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The e-BiliCare: A Step to Automate Care Plans of Neonatal Jaundice

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Abstract

Neonatal jaundice is a very common condition that may potentially cause brain damage due to bilirubin encephalopathy. Fortunately, this hazard is largely preventable if managed early and appropriately. However, its management is complex as it involves considering interaction of several risk factors, with tedious calculations and graphing. Therefore, simplifying this process is highly desired.

Aim: Our aim is to develop a system to ease assessment, visualize decision making points and facilitate care.

Results: an electronic program that combines a large array of relevant data in one Microsoft Excel® sheet is developed, the e-BiliCare. It helped automating many calculations and charting many of the most important data for assessment and management of hyperbilirubinemia.

Conclusion: The e-BiliCare is presented; hoping to facilitate bridging the gap of a complex scientific subject, neonatal jaundice, and practical management by professionals with variable skills and training.

Keywords: e-BiliCare; Encephalopathy; Hyperbilirubinemia; Neonatal jaundice

Abbreviations: SBR: Serum Bilirubin; AAP: American Academy of Pediatrics; ER: Emergency Room; TcBR: Transcutaneous Bilirubin

Introduction

On ontogeny, all newborn infants are transitioned from respiration through placenta to lungs after birth. In utero, extraction of oxygen from the placental lacunae, which has very low oxygen concentration source, necessitates using large amounts of high oxygen-affinity fetal hemoglobin. This is not required after birth with breathing the oxygen-rich air. Therefore, fetal hemoglobin is gradually replaced with smaller mass of low oxygen-affinity adult hemoglobin. Eventually, a large quantity of fetal hemoglobin is sacrificed and degraded over the few transitional perinatal months [1].

The large load of the by-product bilirubin would be effectively disposed while *in utero* by the maternal liver; which has a big mass and is fully mature. Subsequently, the un-jaundiced baby is born and the slowly-maturing small neonatal liver has to suddenly take over the bilirubin clearing task after cutting the cord. This

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transient relative liver function shortage allows gradual accumulation of unconjugated bilirubin with clinical jaundice within few days, until the liver matures adequately to clear the bilirubin backlog and jaundice gradually fades away [2].

Therefore, jaundice is universal in newborns in the first week of life because almost all infants would have a bilirubin over 30 µmol/L. Over 50% of term and 80% of preterm babies develop significant jaundice, within first 2-4 days of life [3]. Physiological jaundice is the commonest cause of icterus, but as bilirubin is potentially toxic, we must watch neonates for early detection of severe cases, or the rare evolution of bilirubin encephalopathy (kernicterus) [4].

Importantly, over 7% of just under 50,000 neonates develop pathological jaundice, that is either recommended or considered for phototherapy according to the 1994 American guidelines in terms of timing, speed, peak and cause/effect, which might herald a kernicterus hazard. This may present in first 24 hours, rise quickly by over 86 mcmol/L/day, reach bilirubin levels over the 95% centile for gestational age or postnatal hourly age (over 256 mcmol/L, in full-terms) or is associated with signs of cause –like hemolysis; or effect –like lethargy and poor health status of the newborn infant. Those cases should be identified proactively if bilirubin toxicity is to be avoided [5,6].

The challenge arises from community and health-economy pressures to discharge newborn babies earlier and earlier and devolving the task of "jaundice watching" –visually unreliable - to untrained mothers, and –at the best- health care settings to some health professionals with variable skills, training, equipment and availability round the clock. Therefore, effective, easy to use and technology-aided guidance is highly required –*again*, if bilirubin toxicity is to be avoided.

In our community, we follow the British practice; our visiting midwife would see babies who are 2 to 3 days old following discharge from hospital –the peak time for physiological jaundice. During the home visit parents are educated regards neonatal jaundice and importance of screening as well as given an educational leaflet. According to our clinical practice guideline all babies regardless of level of jaundice observed are universally screened using the Draeger jaundice meter JM-105 to estimate the transcutaneous bilirubin (TcBR), following explanations and verbal consent.

