Screening for Neonatal Jaundice with a Smartphone

PhD Progress Report (Early Stage)

Felix Outlaw
Department of Medical Physics & Biomedical Engineering
University College London
UK
felix.outlaw.15@ucl.ac.uk

Judith Meek
The Neonatal Care Unit, Elizabeth Garrett Anderson Wing
University College London Hospitals Trust
UK
judith.meek@uclh.nhs.uk

Lindsay W. MacDonald
Department of Civil, Environmental & Geomatic Engineering
University College London
UK
lindsay.macdonald@ucl.ac.uk

Terence S. Leung
Department of Medical Physics & Biomedical Engineering
University College London
UK
t.leung@ucl.ac.uk

ABSTRACT

A method to screen for jaundice in neonates using a digital image of the sclera is proposed. The RGB pixel values from a raw format image are used to derive an estimate for the total serum bilirubin (TSB). A study at UCH Neonatal Unit found a correlation of r=0.71 ($p<0.01$) between measured TSB and TSB estimated by this method. The advantages of using a smartphone camera as a mobile screening device are discussed.

1 BACKGROUND[1]

Jaundice is caused by a build-up of bilirubin in the body, leading to a characteristic yellow discoloration of the skin and eyes. It is very common in newborn babies, with 60% affected in the first week of life [1]. Although in many cases jaundice resolves spontaneously and without harm to the baby, if the bilirubin level in the blood is too high (a condition known as hyperbilirubinemia) there is a risk of brain damage. Premature babies are more likely to become jaundiced (80% in the first week of life) and can be vulnerable to the neurotoxic effects of bilirubin at lower levels [1,2]. Once identified, jaundiced babies can be treated using phototherapy, or, in severe cases, exchange transfusion. The diagnosis of jaundice is time-critical because the longer hyperbilirubinemia remains untreated, the greater the risk of long-term neurological disability. In addition, jaundice can be indicative of underlying illnesses that need urgent attention such as newborn hemolytic disease or sepsis [1].

The most accurate method for measuring the bilirubin level is via a blood test, which indicates the concentration of bilirubin in the blood, or total serum bilirubin (TSB). However, it is neither practical nor desirable to take blood on a regular basis from all babies for the first weeks of their life, as the process is time-consuming, expensive, painful for babies and distressing for new parents. Babies are therefore screened for jaundice by neonatal nurses and midwives, who consider the apparent degree of yellow discoloration as well as factors such as gestational age and feeding behavior. Transcutaneous bilirubinometers (TcBs) can also be used. TcBs are placed directly in contact with the chest or forehead of the baby and measure the absorption of specific wavelengths of light to estimate the TSB.

This project aims to establish a novel, contactless screening method. Recent advances in mobile phone technology allow access to the raw camera data. This opens the door to point-of-care screening based on color measurement. The method relies on a digital image to quantify the yellowness of the white of the eye (sclera) and thus the severity of the jaundice. de Greef et al. have investigated using a smartphone to estimate the level of jaundice in newborns using a photograph of the skin alongside a custom color card [3]. In our work, the sclera is chosen because it is free from the melanin and hemoglobin chromophores found in skin, so its color provides a more direct indication of the TSB. (The conjunctiva covering the sclera also becomes yellow. Here we use “sclera” as a shorthand for “conjunctiva and sclera”.)

A smartphone-based screening method has several potential advantages over existing screening techniques. Visual assessment is inevitably subjective, and can be inaccurate and

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unreliable [4]. A measure based on a digital image of the sclera promises to be more consistent and objective. This approach also has advantages over TcB screening. As well as being an order of magnitude cheaper (a TcB costs approximately £3,400 [1]), it would be contactless, which removes one possible avenue of infection for the vulnerable newborn. Furthermore, TcBs are often unavailable in rural areas of less economically-developed countries. In such areas, the greater number of home births and relative lack of contact with healthcare professionals leads to a higher burden of jaundice-related disability, as cases go untreated [5]. However, smartphones are increasingly commonplace in even the least technologically-advanced healthcare settings, meaning a smartphone-based screening method could have a significant impact in the early diagnosis of this time-critical condition.

2 METHODS AND RESULTS

A study has been conducted at the UCH Neonatal Unit to investigate the feasibility of using a digital image to screen for jaundice. A Nikon D3200 camera in raw capture mode was used to photograph babies immediately before a blood sample was taken to measure TSB. A 30x30 pixel region of interest (ROI) in the sclera was manually selected and the color information was used to derive a TSB estimate. Figure 1 (Top) shows the correlation between the measured TSB and estimated TSB for the 86 subjects where a 30x30 ROI was visible.

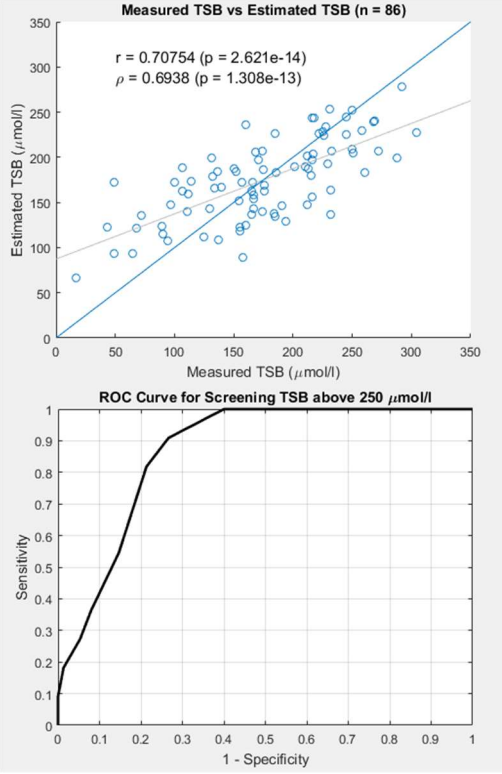

Figure 1. Top: Measured TSB vs Estimated TSB. Bottom: ROC curve for a screening threshold of 250 µmol/l.

As a screening method, the key performance metrics are the sensitivity and specificity. The receiver operating characteristic (ROC) curve (Figure 1 (Bottom)) summarizes the performance of the estimation technique in correctly identifying babies with a TSB greater than 250µmol/l, which is the threshold above which babies ought to be referred for further tests per NICE guidelines [1]. For a sensitivity of 100%, a specificity of 60% can be achieved. This performance is at least as good as a TcB [6].

3 CONCLUSION AND FUTURE WORK

Current work is focused on developing and testing an app to achieve these results using a smartphone camera. Future implementations will include a method to discount the effect of the ambient light and automatically select an appropriate ROI.

After light conditions, the most important source of variability when using a RGB camera as a measuring instrument is the spectral sensitivity. The spectral sensitivity is the relative probability of the R, G or B sensor recording a count from an incident photon of given wavelength. Using the LED target described by MacDonald [7], three mobile phone cameras capable of capturing raw format images have been characterized. Further work is needed to quantify the degree to which the differences in their spectral sensitivities affect TSB estimation.

In tandem, a public app is being developed to crowd source images of babies' eyes. It is hoped new mothers will use the app to track their babies' jaundice with photographs and test results. Such a "jaundice diary" would help midwives by providing an overview of the jaundice progression. It would also provide a rich database of pictures for the validation of future algorithms.

By leveraging near-ubiquitous smartphone technology this screening method has the potential to empower parents and midwives to react sooner to jaundice and thus reduce the global burden of jaundice-related disability.

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