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SYSTEMATIC REVIEW ON NON-INVASIVE METHOD TO DETECT HEMOGLOBIN LEVELS

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Abstract

Digital Image processing techniques can be used to explore primitive diagnostics methods for disease detection at early stages with limited resources and skilled labour. These techniques can also assist doctors during clinical examination without any need for invasive pathological test and this facilitates patient comfort and avoids infection during blood test. Various blood components such as hemoglobin and billirubin whose approximate measure can directly be identified by just viewing the colour of patient skin, nails, eye or any other target area can be measured and classified in terms of the colour content of the image of the targeted area. Analysis of image processing techniques in conjunction with specialized supervision can provide significant exploration in the field of biomedicine and clinical applications. This research work proposes an image processing based non-invasive method of measuring haemoglobin (Hb) concentration present in patient's blood by analyzing the color and texture of digital photographs of patient's palpebral conjunctiva. The images of patient's palpebral conjunctiva were processed and eight relevant features were extracted .Artificial neural network classifier was used to correlate the output quantity to be measured with the values of the quantity measured by the standard method as per the guidelines given by WHO. Further, based on the testing results obtained by the classifier the patients whose Hb concentration was less than 11g/dL were screened as anaemic patients. A confusion matrix was then plotted to evaluate and compare the predicted classification results with the actual value of Hb obtained from invasive test. It was found that the proposed algorithm was able to diagnose anemia with 71.42% sensitivity and 89.47% specificity. The proposed method is helpful for detection of not only severe anemia but works well in detection of moderate anemia too thus predicting the hemoglobin value to an accuracy of 81.81%.The proposed work is useful for

giving assistance to medical practitioners for reliable diagnosis of anaemia in the clinic itself and in low resource settings.

Introduction:

Anaemia is defined as a quantitative reduction of haemoglobin, the oxygen-carrying component of red blood cells [1]. The World Health Organisation (WHO) estimated that 24.8% of the global population was anaemic between 1993 and 2005 [2]. The gold standard for anaemia diagnosis is *ex-vivo* measurement of haemoglobin concentration in whole blood. This method requires venepuncture and specialised equipment, which may introduce delays or be unavailable in resource-poor settings [3]. Point of care testing methods for anaemia are widely available and typically involve analysis of blood by finger-prick sample. These methods are rapid and inexpensive but require liquid reagents and may expose healthcare workers to risks of blood-borne infections [4].

To rapidly screen for anaemia, clinicians often examine for conjunctival pallor. This involves subjective evaluation of the colour of the conjunctival membrane, with the presence of pallor indicating anaemia. Although this clinical sign can be useful, conjunctival pallor has a low sensitivity and specificity for prediction of anaemia and inter-observer agreement is poor [5–7]. Assessment can be improved by the use of colour-scale cards, which are compared directly to the conjunctiva, resulting in improved inter-observer agreement, sensitivity and specificity [8].

Haemoglobin predominantly absorbs green light and reflects red light, and as a result haemoglobin concentration affects tissue colour [9]. An "erythema index" (EI) has been developed to objectively quantify the degree of erythema of skin lesions, using digital photography followed by analysis of the red and green components of images [9,10].

In this study, we aimed to determine whether a conjunctival EI calculated from digital photographs taken in ambient lighting conditions correlates with haemoglobin concentration. Our goal was to develop a non-invasive method of anaemia detection using a consumer camera or smartphone. We found that EI of the palpebral conjunctiva correlated with haemoglobin concentration and compared favourably with clinician assessment. Our findings suggest that quantification of conjunctival pallor using a digital camera or smartphone has potential application as a non-invasive and affordable screening method for anaemia.

Literature Review:

Our primary goal was to build a Non-Invasive instrument which will be painless for the user. Following are some study on Non-Invasive methods. The image-based technique is one of the primary non-invasive techniques. The image based application will be pretty easier to use for self-caring. So it will be helpful for continuous hemoglobin measurement (CHbM). Following is a detailed discussion of this approach.

Article [3] they presented HemaApp, a smartphone application that noninvasively monitors blood hemoglobin concentration using the smartphone's camera and various lighting sources.Given a light source shining through a patient's finger, they performed a chromatic analysis, analyzing the color of their blood to estimate hemoglobin level.

In paper [4], they combined a broadband light source composed of 9 LEDs with grating spectrograph and Si photodiode array, and then developed a highperformance spectrophotometric system to predict non-invasive blood hemoglobin level.In order to deduct the interference of redundant data, principal component analysis (PCA) was applied to reduce the dimensionality of collected spectra. Using the NIR spectrophotometric system, they developed clinical test and collected in vivo spectra of volunteers.

Article [14] a near-infrared spectrophotometric system was constructed adopting InGaAs detector array with 16 pixels and plane grating spectrometer to obtain high signal noise ratio (SNR) spectral data. In this experiment, they applied the device independently to collect spectra data from 91 volunteers' fingertips noninvasively. Two prediction tests were conducted to verify the effects of pre-processing algorithms improving the accuracy of near-infrared Hb detection and exclude the occasionality of satisfactory results in a single trial. Their non-invasive hemoglobin detection methods were based on partial least squares (PLS). In each test, PLS, MSC coupled with PLS, DOSC coupled with PLS, three methods for non-invasive hemoglobin detection, were analyzed respectively.

Paper [15] proposes a non-invasive method for the prediction of the hemoglobin using the characteristic features of the PPG signals and different machine learning algorithms. In this work, PPG signals from 33 people were included in 10 periods and 40 characteristic features were extracted from them. Blood count and hemoglobin level were measured simultaneously by using the "Hemocue Hb-201TM" device. PPG is a photoelectrical method, which is used for measuring the tissue blood volume based on the change in the blood volume at every heartbeat.