The data is entered on the spot in the e-BiliCare system on portable computer. The TcBR result instantly displays as a red circle on the bilirubin normality (75th & 95th centile) and threshold graphs. According to our point of care testing protocol any result over the 75th centile should be reported by telephone immediately to the paediatrician or emergency room (ER) physician. The neonate will be urgently reviewed; total serum bilirubin (SBR) is estimated and reported within 30-60 minutes. The result of the total SBR is charted and compared to previous TcBR finding and saved on a shared file, and if above the threshold line the baby is transferred to hospital for phototherapy.

Aim

The e-BiliCare is presented; hoping to facilitate bridging the gap of a complex scientific subject, neonatal jaundice, and practical management by professionals with variable skills and training.

Methods

The medical literature of hyperbilirubinemia and evolution of its assessment and management world-wide was reasonably reviewed, to guide production of an interactive electronic bilirubin care program –the e-BiliCare. It is mainly based on the British NICE guidelines with consideration of the American Academy of Pediatrics (AAP) guidelines and utilizes a jaundice meter device (and published bilirubin therapy guidance curves) and recognizes the role of risk factors that may modify the pediatrician's decision making, table 1. It cannot be overemphasized that following the British Community Healthcare model is at the heart of applying this system [4,7-11].

Simply, as newborn infants are discharged earlier and earlier the role of community midwifery becomes central to the success of modern management of neonatal jaundice. To cover the lack of midwifery service provision over weekends and holidays, introducing e-BiliCare to Emergency Departments would offer a cost/effective and efficient system of care that may ameliorate hyperbilirubinemia, prolonged hospital admission or even could eradicate bilirubin encephalopathy if implemented and supported appropriately.

Risk factors	Major	Minor	Decreased
Predischarge TSB or TcB	level in high-risk zone	intermediate-risk	low-risk zone
Timing Jaundice observed	First 24 h	Before discharge	
Incompatible Blood Group	Positive direct Coombs		
Other hemolytic disease	G6PD deficiency		
Hemolytic?	Elevated ETCOc		
Gestational age	35–36 wk	37–38 wk	≥41 wk
Previous sibling	Received phototherapy	With jaundice	
Feeding & Weight loss	Exclusive breast feeding Feeding poorly Excessive Weight loss		Exclusive bottle feeding
Race or gender	East Asian	Males	Black mother
Other factors	Significant bruising Cephalohematoma	Mother's age ≥25 y Macrosomic infant of a diabetic mother	Discharge from hospital after 72 hours

Table 1: Risk Factors for Development of Severe Hyperbilirubinemia in Infants of 35 or More Weeks' Gestation (in Approximate Order of Importance).

Results

The e-BiliCare was produced and tested on several scenarios and was found to accurately plot the bilirubin values in the Draeger JM-105®, transcutaneous bilirubin (TcBR) and from total serum bilirubin (SBR) measured in the laboratory. All bilirubin values are plotted against bilirubin normality 75th and 95th percentile curves reproduced from the Draeger Jaundice Meter JM-105® manual that was obtained from 9397 neonates aged 6-96 hours. The 96th hours values were plateaued to the 7th day of age.

This part guides the need for the more invasive blood testing for total serum bilirubin (SBR). Additionally, recording SBR allows plotting against age-specific bilirubin management (phototherapy and blood exchange) curves, similar to those used in NICE guidelines. The e-BiliCare records also important patient data that is relevant to assessment including some of the risk factors to help the clinician make management decisions, figure 1.

