus new-borns during the short two-month period. Larger sample size including preterm babies, phototherapy babies will add more value to the study. Data collection was done solely on iPhone as image collection using other phones was cumbersome probably due to poor image quality. Also, color calibration cards using different printers should be tested for variation.

CONCLUSION

Biliscan bilirubin estimation on thorax has good positive correlation (0.6) with serum bilirubin levels which was highly significant ($P<0.0001$). Biliscan appears to be a good cost effective non-invasive option of monitoring new-borns for jaundice where transcutaneous bilirubinometers are not available.

Hyperbilirubinemia can cause brain damage and serial non-invasive monitoring for jaundice will pick up such cases at an early stage. Transcutaneous bilirubinometers is the currently available option for non-invasive monitoring but due to cost constraints not available everywhere. Smartphones with image processing techniques for detecting jaundice is a cheap option which can be utilised even for home based monitoring by parents. We assessed the accuracy of Biliscan in detecting neonatal jaundice and found good correlation with serum bilirubin values. If we design better apps than Biliscan with even stronger correlations and study them in large number of new-borns, such apps can become an effective replacement to transcutaneous bilirubinometers in the near future.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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