Background and Aims

Anaemia is a major health burden worldwide. Although the finding of conjunctival pallor on clinical examination is associated with anaemia, inter-observer variability is high, and definitive diagnosis of anaemia requires a blood sample. We aimed to detect anaemia by quantifying conjunctival pallor using digital photographs taken with a consumer camera and a popular smartphone. Our goal was to develop a non-invasive screening test for anaemia.

Patients and Methods

The conjunctivae of haemato-oncology in- and outpatients were photographed in ambient lighting using a digital camera (Panasonic DMC-LX5), and the internal rear-facing camera of a smartphone (Apple iPhone 5S) alongside an in-frame calibration card. Following image calibration, conjunctival erythema index (EI) was calculated and correlated with laboratory-measured haemoglobin concentration. Three clinicians independently evaluated each image for conjunctival pallor.

Block diagram

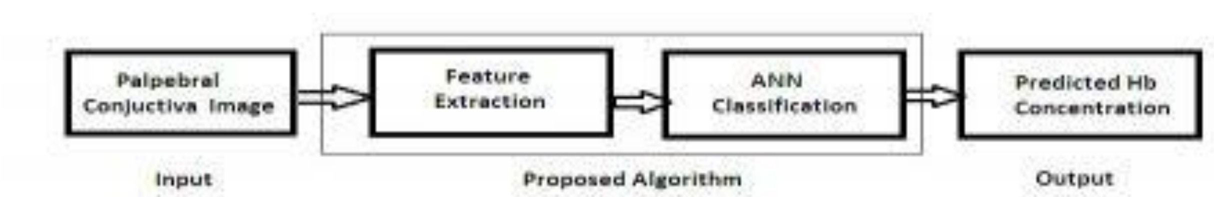
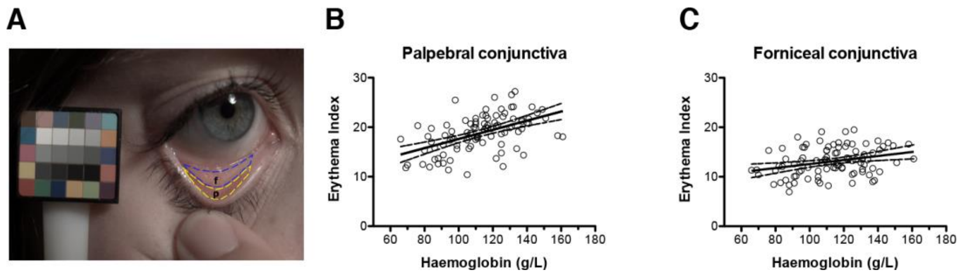


Image sample:



Study design

This was a cross-sectional observational study of hospital inpatients and outpatients attending Wellington Blood and Cancer Centre, a regional haemato-oncology service. Inclusion criteria were: age 18 years or over and laboratory haemoglobin measurement within 36 hours of photography. Exclusion criteria were: active ocular disease, current use of eye drops, total body or ocular radiation within the preceding two weeks, known hypoxia ($SpO_2 < 90\%$), inability or unwillingness to provide written consent, or participant receiving or due to receive blood transfusion between the time of photography and laboratory haemoglobin measurement. All participants provided written informed consent. The University of Otago Human Research Ethics Committee approved this study (reference HE14/014).

Image analysis

Images were imported and catalogued using a personal computer running Windows 8.1 (Microsoft Corporation, WA, USA). Images were processed using ImageJ version 1.48v, a freeware java-based image software available from the National Institutes of Health website [11]. LX5 RW2 ('raw') images were imported into ImageJ using the DCRAW reader plugin (version 1.5.0) [12].

Each image was visually assessed before analysis. The first of the three images meeting all of the following criteria was selected for analysis: conjunctiva and colour card both subjectively in focus; adequate conjunctiva exposed to identify forniceal and palpebral portions and the demarcation between them; no bright conjunctival reflections; no difference in lighting between conjunctiva and colour card. If no suitable image was available for analysis, the participant was excluded.

All images were standardised to enable comparison using a previously established method [13]. First, each image was split into its component 8-bit red, green and blue channels. Each channel's brightness was adjusted by multiplying its brightness by $200/M_B$ where M_B is the mean brightness of the colour calibration card's white square. At this point, the channels were duplicated, with one set merged to produce a 24-bit white-balanced image. This combined image was then saved in the Tagged Image File Format (TIFF) for future clinician assessment. The other set of the standardised colour channels was then used for EI analysis.

The EI was determined using the equation reported by Yamamoto et al [10]: $EI = \log(S_{red}) - \log(S_{green})$ where S is the brightness of the conjunctiva in the relevant colour channel. To calculate this, the log function within ImageJ was used on both the red and green channels individually. As these are 8-bit colour channels, the in-built log function scales the result by a fixed factor to allow for results within the pixel scale of 0–255. Following this, we used the Image Calculator tool to subtract the log green channel from the log red channel. In the image produced by this analysis, the intensity of the pixel brightness values is the EI. Palpebral and forniceal portions of the conjunctiva were selected individually using the 'polygon' tool to maximise sampling area and measured on the EI image. A macro was written within ImageJ to semi-automate this process.

Conclusion:

We report a screening technique for the non-invasive detection of anaemia based on digital analysis of the palpebral conjunctiva in a digital photograph. Using either a compact camera or the internal camera of a popular smartphone, we could detect anaemia at reasonable sensitivity and specificity. Conjunctival EI analysis might offer an improvement over clinical assessment of conjunctival pallor. We conclude that digital photography of the conjunctiva may prove useful for the screening of anaemia.

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