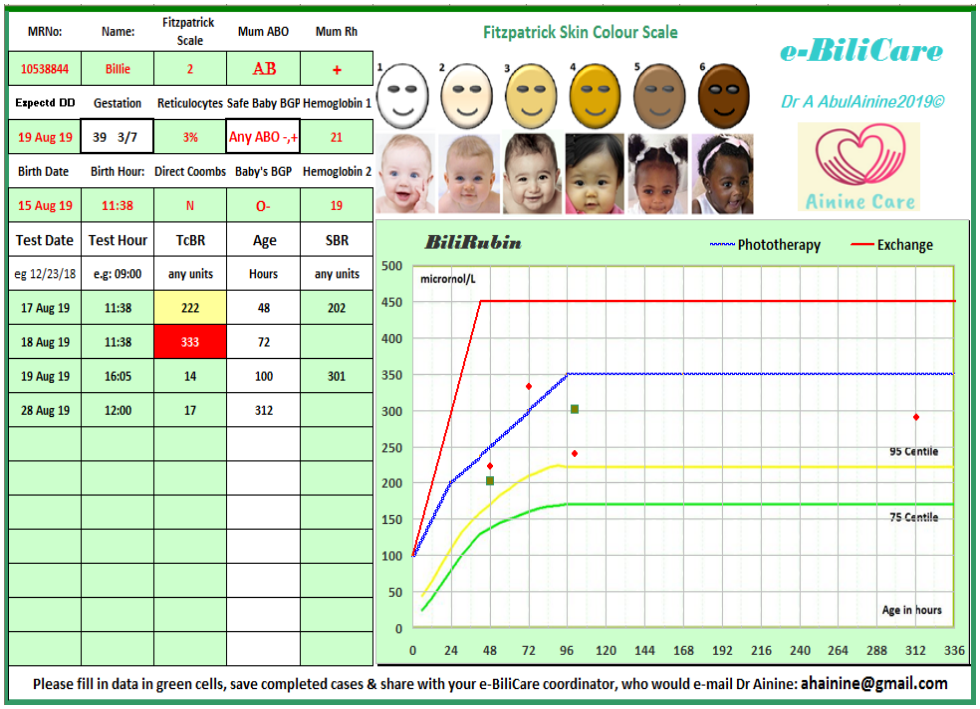

Figure 1: The e-BiliCare.

The e-BiliCare utilizes Microsoft Excel ® sheets with a "User Manual" tab (table 2) that explains how to enter various data and an "e-BiliCare" tab where to enter jaundice assessment data and read off the automatically plotted bilirubin against graphs of both gestational- and postnatal-ages. The patient file is saved on network shared file and subsequent bilirubin values are added as it happens from healthcare professionals who have their appropriate access. We included Fitzpatrick Skin Color Scale to improve interpretation of jaundice meter readings compared to laboratory serum bilirubin test [12].

The e-BiliCare program is attached for free use by healthcare professionals from around the world, who are cordially invited to collaborate with authors to validate this and develop a fully automated system of assessment and management of neonatal jaundice.

The left side 5 columns for entering infant data and it works out gestational age from expected delivery date (DD) and birth date; once mothers blood ABO and Rh group is entered the blood groups of the baby with no hemolysis potential would be shown under "safe baby BGP". On entering test date and hour the infants age in hours would be displayed and once TcBR is documented it is plotted on the appropriate position on the graph as a red dot. In case of high TcBR reading a blood SBR test is measured and written against TcBR it is plotted on the graph as well, but as a green square. The phototherapy threshold yellow line and blood exchange transfusion red line are shown. Both line graphs would change position to represent the auto-calculated gestational age.

e-BiliCare
e-BiliCare may help assess jaundice, automatically calculate age & plot bilirubin graph
The ***Dräger Jaundice meter JM-105*** measures skin "yellowness", or degree of Jaundice
Our ***BiliMeter*** may differ +/- 20-50 micromoles/L from the laboratory blood test
The trend of measurements is valuable in assessing progress of cases
However, accuracy may be affected by skin complexion (Fitzpatrick scale) & prematurity
Fitzpatrick Skin Color Scale:
Is used to quantify degree of darkness of the skin: 1: fairest to 6: darkest skin
Use the pictorial numerical scale to the nearest match of the assessed baby's color
Entering Data (only in pale green cells)
Enter Reticulocytes count as percentage, e.g.; "2 %"
Enter "Mum's ABO" blood group and "Mum's Rh", in format + or -
The "Safe Baby BGP" will be automatically displayed in the cell below
Enter Direct Coombs Test result as; N = negative or P = positive
Enter Trans cutaneous /Serum Bilirubin (TcBR/ SBR) in any unit it will plot as micromoles/L
How to use e-BiliCare:
Enter Expected Delivery Date (DD) & Birth Date to AUTO calculate the Gestational Age (GA)
Then NICE GA appropriate Phototherapy and Exchange Transfusion graphs will show up
Enter Test Date in format: mm/dd/yy, it displays dd Mmm yy (wrong format yeilds #VALUE!)
To compute hourly age enter Test Hour as Hour:Minute (format HH:MM)
Enter Birth & Test Date/Hour to AUTO calculate the hourly Age & (if it is<168 hrs) plot TcBR
If age > 90 hours, entering TcBR (umol) turns cell color amber if TcBR > 75-95% or red if > 95%
Hemolysis & Major Blood Group (BGP) incompatibility
Blood Group incompatibility between mum & baby may occur
It may result in hemolysis, leading to anemia & severer early jaundice -in first day of life
Once you enter mum's BGP, the range of "Safe Baby's BGP" will be shown in cell below
BUT, hemolysis may still occur if there is MINOR BGP incompatibility (e.g.; Kell, Duffy, Kidd)

Table 2: User's manual of e-BiliCare instructions.

Discussion

This work combined the most important risk factors used to manage neonatal jaundice. It is useful in various settings: community, clinic, and pediatric wards as well as in neonatal intensive care. The authors are not aware of any published similar work that is so comprehensive and covers the full gestational range and places of care in one electronic program. Possibly, since it was only recently that transcutaneous bilirubinometry was documented [8].

The updated British guideline NICE 98 of 2016 deals with phototherapy and blood exchange aspects of care in the graphical part in nicely detailed way. It emphasizes gestational age-specific curves, week-by-week from 23 to over 38 weeks. However, guidance on use of jaundice meters in decision making is minimal; but is sufficiently detailed by the e-BiliCare [7]. The American guideline, of AAP 2004 deals with phototherapy and blood exchange aspects of care with emphasis on only a limited scope of gestation, 35 weeks and above. Therefore it provides no guidance for the more preterm babies. Consequently, neonatal intensive care units have to use additional guidelines [4].

The e-BiliCare would automatically execute two tedious tasks, the hourly age and plot TcBR against the jaundice meter generated normal centile curves and SBR against NICE guideline similar curves. This is expected not just to save time and printing out but also minimizes errors of plotting and hence making wrong decisions. Both features may not be fully available in other programs.

Caveat

The benefits of using the e-BiliCare program in terms of time saving, error reduction, simplifying decision making and optimizing user's job satisfaction have not been fully elucidated. Despite such benefits of computer-assisted medical care are well proven, this aspect is a work in progress and hopefully would be published shortly.

Despite that this work automated decision making to a larger extent, full automation is not achieved. Although automation is not yet available in any of the great guidelines, we believe it is important even though it requires the challenging quantification of various risk factors. We are working towards developing clinical scoring by converting the nominal risk factors into continuous numerical scores. This might enhance the ability to guide smoothed management decisions, rather than the 4-step decisions: low, low-intermediate, high-intermediate, and high risk.

Conclusion

The e-BiliCare program is produced and ready for use by healthcare professionals. It facilitates making decisions on which infant should be considered for: parental reassurance to discharge; watched repeatedly; reviewed by a physician and SBR blood testing; hospital referral for further management with phototherapy, intravenous immuno-globulin or blood exchange. Further work is underway to quantify benefits of using e-BiliCare and to incorporate quantitative risk factors hoping to reduce reliance on human decision-making.

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